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ORIGINAL PAPER

SMART FACTORY: FROM CONCEPTS TO OPERATIONAL SUSTAINABLE OUTCOMES USING TEST-BEDS

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ABSTRACT. **Background:** The concept of "Smart Factory" is a new paradigm. Past studies in literature point out several conceptual understandings of Smart Factory and their classifications. This paper answers the following scientific questions, where does the Smart Factory stand? What are its core characteristics and capabilities? What are the operational outcomes of the currently developed system? How can these pieces of equipment be integrated into an R&D methodology?

Methods: Smart factory test-beds are used as a supporting case for this research work. A top-down hierarchical methodology is used to review the recent studies and analysis of the Smart Factory test-beds. The study follows these different steps 1) Literature review on the Smart factory concept on recent studies 2) Reasoning to capture the key characteristics and capabilities from the current developments 3) Experimental investigations to analyze the performances and explicit the sustainable impacts of different cases.

Results: We present the Smart Factory "from the concept to operational outcomes". The results stress: key characteristics, capabilities, influencing factors. Two case studies (literature and own investigation) illustrated the operational outcome and their sustainable impacts.

Conclusions: The presented framework summarizes the current body of knowledge of the Smart Factory from review to the operational outcomes.

Key words: Smart factory, Industry 4.0, sustainability, Smart production and warehouse, Environmental impacts.

INTRODUCTION

In today's world, the Industries are focusing on digitalized transformation as an industry revolution 4.0, which encompasses numerous areas of innovations in the value chain and creates new market dynamics. This part of the shift from automation to digitization corresponds to a new way of organizing the means of the complete value chain of the industry. The core of this transformation refers to the intelligent networking of machines, processes, people with the help of smart technologies [Sun, 2018]. The technologies, which encompass the Internet of things (IoT), Big-data technologies, Cyber-physical systems, and cloud computing [Schlund, 2018], support the industries to achieve the objective of customer-oriented solutions, achieve competitive market demands, and resource-efficient circular economy [Sun, 2018]. Industry 4.0 fosters the Smart Factory concept. This term describes the factory whose degree of integration that has reached the level of self-organizing functions possible in production and all business processes relating to production [Platform Industrie 4.0, 2016]. It combines and integrates the physical and virtual world of production in networked modules.

The global Smart Factory concept can expand to smart production-logistics networks [Zhang, 2018]. Figure 1 specifies the globalized networked of Smart Factory

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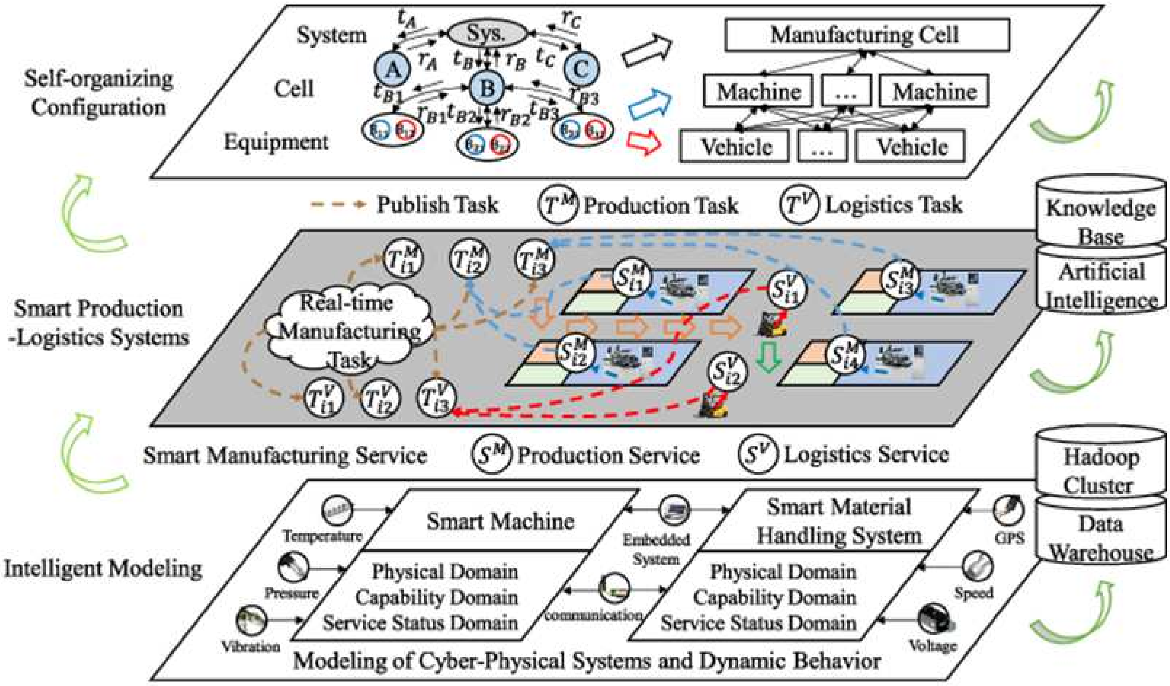
production and logistics system. [Monostori, 2014] stated that a future system is “autonomous and cooperative elements connecting in situation-dependent ways, on and across all levels of production, from processes through machines up to production and logistics networks, enhancing decision-making processes in real-time, response to unforeseen conditions and evolution along time”.



Source: Zhang, 2018

Fig. 1. Globalized networked Smart Factory production-logistics system

Several past studies point out a conceptual understanding of the Smart Factory and its benefits. However, there is a lack of studies on switching from concept to reality from a Smart Factory perspective.

Smart Factory test-beds were introduced in recent years to put forth step forward the concept into reality. These test-beds are a universal factory of the future, which are modular, networked, and adaptable factories. They can assist industries and universities in experimenting with industry 4.0 solutions in real-time. [Abele, 2015]

The next section specifies the scientific aim and methods used in this study.

SCIENTIFIC AIM AND RESEARCH METHODS

This paper aims to support the common understanding of the Smart Factory concept, and to give visibility for a larger audience of researchers and practitioners. This paper addresses the following questions: where does the Smart Factory concept stand? What are the core features and capabilities from initial development? What are the sustainable operational outcomes?

To achieve this, the analysis follows a top-down methodology, Cf. Figure 2.

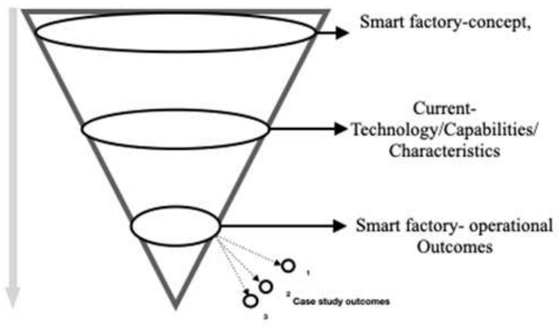


Fig. 2. Top-down hierarchal methodology followed

The framework is categorized into different levels:

- Level-1: Where does the Smart Factory concept stand? – Literature review
- Level-2: Key Technology level- Recent studies and test-beds
- Level-3: Key Characteristics and Capabilities level- test-beds
- Level-4: Operation and outcomes level- Case study investigation on test-beds and analysis of the operational outcomes.

This study firstly reviews the current literature to give a brief explanation, and history of smart factories and their stands. Secondly, we analyze the currently developed smart factory test-beds on different levels and categorized, starting from the technology to capability of the system. Finally, the test-bed case studies are investigated to explicit the operational outcomes and analyze its sustainable impacts.

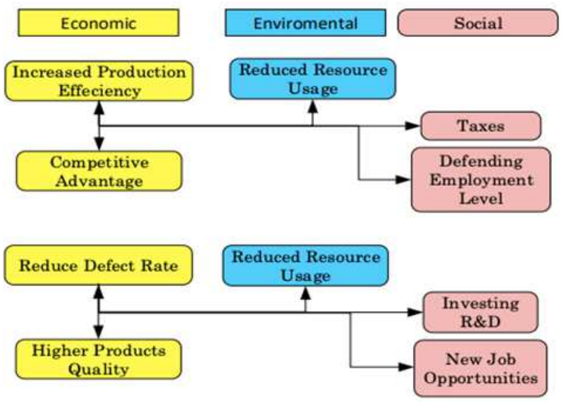
INDUSTRY 4.0

Industry 4.0 is a strategic initiative introduced by the German government in 2011. Its goal is the transformation of industrial manufacturing through digitization and exploitation of potentials on new technologies [Abele, 2006]. Industry 4.0 corresponds to a new way of organizing the means of a complete value chain of the industry [Odważny, 2018]. After the initiatives of Industry 4.0, the visionary concept of the Smart Factory emerges [Strozzi, 2017].

Level 1. Smart Factory concept and standpoint of implementation

The concept and current standpoint of Smart Factories are specified in this section. The smart Factory is a visionary concept. In Hannover Trade Fair 2014, the German-based organization called 'Smart Factory kl' introduced a concept called smart Factory. They demonstrated how the production line of the industry 4.0 paradigm in the future should be. According to Platform Industrie 4.0 [Platform Industrie 4.0, 2016], the Smart factory denominates a factory who reached a level that makes self-organizing functions possible in production and all processes relating to production. It is composed of diversified areas in the production eco-system [Strozzi, 2017], from smart production to smart logistics networks.

The core function of Smart Factory is self-configuration, self-organizing, self-sensing, self-decision making [Jung, 2016]. These foreseeable functions, elements, and advanced technologies of smart factories will lead to less waste, fewer losses, and resource depletion to satisfy all three sustainability pillars (Economical, social, and environmental) [Odważny, 2018], see figure 3. From the economic perspective, this factory will indeed improve the overall process and performance, producing a quality product, while being highly flexible to customized market demands. This shift will require a considerable amount of capital investment on deployment and implementation [Yuan, 2017]. However, thanks to the operational and running cost perspective, it will bring economic sustainability to the organization. From an environmental point of view, the factory will reduce resource usage and material waste [Thiede 2018]. On the Social view, it is expected to foster significant changes in how industrial workers perform their jobs. The high technology-centric with advanced automation of work processes are expected to have a deskilling impact [Dworschak 2014]. At the same time, the factory should increase the demand for new jobs.



Source: Braccini, 2019

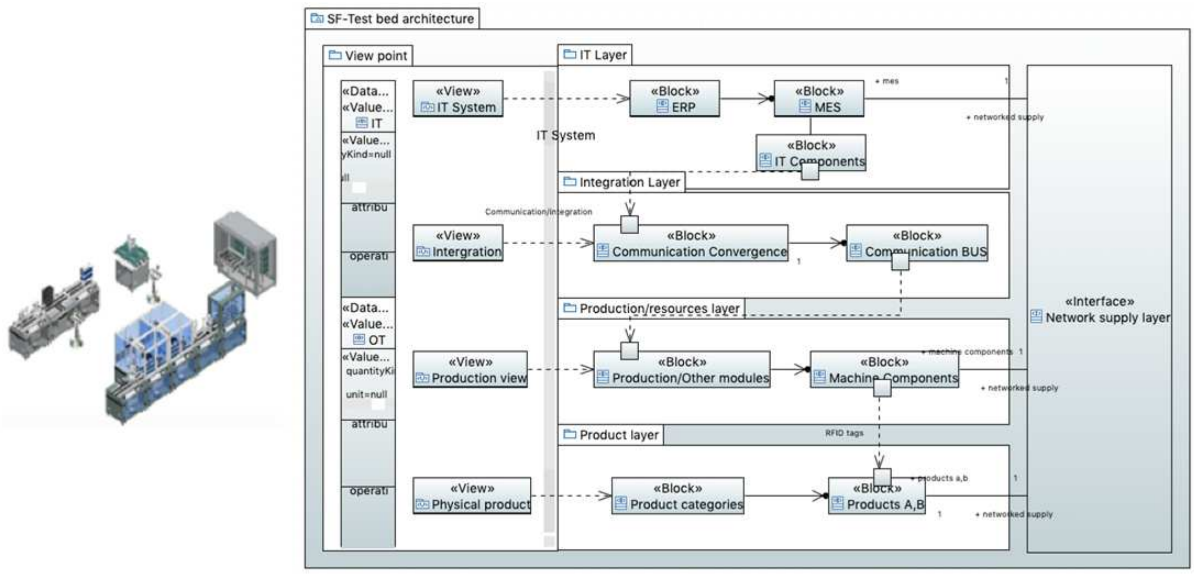
Fig. 3. Interactive benefits in Triple Bottom line concept due to factory 4.0

The transition from the traditional production and logistics systems into "smart" will bring many values added service to the firm. According to the United Nations Industrial Development Organization [UNIDO, 2019] 81 % of industries are currently investing in Smart Factory initiatives; however, 70 % are still in pilot purgatory because of a lack of values and return on investment (ROI) (according to the World Economic Forum) [WEF, 2019].

As for now, only smart factory test-beds are completely emerged [Zuehlke, 2008]. These testing-beds are replications of Smart Factory and serve for many purposes like training, experimental tests, analysis. They assist industries in deploying in real system technologies. They incorporate a variety of industry 4.0 technologies and present the eco-system as like future. The next section shows the smart factory test-bed architecture.

SMART FACTORY TEST BEDS

This section shows a description of Smart Factory test-beds and its architecture. The test-beds illustrate the comprehensive, modular, expandable, and networked factory model. Figure 4 represents test-beds [Festo,2017] and system architecture using SysML (system modeling language syntax), which are arranged in RAMI 4.0 frame (Reference architecture model Industrie 4.0) and represented in black-box view. It is divided into four main layers that group the different types of modules. The main layers include the product layer, production layer, integration layer, and IT system layer.



Source: authors work

Fig. 4. Test-beds architecture

The production layer combines all types of equipment to produce the product. They can be workstations, logistics systems, and other stations. They are modular (with standard interfaces) and automated, which ensures and creates the preconditions for the integration of a new production process with minimal physical effort configurations. The modules/workstation components have a networked supply that incorporates to have communication exchange between the modules.

The product layer includes all the products to be manufacture which stays in this line.

Integration layer- This layer connects the production and IT layer and groups all modules that makes up the communication connection, for example, the communication b/w layer. It serves as a standardized service, which is responsible for the integration of the data interface between IT systems and production modules.

The IT layer encapsulates elementary services, analogous to the production components of the production layer.

The above-specified architecture corresponds to currently developed test-beds, which is arranged in a RAMI 4.0 frame. However, the technologies used, advanced principles, and benefits specified in the upcoming section.

Cluster2 Technology level

In this section, the key technologies used for smart factory are specified. Smart factories will be based on advanced intelligence technologies, autonomously functioning, and mechatronic modules. Figure 5 shows the technologies used in Smart Factory using the layer described in the previous section.

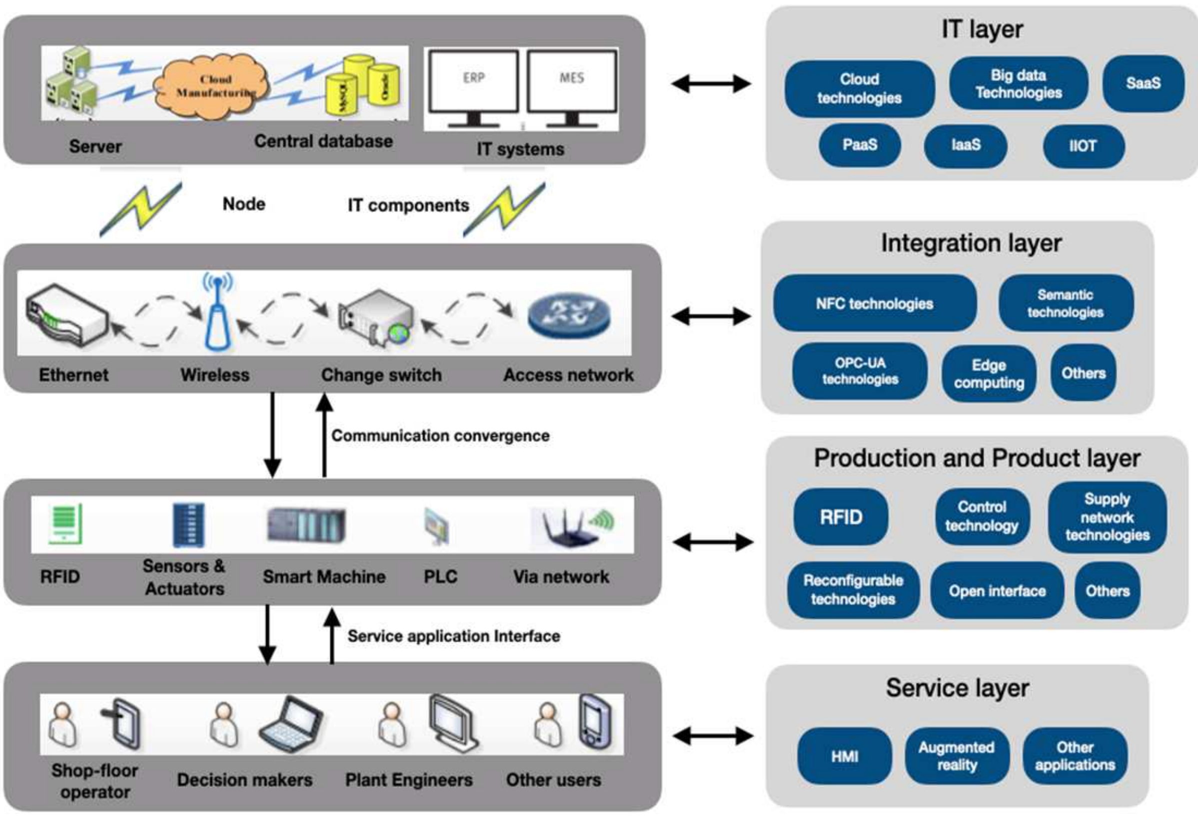


Fig. 5. Key Technologies of the smart factory in a layer-wise

The technologies, used throughout the entire layer, which includes- IIOT (Industrial Internet of things), build on identifying and communicating with each other which links in the industrial value chain: machines, products in production, employees, suppliers, customers, infrastructures, etc. In today's smart machines, IIOT excels accurately and consistently in capturing and communicating data, enabling less downtime and better overall efficiency of machines.

A cyber-physical system is an application in which the collaboration of physical and software components that are deeply intertwined, which can operate and interact with each other was a change in context. It transforms technologies and enables the connection of the operations of physical assets and computational capabilities [Bagheri, 2015].

Along with the generic technologies, some of the technologies used in Smart Factory test-beds on specific layers whereas,

1. IT layer- Big data technologies refer to a new generation of technologies that extract value through discovering, capturing, and analyzing very large volumes of a wide variety of data [LaValle, 2011]. In connected production, it generates a considerable amount of data (big data) that enables analysis and determines to improve its operation and remain competitive. Cloud computing and technology refers to the delivery of resource and service demands over the Internet. It helps to store and access data through the Internet rather than a computer's hard drive. Main service are offered in cloud computing SaaS (Software as service), PaaS (Platform as a service), and IaaS (Infrastructure as service). It helps to share services on a large number of customers. [Oliveira, 2014]. These technologies support each entity in discovering, capturing large volume of information in the eco-system.
2. Integration layer- Near field communication (NFC) technologies allowing to exchange of information between the devices, machine to machine communication within the specified distance and has the capability of wireless connection. The communication protocols are used in the lower level, close to the machines and at a higher level, close to cloud or enterprise information systems, which enables the contactless communications, information sharing, and networking the ecosystem. The instrumentation used in the layer TCP/IP, PROFINET, RFID, OPC UA, Ethernet-Wi-Fi are currently developed test-beds. Semantic technologies can provide common standards for communication that help machines understand data [Janev, 2011]. It provides an abstraction of existing IT technologies that enables bridging and interconnection of data, content, and processes.
3. Production and product layer - The RFID technology used in wireless products to send signals and communicates with the stations, which enables us to know their histories, routes, and data memories through network and communication ability. Control technologies used in Smart Factory test-bed are modernized control, whereas, Industrial PC, PLC, human-machine interface (HMI), drive controller, Plug and play control used to facilitate controlling the systems, which enable them to achieve the desired performances. [Festo, 2017].
4. Service layer- This layer integrates humans with the technologies, which enables to achieve the smart service in the eco-system. Augmented reality plays a vital role, it allows for visualization of the real world, sharing entities' information to the users. It enhances and offers the personal benefits with distinctive experiences of the eco-system [Damiani, 2018]. This technology allows the operators to control and operates the machines. Other technologies, like enhanced touch, and gesture interface, virtual technologies are also there in the service layer.

These generic advanced technologies are widely used for smart factory concepts in literature and test-beds [Schlund, 2018].

Level 3 System: Key capabilities and characteristics level

In this section, the Smart factory system's key capabilities and characteristics are summarised. Everything in the eco-system has a certain degree of built-in intelligence. The intelligence in the central system moves to each small entity of the system [Zuehlke, 2010]

The enabling technologies (presented in the previous section) form potential technical capabilities. These capabilities enable to successfully perform a particular job or task. The smart factory has advanced abilities and characteristics to achieve foreseeable objectives. We have grouped their capabilities and characteristics into five aspects based on set of relations to have better readability (see Fig 6).

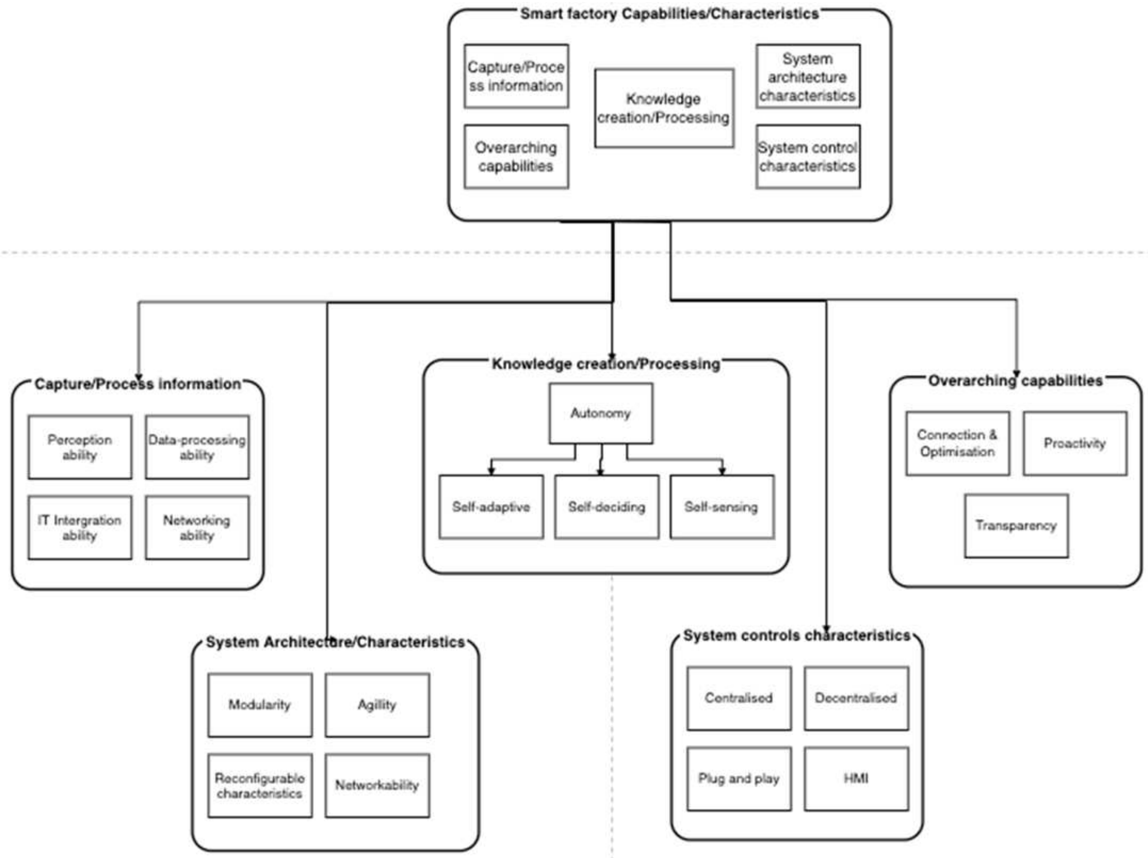


Fig. 6. Grouping of Key capabilities and Characteristics

Grouping of Capabilities/characteristics based on set of relations

We have grouped the key capabilities and characteristics into five categories based on set of relations. They are:

1. **Capturing/processing the data and information** – It is the ability of the system to handle itself and its environment. It relates to the set of Data-processing ability, Networking ability, Perception ability, IT integration abilities.
2. **Knowledge creation/Processing ability** - It assists the system creating and processing the knowledge to its entities in a concrete situation. The set of relations for knowledge creation/process is the autonomy where the machine makes the decision with the following aspects of autonomy- self-deciding, self-adaptive, and self-sensing.
3. **Overarching capabilities** - It is the natural ability of the smart factory eco-system. It assists more informed decision-making and help eco-system in a wide perspective. The set of characteristics are, Connected & optimised, Agile, Proactive, Transparent system.
4. **System architecture characteristics** - The key architecture characteristics, and set of relations include the modular, agile, networkable and reconfigurable characteristics.
5. **System Controls characteristics** - The system has modernised control ability. It controls itself and the external environment on different levels. The set of relations and levels of control are Centralised, Decentralised, Plug and Play, HMI Controls.

The five categories are detailed below.

Capture/processing of data and information

Data processing ability

The smart system has a complex and rapidly changing behavior, which involves enormous quantities of data that can be able to access different database and process information on time. Especially, the data processing is accessible quicker when it is distributed on the different modules in the eco-system.

Perception ability

The perception ability of the system describes the perception to recognize the entity that affects itself or its environment. It is dependent on the data processing ability and be influenced by sensor fusion and a variety of sensors. This ability has many advantages, which include, for example the ability to recognize the workstation and determines that the work piece was not well aligned or broken.

Communication & Networking ability

The networked and communication ability describes the network connection of each entity in the eco-system that allows them to set up, transfer information between the modules, and maintain a reliable infrastructure. For example 1) In current developments, the Workstation able to read work piece operation through barcode and do operations, 2) RFID tag on each work piece can send a signal to the work station and enables to know their histories, routes and data memories through network and communication ability.

IT integration ability

IT system is integrated into the overall system architecture, it serves as a comprehensive solution and connects the modules to obtain the greatest benefits. In test-beds, the IT integration encapsulates as elementary services, which analogous to the production components. It provides standardized data interface services between the IT system and production modules (see Fig 6).

Knowledge creation/ reasoning

Knowledge creation and reasoning ability describes the intelligent system. It can create its knowledge to understand its environment or to access its knowledge and thereby even understanding the reason for a problem and find a solution. For example: 1) Workstation learns some samples before so that it can classify the work piece on the main operation run. 2) Based on the appearance of a work piece, the workstation can create reasoning. 3) The work station module is self-awareness as like humans on the operation.

This category includes the ability to decides, sense, adapt, and organize themselves on their own. Below shows the ability with possible categories,

Autonomy

Autonomy is an important factor in the future generation of the system. The current development of the test-beds system needs human interventions to make decisions (See Fig 7. Current developments trend on autonomy). It is possible in the capability view; certain degrees of autonomy affect other factors like socio in the future. Some of the self X capability functions in current developments are:

- Self-sensing: the system captures the data and critical information from the environment involving product, quality, materials, machines etc.
- Self-deciding: the system makes the data-driven decision in manufacturing, including the identification, collection, communication, analysis and learning.
- Self-adaptive: the system adapts to changes in real market demands and adapts to uncertain situations.

Over-arching capabilities

Over-arching capabilities play a vital role in enabling decisions that are more informed and can help organizations improve the production process. The over-arching capabilities allow operations to execute with minimal manual intervention and high reliability. It assists in different aspects of the ecosystem whereas, high values of automated workflows, synchronization of assets, improved tracking and scheduling, optimized energy consumption that inherent the smart Factory on increasing yield, uptime, and quality.

The key overarching abilities of the smart factory are connected, transparent, proactive, and agile. It assists in the overall supply network efficiency of the eco-system. The categories are described below.

Connection and optimization

The main characteristic of a Smart Factory is its connected and optimized nature, which is one of its most crucial sources of value. The Connected nature indicates integrating at various levels from small agents to the entire business production eco-system. It enables a holistic view of upstream and downstream supply chain processes, driving greater overall network efficiency.

Transparency

The transparency is a real-time data-visualization, which captures from the field and physical production products that are, convert them into actionable insights, information exchange for human and even autonomous decision-making. The visibility across the modules ensures the organization to make accurate decision making by providing real-time views, alerts, notifications and real-time monitoring of the system.

Proactivity

Generally, proactively helps the system can anticipate and act before the issues or challenges arise, rather than reacting to them. In a smart factory, the ability is to predict the future outcomes on real-time data that can improve uptime, yield, and quality. It also enacts processes that, enabling them to digitize an operation and move beyond the automation and integrate into predictive capabilities.

System Architecture characteristics

In current developments, the fundamental change in the system characteristics are redefining the numerous areas in the eco-system. The involved main characteristics are modular, agile, networkable and reconfigurable characteristics. The system modular architecture has standard interface, which allows to exchanging the other modules in a minutes of time. In addition, it has the capacity to quickly changeable and reconfigurable on the specific customer product variants. Specifically, the system has the networked communication between the machines, products and people.

Modularity

The system architecture is a module-based design. Each module is physically independent from the rest of the system. These individual module structures assist in quickly changeable, customer's specific product variants. It allows the system performance effective, and foster the diagnosis changes.

Reconfigurable characteristics

Reconfigurable characteristics give the potential of a rapid change in its structure of software and hardware components. The core characteristics are changeability, integrability, customizability, convertibility, scalability, diagnosability. It quickly adapts its production capacity and functionality within a part family in response to change in market demands or intrinsic system change.

Agility

Agility can move fast and quick. In current test-beds, each module has an agility function, which is an asset on increasing the factory uptime and yield by minimizing the changeover in a few minutes. It enables flexible scheduling, rapidly changing, and structuring the ecosystem.

Networkability

The networkability describes the network connection of each entity in the eco-system. It ensures the communication between the machines, products and people to perform a corresponding and overall task.

System Controls

The modern control systems are the foundation for the industry 4.0/IIOT based concepts. In contrast the diverse level of the controller on various aspects is used in current developments. The key controllers/Open interfaces are Industrial PC, Programmable logic controller (PLC), Human-machine interface (HMI), Drive controller, Plug, and Produce control-which is a new development for decentralized module control. It is facilitated with smart, interoperable modules with standard interfaces. However, this category includes the modern controls and open interfaces, which is described below.

Centralization and Decentralization

The module-based developments incorporate both the centralized and decentralized controls. Figure 7 shows the current development trends towards the need for both the control architectures that enable human intervention. In current test-beds, the decentralized and federative system is comprised of sub-systems that communicate and work well with each other with or without human intervention on a certain degree of autonomy. It provides the necessary freedom to act in the eco-system.

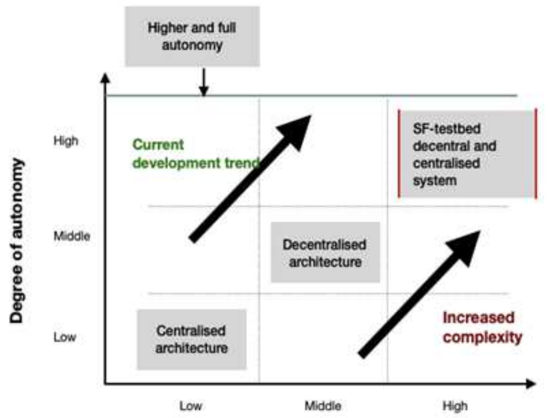


Fig. 7. Current development trends on the degree of autonomy

Plug and play principle

Plug & play principle and control are introduced in current test-beds, whereas it is borrowed from computer sciences. It processes the elements and then leading to changeable or reconfigurable systems. It assists the reconfiguration in production that can then be quickly accomplished. It facilitates the use of smart, interoperable modules with standard interfaces.

Human-machine Interaction

The human-machine interaction (HMI) or human-computer interaction is discussed for a long time. According to currently developed test-beds, human-machine interaction (HMI) implies that human and machine agents can be no longer be considered in isolation. It should be regarded as a dynamic unit or team collaborating towards an overall task and allocates among the participants.

This explicit analysis is described based on real capabilities on test-beds without any conceptual intervention from the literature. Next section 4.3 specifies the operational outcomes of the smart factory.

Level 4 Operational outcomes

Test-beds case study

This section deals with currently developed Smart Factory test-beds operational outcomes in a case study investigation. Two different case-studies are described using the following axes:

1. Smart Factory- Production and warehouse- Authors investigation and outcomes
2. Smart Factory- Environmental Impacts- Literature case study

Case study-smart production/warehouse (authors work)

The test-bed used in this case study consists of smart production and warehouse modules, combining a variety of applications. The system assembles mobile phones for different strategies: standard production, mass-customized production, and personalized production.

The question is whether the smart production and warehouse provide sustainable operational outcomes.

The experimental case study compares different demands' scenarios and evaluates the operational outcomes of the modules for standard production (S1), mass customization

(S2), and personalization (S3) operation. The standard (S1) operation is taken as a reference scenario to calculate the other scenarios from the given metrics. For each scenario, 20 customer's orders are launched in the factory separately.

In the mass customization portfolio the diversity of final products is enabled by the multiplicity of shape and color (Figure 8).

Fig. 8. Product portfolio

Table 1. Operation Scenarios and diversity Product portfolios

Mode	Number of colors	Number of shapes	Diversity fuses	Size of portfolio
Standard (S1)	1	1	4	4
Customization (S2)	4	1	4	64
Personalization (S3)	4	2	4	α

Evaluation of KPI

We have selected and classify KPI based on the Equipment's reliability and how the equipment is responding to the demanding entities (see Table 2).

Table 2. KPI's description and formulation

Performance Attributes	Key Performance Indicators (KPI)	Description	Formulation
Equipment Reliability (Production and Warehouse)	OEE	OEE is the estimation of equipment is truly productive	(Availability factor * Performance factor * quality factor) *100
	Utilization	The proportion of time equipment is used	Actual Operation time(At)/Possible time(Pt)) * 100
Customer satisfaction	Quality products produced	Proportion of products produce to the demand	Good product/Total product * 100

Customer satisfaction evaluation the match between product produced and product required.

The utilization of the system is leveraging its full capacity or work potential in a given period. Here, this indicator is measured based on the different sensors on the equipment:

Overall Equipment Efficiency is a measure of how well manufacturing operation (facilities, time, and material) are utilized compared to its full potential during the periods when it is scheduled to run. Here, OEE is evaluated based on three factors,

1. Availability: Machine available for production/total time
2. Performance: duration of production/total time
3. Quality: time spend on producing good products/total time

The monitored results, coming from the machines, are shown in the bar graphs (Fig. 9, Fig. 10, and Fig. 11 The white bar indicates Availability, Gray bar indicates quality, Black bar indicates Efficiency, and Blue bar indicates OEE.

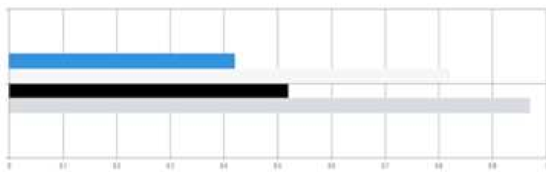


Fig. 9. Standard (S1) Operation

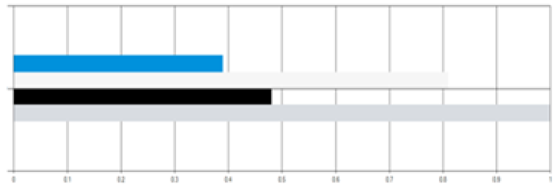


Fig. 10. Customized (S2) Operation

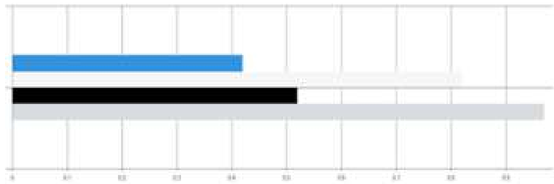


Fig. 11. S3-personalized Operation

It calculates the OEE and OEE factors-Availability (A), Performance (P), Quality (Q) factors of the three scenarios.

Table 3 shows the results of the experimental investigation.

Table 3. Results of Evaluated Key Performance Indicators

KPI	Scenario 1	Scenario 2	Scenario 3
OEE	0.42	0.41	0.39
Utilization	51 mins	49 mins	50 mins
Customer satisfaction	19/20	20/20	19/20

From the overall experimental case study, the results indicate that the factory is efficient and flexible since it can operate with the same performance for 3 different production strategies.

Influencing value-driven factors

From the case study analysis, it can be observed that the technology and characteristics influence the modules and drive value in the operation.

Figures 12 and 13 show the value-driven influencing factors of a Smart warehouse and production.

The Smart production module provides the value of “Fast conversion" “Transparent production" “optimized production” and “shorter product life cycle”. It signifies that the modules are reactive and change in the uncertain situation that leads to a sustainable operational outcome.

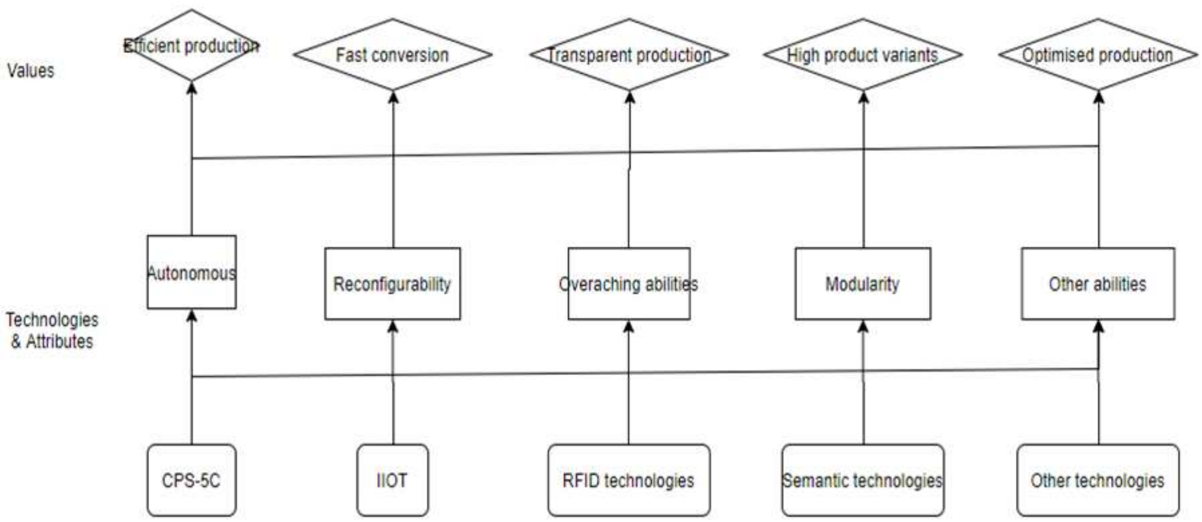


Fig. 12. Smart-Production influence factors

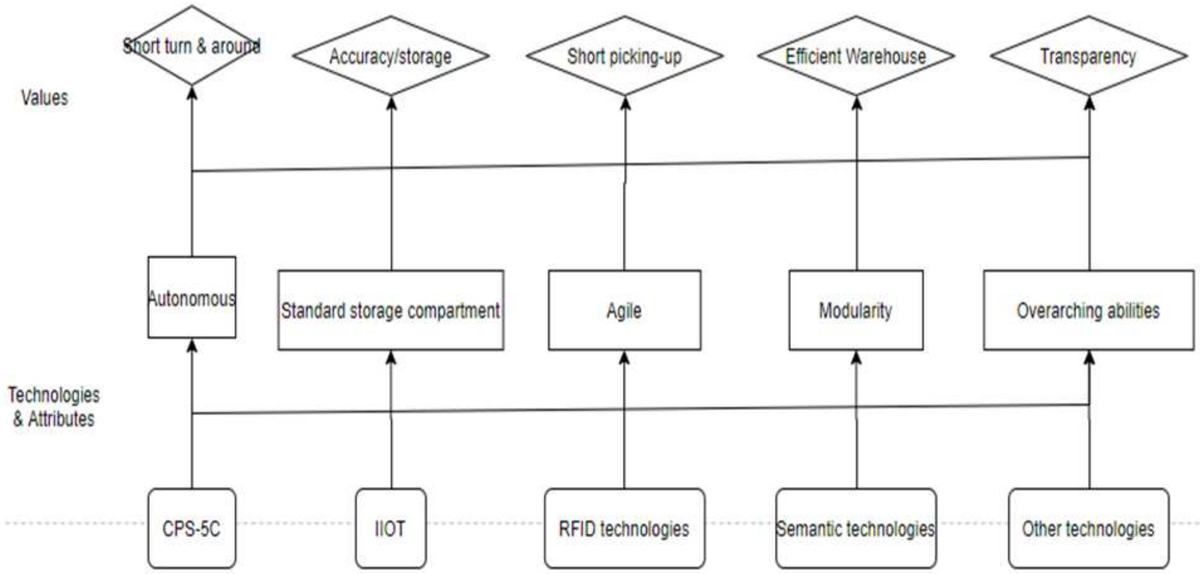


Fig. 13. Smart Warehouse influence factors

Case study example-Smart Factory Environmental Impacts (EI) [Thiede, 2018]

This case study investigates the Smart factory environmental performances. In this work, [Thiede, 2018], the environmental feasibility of smart factory in manufacturing is investigated and the study analyses the environmental impacts on qualitative consideration then proposing a generic methodology to assess the smart factory environmental aspects. The work is summarized through the case studies and the life cycle assessment (LCA) methodology is used to investigate the system.

The study is divided into two different case studies. In case study-1, the authors stress the environmental impacts of the smart factory. The authors added an additional smart component like sensors, devices and computer peripherals in the system. This study is evaluated through the continuous energy monitoring system to calculate the energy for this case.

In case study-2 the authors remove the incorporated additional component and test the system. They then analyse the environmental impacts without the smart components. This study is evaluated through a thermal 3D emission monitoring system for this case. These two environmental assessment case studies are evaluated for 3 years separately.

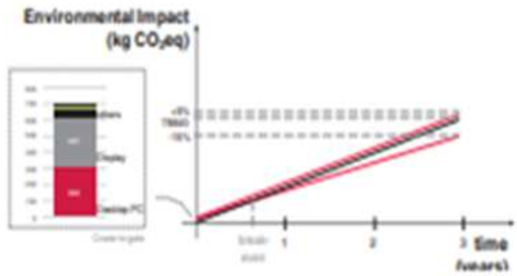


Fig. 14. Environment impact of case study-1

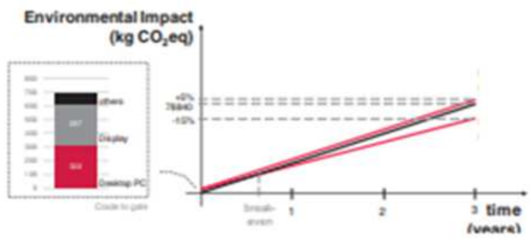


Fig. 15. Smart Warehouse influence factors

For case study-1, the result (shows in Fig 14) stresses that, over the 3 years along with environmental impacts, the potentiality of the system improves in the production.

In addition, the Energy flow is improved. This overall improvement, below 10% would not lead to breakeven in three years. It is noted that, the additional smart component of the system has minimize the environmental impact of the physical production.

Thermal 3D emission monitoring (Case study-2)

Case study-2 investigates environmental impacts without the smart components. Fig 15 shows the environmental impacts of case study-2. It is noted that, energy improvement (cradle to gate(approx. 700 kg CO_2 eq) is a bit lower in this case due to less complex infrastructure. In contrast, energy improvement during the use phase is significantly higher (4.00 kg CO_2 eq) since the computer needs far more energy for the complex simulations. The result indicates the potential improvement of 20% is gain a positive feasibility for the CPPS. Its actual potential is 5-8% more realistic values that clearly shift the breakeven point towards the three years.

From the investigation, the authors point out as a general synthesis, the environmental feasibility of CPPS is high on specific cases, depends on configuration, operation modes and general circumstances. In addition, the energy consumption is more without the components than with smart components.

CONCLUSIONS

Using a top-down hierarchal methodology, this paper clarifies the concept and where the smart Factory currently stands. The study also stresses the key technologies and categories the capabilities of currently developed Smart Factory test-beds. To realize the concept into reality, the operational experimentation of smart factory test-bed presented on two different case studies. From the authors and literature investigation, it summarized and analyzed the sustainable operational outcomes.

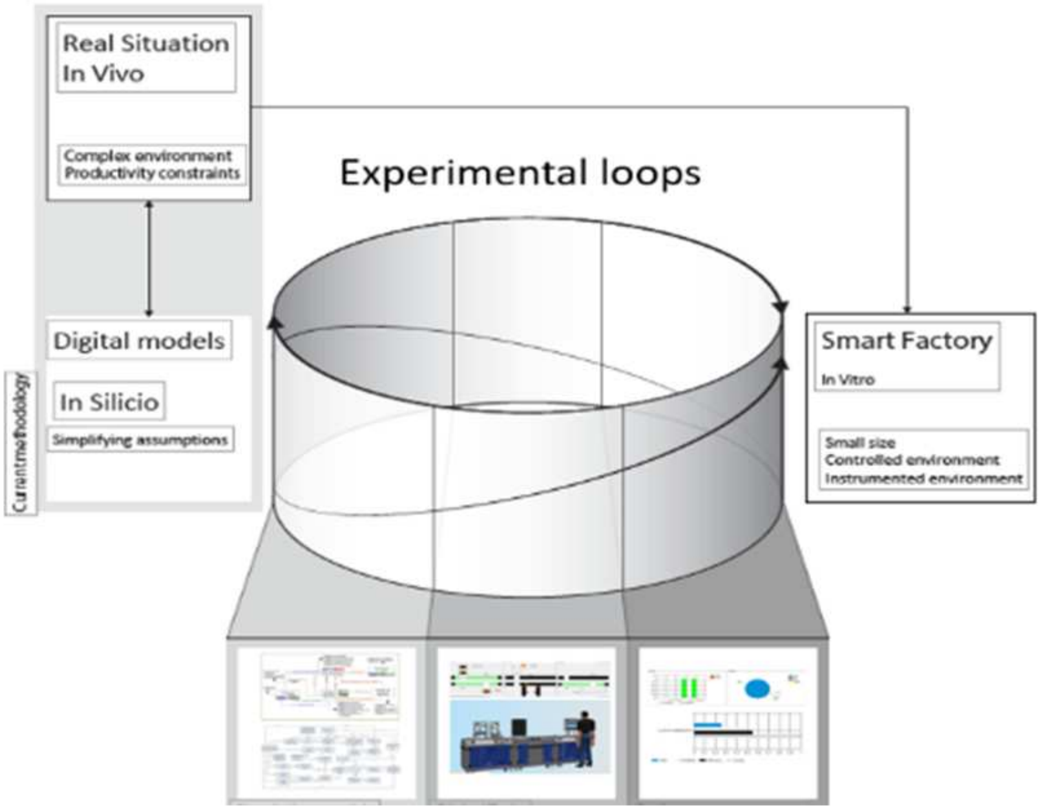


Fig. 16. Smart factory Experimenting loops

Case study-1. The factories smart Production and warehouse modules is efficient and flexible which brings the operational sustainable outcomes.

Case study-2. The smart factory and their components energy consumption is less and has feasible environmental impacts which bring sustainable outcomes.

With the findings from this article, we can conclude that Smart Factory test-beds enable us to implement a new research methodology. This methodology relies on experimental loops between the digital model and the Smart Factory test-beds (see Figure 16). This real size test-bed is a controlled and instrumented environment that can mimic real situations without having productivity constraints.

It is, therefore, feasible to test a solution, and if discrepancies between expected and observed performances are observed, the digital models may be enhanced. Only a solution performing both in silicio and in vitro will then be implemented in vivo, in the real industrial environment. This methodology will benefit industries, by avoiding the costly implementation of ill-fitted solutions, and academia, by improving the digital models.

The presented study puts a step forth on the concept into reality by summarizing a framework of the current body of knowledge of smart factory from concept to sustainable operational outcomes. This study assists as visibility for a larger audience of researchers and practitioners in a wider perspective.

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REFERENCES

Abele E., Kluge J., Näher U, 2006. Handbuch globale produktion. Munich: Hanser.

Abele E., Metternich J., Tisch M., Chryssolouris G., Sihn W., ElMaraghy H., Hummel V., Ranz F., 2015. Learning factories for research, education, and training. Hochschule Reutlingen.

Bagheri B., Yang S., Kao H.-A., Lee J. ,2015. Cyber-physical systems architecture for self-aware machines in industry 4.0 environment. IFAC-PapersOnLine, 48, 3, 1622–1627. http://doi.org/10.1016/j.ifacol.2015.06.318

Braccini A.M., Margherita E.G., 2019. Exploring organizational sustainability of industry 4.0 under the triple bottom line: The case of a manufacturing company. Sustainability, 11, 1, 36. http://doi.org/10.3390/su11010036

Damiani L., Demartini M., Guizzi G., Revetria R., Tonelli F., 2018. Augmented and virtual reality applications in industrial systems: A qualitative review towards the industry 4.0 era. IFAC-PapersOnLine, 51, 11, 624–630. http://doi.org/10.1016/j.ifacol.2018.08.388

Dworschak B., Zaiser H., 2014. Competences for cyber-physical systems in manufacturing–first findings and scenarios. Procedia CIRP, 25, C, 345–350. http://doi.org/10.1016/j.procir.2014.10.048

Festo didactic, 2017. CP-Factory, Centerpiece-Smart factory, deliverables. Festo Inc.

Jung K., Kulvatunyou B., Choi S., Brundage M.P., 2016. An overview of a smart manufacturing system readiness assessment. IFIP International Conference on Advances in Production Management Systems, 705–712. http://doi.org/10.1007/978-3-319-51133-7_83

LaValle S., Lesser E., Shockley R., Hopkins M.S., Kruschwitz N., 2011. Big data, analytics and the path from insights to value. MIT Sloan Management Review, 52,2, 21–32.

Monostori, L. ,2014,. Cyber-physical production systems: Roots, expectations and R&D challenges. Procedia Cirp, 17, 9–13. http://doi.org/10.1016/j.procir.2014.03.115

Odważny F., Szymańska O., Cyplik P., 2018. Smart Factory: The requirements for implementation of the Industry 4.0 solutions in FMCG environment-case study. LogForum, 14, 2, 257–267. http://doi.org/10.17270/J.LOG.2018.253

Oliveira T., Thomas M., Espadanal M., 2014. Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. Information & Management, 51, 5, 497–510. http://doi.org/10.1016/j.im.2014.03.006

Platform Industie 4.0. 2016. Industrie 4.0–Anstoß, Vision 2030. Berlin: Platform industrie 4.0, Federal ministry for economic affairs and energy.

Schlund S., Baaij F., 2018. Describing the technological scope of industry 4.0. A review of survey publications. Logforum, 14, 3, 341–353. http://doi.org/10.17270/J.LOG.2018.289

Thiede S., 2018. Environmental Sustainability of Cyber Physical Production Systems. Procedia CIRP, 69, 644–649. http://doi.org/10.1016/j.procir.2017.11.124

Strozzi F., Colicchia C., Creazza A., Noè C., 2017. Literature review on the 'Smart Factory'concept using bibliometric tools. International Journal of Production Research, 55, 22, 6572–6591. http://doi.org/10.1080/00207543.2017.1326643

Sun Z., 2018. Innovation and Entrepreneurship in the 4th Industrial Revolution. Joint Workshop on Entrepreneurship, 1–34.

UNIDO, 2019. Smart factory initiative-reprot 2019. UNIDO.

WEF, 2019. Sustainable production- Annual report. US: World Economic forum.

Yuan Z., Qin W., Zhao J., 2017. Smart manufacturing for the oil refining and petrochemical industry. Engineering, 3, 2, 179–182. http://doi.org/10.1016/J.ENG.2017.02.012

Zhang Y., Guo Z., Lv J., Liu Y., 2018. A framework for smart production-logistics systems based on CPS and industrial IoT. IEEE Transactions on Industrial Informatics, 14, 9, 4019–4032. http://doi.org/10.1109/TII.2018.2845683

Zuehlke D., 2008. Smartfactory–from vision to reality in factory technologies. IFAC Proceedings Volumes, 41, 2, 14101–14108. http://doi.org/10.3182/20080706-5-KR-1001.4283

Zuehlke D., 2010. SmartFactory—Towards a factory-of-things. Annual Reviews in Control, 34, 1, 129–138. http://doi.org/10.1016/j.arcontrol.2010.02.008

SMART FACTORY: OD KONCEPCJI DO ROZWIĄZAŃ OPERACYJNYCH PRZY ZASTOSOWANIU PANELI TESTUJĄCYCH

STRESZCZENIE. **Wstęp:** Koncepcja "Smart Factory" jest nowym paradygmatem. Najnowsze badania naukowe wskazują na co najmniej kilka znaczeń pojęcia Smart Factory oraz ich klasyfikacji. Prezentowana praca odpowiada na następujące pytania naukowe: na jakim etapie rozwoju jest Smart Factory? Jakie są jego najistotniejsze cechy charakterystyczne i zdolności? Jakie są operacyjne wyniki i możliwości z obecnie rozwijanych systemów? Jak różne elementy wyposażenia mogą być zintegrowane w metodologię R&D?

Metody: Panele testujące są używane do wspomagania pracy naukowej. Pionowa hierarchiczna metodologia została zastosowana do analizy ostatnich badań naukowych oraz używanych paneli do testowania Smart Factory. W badaniu można wyodrębnić następujące etapy: 1. Przegląd literatury dotyczący koncepcji Smart Factory, 2. Określenie podstawowych cech charakterystycznych i zdolności w oparciu o najświeższy etap rozwoju, 3. Badania eksperymentalne mające na celu analizę działania i wpływu na rozwój zrównoważony różnych scenariuszy.

Wyniki: W pracy przestawiono Smart Factory od przestawienia koncepcji do operacyjnych wyników. Wyniki obejmują: cechy charakterystyczne, zdolności, wpływ czynników. Dwie analizy (literatury oraz badania własne) ilustrują wynik operacyjny i jego wpływ na rozwój zrównoważony.
Wnioski: Zaprezentowana praca podsumowuje obecny stan wiedzy na temat Smart Factory w oparciu o przegląd rozwiązań operacyjnych.

Słowa kluczowe: Smart factory, Industry 4.0, rozwój zrównoważony, zaawansowany technologicznie magazyni dom, wpływ na środowisko

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ORIGINAL PAPER

THE ROLE OF ORGANIZATIONAL COMMITMENT IN EMPLOYEE TURNOVER IN LOGISTICS ACTIVITIES OF FOOD SUPPLY CHAIN

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ABSTRACT. **Background:** Due to challenging times caused by the global pandemic and the common dynamic reality of contemporary food supply chains, logistics employees inevitably become the most valuable resource. Companies are forced to continuously monitor and forecast employee satisfaction and possible turnover intention. The paper aims to explore the impact of organizational commitment on the turnover intention among employees in logistics organizations of food supply chain companies. While the direction of this impact is rather unquestionable, the main purpose is to determine the strength of correlation and defining the more dominant commitment aspect in shaping turnover intention.
Methods: A primary empirical study was conducted on a sample of 121 employees working on logistics activities workplaces from 5 companies in the food supply chain in Croatia. The turnover intention scale and organizational commitment scale were used to measure the effect of organizational commitment on turnover intention. For regression analysis, and structural equation modeling (SEM), SPSS 21.0, and AMOS 21.0 software were used to analyze the relationship of these variables.
Results: After testing the proposed structural model and achieving the model fit, the explanation of variance in turnover intention was 43.4%, and after including the activity type and the personal monthly income as control variables, 44.5%. The strong, direct, significant, and negative influence of affective organizational commitment on employee turnover intention has been proven, while there was no significant influence of normative commitment. Control variables have improved the model, but without significant influence on turnover intention.
Conclusions: This research has filled the gap and highlighted the importance of overall organizational commitment among employees in logistics activities, emphasizing affective commitment. It was confirmed that an emotional connection with the organization is of particular importance to retain employees in the organization. Organizations' investment in building and strengthening long-term affective commitment is time-consuming and seeks for interpersonal skills for managers, which could be neglected in logistics activities focused on flow improvement.

Key words: logistics activities, food supply chain, organizational commitment, employee turnover intention, structural equation modeling.

INTRODUCTION

Logistics is defined as a crucial part of supply chain management [Vitasek, 2013, Niewiadomski 2020], and in most part consists of transportation and warehousing activities. Due to enormous technological developments in logistics, the number of employees needed for efficient job execution has been decreased, but requirements for employee's knowledge, skills, and responsibility levels have never been higher [Odważny et al., 2019]. Therefore, shortage of skillful logistics staff has become a common problem for companies globally (especially in developed countries). Employees in the logistics sector (specialized logistics companies, logistics service providers also called 3PL or 4PL, and most of the distribution companies), as well as employees of other companies in the food supply chain that regularly work on logistics processes and activities, have once again become the most valuable resource of the supply chain. Therefore, companies are intensively considering their employees' satisfaction and

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attitude towards work. Monitoring and knowing reasons for a potential and actual job change (employee turnover) as well as for organizational commitment has become an unavoidable factor in logistics employee retention.

While rather well studied generally and in the majority of industries, Acar [2012] states that scientific research on organizational issues, including organizational commitment, are neglected in the logistics industry. To the best of the authors' knowledge, there was no such research among Croatian companies and employees in the logistics industry.

The main goal of this paper is to fill a gap in scientific research on how affective and normative organizational commitment affects employee turnover intention in logistics activities in the food supply chain, particularly in the Croatian food supply chain. The developed hypothesis will be tested using regression analysis and structural equation modeling (SEM), all based on empirical study conducted in companies in the Croatian food supply chain.

After the introduction, the paper presents a literature review on the general basis of employee turnover, employee turnover intention and organizational commitment, and their interrelationship [Ciszewski, Wyrwicka, 2020]. The following chapter provides a review of previous research results of employee turnover, employee turnover intention and organizational commitment in logistics, as a starting point for this paper's research. Detailed methodology and research results follow, and the paper finishes with a conclusion and discussion.

EMPLOYEE TURNOVER AND ORGANIZATIONAL COMMITMENT

Employee turnover is one form of organizational behavior that represents permanent employee withdrawal [Robbins, Judge 2017] and is a dependent variable on many other different independent variables, individual, environmental, and organizational. From an organizational point of view, many influencing factors create employees decision about leaving current work organizations, but the final decision and the action are preceded by turnover intention [Bothma, Roodt 2013, Treuren 2013, McInerney et al. 2015]. Employee turnover is a problem faced by organizations in every industry but in some particular, such as logistics, dysfunctional turnover rates are higher than in others [Min 2004].

Numerous studies have shown that at the organizational level, employee turnover mostly depends on job satisfaction [e.g. Pepra-Mensah et al. 2015, Lee et al. 2017], but it is increasingly argued that the organizational commitment can have an even more significant influence on turnover intention than job satisfaction. Some authors, therefore, found that organizational commitment correlates more strongly with turnover intention than job satisfaction [Johns 2001]. Since organizational commitment is divided into three different types of commitment (affective, normative, and continuous commitment), it is necessary to examine their separate influence on turnover intention. When viewed together, all three types of commitment negatively affect turnover intention and actual turnover [Holtom et al. 2008, Robbins, Judge 2010, Bryant, Allen 2013, Kim, Chang 2014, Shuck, Reio 2014, Robbins, Judge 2017].

Organizational commitment can be defined as "an attitude or orientation toward an organization that connects and reinforces a person's identity with the organization" [Mowday et al. 1979: 2]. There is a consensus that employees with greater organizational commitment are more focused on their work with consumers, clients, service providers, supervisors, workgroups, occupations, and organizations as a whole, and they act more positively in these relationships [Bingham et al. 2013]. Thanks to Meyer and Allen, today organizational commitment is studied at the level of affective, continuous, and normative commitment. Affective commitment refers to an emotional connection and identification with an organization, continuous commitment represents a commitment that results from dependence on an organization due to the potential negative consequences of leaving the organization where employees feel they have invested too much, or given to much to the organization [Meyer, Allen 1984], while normative commitment represents a perceived obligation to remain in the organization [Meyer et al. 1990]. These three dimensions suggest that people actually stay in their organization "because they want to (affective commitment); because they feel they need to (normative commitment); and because they must (continuous commitment)" [Eslami, Gharakhani 2012].

Understandably, research show [Robbins, Judge 2010, Kim, Chang 2014, Robbins, Judge 2017] that all three forms of commitment are in a direct negative relationship with turnover intention and actual turnover [Holtom et al. 2008, Bryant, Allen 2013, Shuck, Reio 2014] where the strength of the influence is strongest in the case of affective, then normative and finally continuous commitment. Most researches show that affective organizational commitment, or emotional connection of an individual with the organization, is crucial when thinking about staying or leaving the organization, so some researchers think that it is quite justified to examine only this type of commitment [Vandenberghe et al. 2004, Larkin 2015]. Bonds [2017] disagrees with this, arguing that normative commitment can also have a strong influence on turnover intention. The link between turnover intention and continuous commitment is so weak or non-existent that researchers are allowed to eliminate the continuous commitment as a variable [Jaros 2007], especially if the overall organizational commitment is partially examined.

EMPLOYEE TURNOVER AND ORGANIZATIONAL COMMITMENT IN LOGISTICS

The logistics industry nowadays is characterized as highly dynamic and competitive, since there are no clear boundaries between local, international, and global [Acar 2012]. According to Eckler [2010], high employee turnover in logistics companies has roots in hiring for skills rather than for attitude. Additionally, both skills and attitudes will be tested every day more intensively than ever before. In the introduction of their analysis of job satisfaction and dissatisfaction factors in the logistics industry, Anandhi and Perumal [2013] highlighted how logistics companies and their employees face growing trade volumes (double once in 5 to 7 years) and with the pressure that comes with it.

Furthermore, employee turnover intention could be even stronger since there are more opportunities on the market, and the logistics knowledge and experience are desirable in many companies regardless of the country. However, looking only Croatian labor market, there are not many alternative job opportunities in a country with a strong focus on tourism, a neglected manufacturing industry and untapped potential for stronger logistics development, especially considering the geographical location of the country. Research papers considering questions of employee turnover (and its intention) and organizational commitment in logistics are not common, and there is clear research gap that needs to be addressed. Nevertheless, the conclusions of the most important research are listed below.

Keller and Ozment [2009] performed a comprehensive literature review regarding logistics personnel issues and provided two theoretical integrated models about factors affecting logistics employee satisfaction (first for frontline logistics employees and second for their managers). Although general, this work provides a solid base for further research.

To prevent employee turnover, companies use different employee retention methods (intent to stay). Sishuwa and Phiri [2020], made a study in the transport and logistics industry of Zambia that recommended implementing strategies aimed at improving the workplace structures, job satisfaction, and organizational commitment primarily to promote job security and career development as the two most important factors influencing employee retention.

Additionally, Choi and Kim [2017] have proven a positive correlation between service orientation of logistics companies and job satisfaction and organizational commitment.

Guo-ying [2007] also highlights the problem of employee turnover for logistics companies and suggests certain countermeasures for lowering turnover and implementing early warning mechanism. When it comes to transportation, for many years the main problem is the increasing shortage of staff, namely truck drivers. As Sishuwa and Phiri [2020] stated, losing of right people means losing not only knowledge, experience, customer relations and technical skills, but all these features become an additional value for competitors that manage to hire our former employees.

Min [2007] has been examining sources of warehouse employee turnover and found that job security is the most important factor for employee retention and that financial incentives have a low influence on warehouse employee turnover. Also, employee turnover increases with the size of the warehouse and the number of its employees. Some authors [Hofbauer and Putz 2019], as an answer to a huge shortage of skilled workforce, have recently suggested using gamification in logistics as „a new approach to attract people's interest by applying game elements in a non-game context“. By improving the image of logistics, they expect higher interest for a career in this sector. Finally, according to Maloni et al. [2017], factors or divers influencing job satisfaction and commitment of the supply chain employees are different on different workforce levels. To be successful in their retention, companies have to understand and adapt to these differences. Mostly researchers conduct their research primarily on the example of companies from one (their) country [Acar 2012, Min 2007, Min 2004, Choi, Kim 2017, Guo-ying 2007, Anandhi, Perumal 2013], hence this is the case with the research conducted in this paper.

METHODOLOGY, RESEARCH AND SAMPLE

In 2019, a primary empirical survey was conducted on a convenient sample of 121 employees working on logistics activities workplaces from 5 companies in the food supply chain (2 distributors, 2 manufacturers, and 1 logistics service provider), and that have an annual average of more than 50 employees and operate in Croatia in the region of Slavonia and Baranja. Data analysis includes regression analysis and structural equation modeling (SEM). The used software packages were Statistical Package for the Social Science (SPSS) ver. 21.0 for Windows and AMOS for SPSS ver. 21.0.

The questionnaire includes turnover intention and organizational commitment scales. The turnover intention scale is a combination of scales taken directly from Schwepker Jr. [2001], (indirectly: (1) Bluedorn's [1982] "staying-leaving" index which measures turnover intention in the future through different time periods, and; (2) statements that are part of a scale developed by Wayne et al. [1997] and taken over through Yamazaki and Petchdee [2015] that measure the degree of thinking about a new job and the level of activity in search of a new job). Organizational commitment was measured by a modified version of the 1997 Meyer and Allen's scale that included 18 items and all three previously mentioned types of commitment. This scale is the most commonly used scale of organizational commitment in general, but also the most commonly used scale when investigating the influence of organizational commitment on the turnover intention [Jaros 2007, Bonds 2017]. All statements, except for demographic questions, were measured using a 5-point Likert scale.

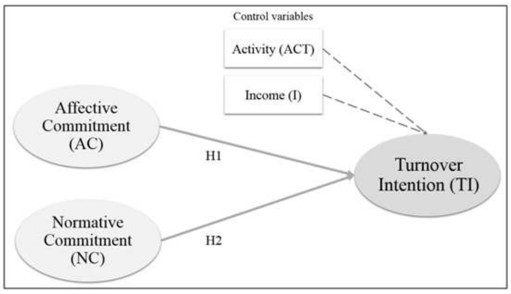
Since factor analysis shows that continuous commitment often does not load appropriately, relatively is independent, and does not correlate with an affective and normative commitment [Maslić Seršić 1999], this commitment dimension is excluded from the proposed model. Namely, continuous commitment has two subdimensions, personal sacrifice and available alternative opportunities [Vandenberghe and Pannacio, 2015] so in a market where there are very few alternative job opportunities depending on external regulation (such as labor market in Croatia), this variable cannot be expressed properly.

Based on the theoretical framework, the following hypotheses are proposed for testing:

Hypothesis 1: Affective organizational commitment directly, significantly, and negatively affects employee turnover intention in logistics activities in the food supply chain.

Hypothesis 2: Normative organizational commitment directly, significantly, and negatively affects employee turnover intention in logistics activities in the food supply chain.

Except for the main variables, the proposed model (Figure 1) includes control variables to help with upcoming interpretations, ensuring internal validity, and for reducing potential statistical errors. Therefore, the influence of organizational activity type (manufacturer or distributor/logistics service provider) and personal monthly income on the turnover intention will be tested.



Source: own work

Fig. 1. Proposed structural model

Before the research on the target sample, a pilot study was conducted on a smaller sample to check the comprehensibility and clarity of the questionnaire and to examine the reliability of the measurement scales. After the data collection, missing values and outliers analysis were performed, so the total number of respondents was 121. Awang and associates [2015] say the lower limit for implementing the SEM methodology is a sample of 100 respondents. The ratio of respondents to the number of variables in the model should be a minimum 10:1 [Yong, Pearce 2013], and since the presented model consists of 5 variables, the sample is considered sufficiently appropriate.

The sample represents 46% of men and 54% of women in medium-sized (50-249 employees, 67.8%) and large-sized organizations (250+ employees, 32.2%). They are equally represented in all age groups, whereas expected, more than half of them are between 27 and 44 years (58%). 5.8% of respondents are older than 54 years, so the percentage of those who are closer to natural unavoidable turnover are the least represented in the total sample. The largest number of respondents completed high school (52.1%), followed by undergraduate and graduate studies (30.6%). 95% of respondents are full-time employees, 80% are at the operational level, and the largest percentage of respondents has 1 to 5 years of work experience in the present organization (45.5%). 75.1% of respondents have already changed 3 to 5 work organizations in their career so far. Personal monthly income for 62% of respondents is 300-800 €, and 24% is 800-1200 €. Only 0.8% of respondents have a salary higher than 1200 €.

RESULTS

Factor analysis and model validity

Firstly, exploratory factor analysis (EFA) was conducted. It should determine the appropriate number of common factors based on the data [Hair et al. 2014]. The chosen method for the factor extraction was principal axis factoring and for the rotation direct oblimin. To check the sampling adequacy of data, Kaiser-Meyer-Olkin (KMO) test, and Bartlett's test of sphericity were used. Given the obtained results, KMO: 0.911 and Bartlett's test of sphericity: sig=0.000, which are respectively higher than 0.5 and $p<0.05$ [Williams et al. 2010], the sampling adequacy for conducting EFA was confirmed. Ranging from -0.527 to 0.932, all factor loadings are quite high and strong.

Furtherly, confirmatory factor analysis (CFA) was conducted in AMOS for SPSS ver. 21.0. For CFA, which estimates the model parameters and model fit, and later structural model testing, it is necessary to use model fit indexes. According to Kline [2011], at least a few indexes should be used because each describes the model fit from a different perspective. The same author suggests using Chi-square ($\chi2$/df), RMSEA, CFI, and SRMR as model fit indexes. The first results of CFA suggested that there are few manifest variables that are disrupting the proposed model. Therefore, after analyzing the obtained results, two manifest variables were excluded from the model: AC1 (I feel the emotional connection to the organization I work for.) and TI3 (As soon as I find a better job, I will leave the current organization). By running the CFA again, the following model fit indexes were achieved: $\chi 2/df=1.594$; CFI=0.963; RMSEA=0.70; SRMR=0.0507; IFI=0.964; TLI=0.955. All indexes were acceptable (see Schreiber et al. 2006 for acceptable fit for shown indexes), confirming the model fit with the given data sample.

To validate the measurement model, internal consistency reliability, convergent validity, and discriminant validity were checked. Internal consistency reliability includes Cronbach's alpha (CA) and composite reliability (CR). Values above 0.7 are recommended for CA [Hair et al. 2014], while values recommended for CR range between 0.7 and 0.9. [Rossiter 2002], which was achieved for all variables. To confirm convergent validity, the average variance extracted (AVE) was used. It can be said that convergent validity is confirmed if the AVE is greater than 0.5 [Fornell and Larcker 1981]. The results for internal consistency reliability and convergent validity are shown in Table 1.

Table 1. Reliability and validity indicators of constructs

Variable		Loadings	Internal consistency reliability		Convergent validity
			CA	CR	AVE
Affective commitment (AC)	AC2 - I have a strong sense of belonging to my organization.	0.801	0.931	0.925	0.711
	AC3 - I feel like "part of the family" at my organization.	0.825			
	AC4 - I would be very happy to spend the rest of my career with this organization.	0.877			
	AC5 - The organization I work for deserves my loyalty.	0.847			
	AC6 - The organization I work in is very important to me personally.	0.865			
Normative commitment (NC)	NC1 - Even if it were to my advantage, I do not feel it would be right to leave my organization now.	0.587	0.894	0.892	0.582
	NC2 - I feel obligated to stay in the organization I currently work for.	0.716			
	NC3 - I owe a lot to the organization I currently work for.	0.835			
	NC4 - I really feel as if this organization's problems are my own.	0.766			
	NC5 - I would feel guilty if I left my organization now.	0.863			
	NC6 - At the moment, I would not leave the organization I work for because of a sense of responsibility towards the people who are in the organization.	0.779			
Turnover Intention (TI)	TI1 - I intend to leave the current organization in the next year.	0.826	0.902	0.905	0.705
	TI2 - I intend to leave the current organization in the next two years.	0.789			
	TI4 - I am actively seeking for a new job outside the current organization.	0.890			
	TI5 - I am seriously considering the possibility of resigning.	0.851			

Source: own work

Table 2. Discriminant validity of the model

Constructs	**Correlation**	**Squared correlation**	**AVE1**	**AVE2**	**Discriminant validity**
AC<->NC	0.705	0.497	0.711	0.582	Confirmed
TI<->AC	-0.658	0.433	0.705	0.711	Confirmed
TI<->NC	-0.482	0.232	0.705	0.582	Confirmed

Source: own work

Discriminant validity is checked by comparing the squared correlation between the two variables with their individual AVE indicators. If both AVE indicators of individual variables are greater than their squared correlation, discriminant validity can be considered achieved [Farrell 2010]. It can be seen in Table 2 that discriminant validity was confirmed.

Finally, after verification of the measurement model, the structural model was tested.

Structural Equation Modeling

In the tested structural model, the following fit indexes were achieved: χ2/df=1.594; CFI=0.963; RMSEA=0.070; SRMR=0.0507; IFI=0.964; TLI=0.955. Given that all model fit indexes have acceptable values, the model can be accepted. The proportion of the variance in the dependent variable (turnover intention) that is explained by this model is R^2= 43.4%. In the social sciences, the explanation of variance is lower than in other sciences. It usually ranges from 50% to 60% [Henseler, Fassott 2009], and due to the sensitivity of a research area, an acceptable explanation may be over 40% [Williams et al. 2010]. Although the explanation of variance in turnover intention is not very high, considering that the model includes only organizational commitment, it is very satisfying.

After including organizational activity type and personal monthly income as control variables, the following model fit indexes were achieved: χ2/df=1.410; CFI=0.967; RMSEA=0.058; SRMR=0.0497; IFI=0.968; TLI=0.960. Since all model fit indexes are slightly improved, thus improving the whole model, the introduction of these control variables is justified. Furtherly, the explanation of the variance in turnover intention is slightly increased R^2= 44.5 %. The significance and direction of the influences of organizational commitment dimensions on turnover intention remained the same, only the strength has slightly changed (Table 3).

Table 3. Results of hypothesis testing

Hypothesis	Relationship	Without control variables		With control variables		Result	
		Standardized Regression Weights	p-value	Standardized Regression Weights	p-value	Without the control variable	With the control variables
H1	AC>TI	**-0,634**	**0,000**	**-0,604**	0,000	**Confirmed**	**Confirmed**
H2	NC>TI	-0,035	0,786	-0,035	0,781	Not confirmed	Not confirmed
Supposed influence of control variables							
	ACT>TI			0,006	0,939		No influence
	I>TI			-0,110	0,163		No influence

Source: own work

Hypothesis 1 is confirmed, i.e. affective organizational commitment in logistics activities of food supply chain companies directly, significantly, and negatively affects employee turnover intention, both without and with included control variables. The strength is a little bit weaker (-0.634 comparing to -0.604) in the model including control variables, however, it is still quite strong. On the other hand, results do not suggest that normative organizational commitment in logistics activities of food supply chain companies directly, significantly, and negatively affects turnover intention, thus hypothesis 2 is not confirmed.

Furtherly, it can be seen in Table 3 that even though the model fit was improved by including control variables, no statistically significant influences of organizational activity type and personal monthly income on turnover intention were found. The obtained results will be more discussed in the discussion and conclussion section.

DISCUSSION AND CONCLUSSION

Dedicated employees are usually both satisfied employees and even more engaged employees who have lower absenteeism rates and less turnover intention. According to previous research, this paper has confirmed that the relationship between affective commitment and turnover intention is direct and negative, i.e., it has been proven that affective organizational commitment in logistics activities of food supply chain companies directly, significantly, and negatively affects employee turnover intention. On the other hand, no significant correlation was found between the normative commitment and the turnover intention of employees in the logistics activities of the food supply chain.

Employees in logistics activities of the food supply chain have been shown not to attach importance to the investments that the organization has invested in them so far when thinking about staying in the organization or leaving it, and do not think that all effort and investment would be lost if they wanted to separate from that organization. Behind this may be a weakened awareness of the investments, effort, and time the organization has provided to its employees, or a truly real lack of the same investments. Furthermore, these results may also indicate a potentially increased occupational commitment relative to overall organizational commitment, which is certainly desirable to explore in future research. Perhaps logistics employees are more committed to their profession than other employees, so their sense of obligation to stay is not expressed. Certainly, this is the area that needs to be thoroughly explored and, if possible, spatially expanded in order to obtain relevant data to draw more complex conclusions, and even comparing the influence of organizational commitment on actual employee turnover, not just the intent.

Despite the insignificant influence of normative commitment, the sample of the same employees confirmed that the emotional connection with the organization keeps employees in the organization mostly. Affective organizational commitment is a higher degree than mere job satisfaction, which in itself as an attitude, is more transient in nature than a commitment that is difficult to establish but therefore binds the employee more strongly to the organization. While job satisfaction is tied only to the characteristics of the job, not necessarily related to the organization, organizational commitment, and especially affective commitment, explains employee's true connection to the organization. This research confirmed that even in logistics, employees who are emotionally connected to their organization, who have a strong sense of belonging to their organization, show their loyalty to it in the form of staying in it.

Strengthening organizational commitment, therefore, needs to focus on affective commitment, because although it is more difficult to establish, it is not fleeting and eliminates leaving more than the obligation to stay in the organization, especially in a situation where alternative employment opportunities are greater. Although the context in which this research was conducted does not suggest desirable competitiveness in the labor market, which is why continuous commitment is omitted, building and strengthening overall organizational commitment, and especially affective one, should not be neglected.

The paper seeks to pay attention to the internal organizational context, which, if ignored, can permanently result in the loss of desirable and quality employees, who are much-needed employees in logistics in the Republic of Croatia. The loss is extremely significant in the region of Slavonia and Baranja, which over the past few years has been progressively losing people in logistics, especially professionals whose outflow can be prevented in time by valid organizational approaches. Maintaining positive emotions can then be more the task of a psychologist or sociologist, so human resource management should invest in this segment of the business, but also provide appropriate conditions for education and training to acquire interpersonal skills for existing managers. Unfortunately, only one in ten managers possess the necessary skills to increase the organizational commitment of their employees [Harter, Adkins, 2015].

Due to the simplicity of the structural model, which is the main limitation of the research, this research can be seen as indicative. However, it points out the necessity and opportunity for future research of organizational issues in logistics activities. Research limitations could be reduced by increasing the number of respondents, and as already mentioned spatial expansion, which would allow more comprehensive model development.

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REFERENCES

Acar A.Z., 2012. Organizational culture, leadership styles and organizational commitment in Turkish logistics industry, Procedia-Social and Behavioral Sciences, 58, 217-226, http://doi.org/10.1016/j.sbspro.2012.09.995.

Anandhi K., Perumal R., 2013, Job satisfaction in logistics sector: A review and research agenda, International Journals of Marketing and Technology, 3(5), 114-126.

Awang Z., Afthanorhan A., Asri M.A.M., 2015. Parametric and Non Parametric Approach in Structural Equation Modeling (SEM). The Application of Bootstrapping, Modern Applied Science. 9(9), 58-67, http://doi.org/10.5539/mas.v9n9p58.

Bingham J.B., Mitchell B.W., Bishop D.G., Allen N.J., 2013. Working for a higher purpose: A theoretical framework for commitment to organization-sponsored causes, Human Resource Management Review, 23(2), 174–189, http://doi.org/10.1016/j.hrmr.2012.07.004.

Bluedorn A.C., 1982. A unified model of turnover from organizations, Human Relations, 35(2), 135–153, http://doi.org/10.1177/001872678203500204.

Bonds A.A., 2017. Employees' Organizational Commitment and Turnover Intentions, A dissertation presented to the Walden University, College of Management and Technology.

Bothma C.F.C., Roodt G., 2013. The validation of the turnover intention scale, SA Journal of Human Resource Management/SA Tydskrif vir Menslikehulpbronbestuur, 11(1), 507-519, http://doi.org/10.4102/sajhrm.v11i1.507.

Bryant P.C., Allen D.G., 2013. Compensation, Benefits and Employee Turnover, Compensation & Benefits Review, 45(3), 171–175, http://doi.org/10.1177/0886368713494342.

Choi Y.R., Kim H.D., 2017. The Effect of Service Orientation Effort on Job Satisfaction, Organizational Commitment and Turnover Intention in Logistics Firms, Journal of Korea Port Economic Association, 33(2), 33-52, http://doi.org/10.4236/jss.2020.86013.

Ciszewski M., Wyrwicka M.K., 2020. Shopfloor management (SFM) as a tool for improving control of production and visualization of results. LogForum 16 (2), 299-310, http://doi.org/10.17270/J.LOG.2020.385

Eckler J., 2010. Why we need to re-invent logistics outsourcing, Wareh Forum, 25(11), 1-3, Available on the Internet: https://ecklerassociates.com/wp-content/uploads/2016/10/Ackerman.pdf (29/07/2020).

Eslami J., Gharakhani D., 2012. Organizational Commitment and Job Satisfaction, ARPN Journal of Science and Technology, 2(2), 85-91

Farrell, A.M., 2010. Insufficient discriminant validity: A comment on Bove, Pervan, Beatty, and Shiu (2009). Journal of Business Research, 63(3), 324-327, http://doi.org/10.1016/j.jbusres.2009.05.003

Fornell, C., Larcker, D.F., 1981. Evaluating structural equation models with unobservable variables and measurement error. Journal of marketing research, 18(1), 39-50, http://doi.org/10.2307/3151312.

Guo-ying W, 2007. Analysis of the Employee Turnover of Logistics Enterprises [J], Logistics Sci-Tech, 7. Available on the Internet: https://en.cnki.com.cn/Article_en/CJFDTotal-LTKJ200707041.htm (17/08/2020).

Hair J.F., Black W.C., Babin B J., Anderson R.E., 2014. Multivariate data analysis: Pearson new international edition. Essex: Pearson Education Limited.

Harter J., Adkins A., 2015. What great managers do to engage employees, Harvard Business Review. Available on the Internet: https://hbr.org/2015/04/what-great-managers-do-to-engage-employees (11/03/2019).

Henseler J., Fassott G., 2009. Testing Moderating Effects in PLS Path Models: An Illustration of Available Procedures, Handbook of Partial Least Squares, 713–735, http://doi.org/10.1007/978-3-540-32827-8_31.

Hofbauer F., Putz L.-M., 2019. Can gamification reduce the shortage of skilled logistics personnel? In: Kersten W., Blecker T., Ringle C.M. (Ed.): Artificial Intelligence and Digital Transformation in Supply Chain Management: Innovative Approaches for Supply Chains. Proceedings of the Hamburg International Conference of Logistics (HICL), 27, 331-354, http://doi.org/10.15480/882.2475.

Holtom B.C., Mitchell T.R., Lee T.W., Eberly M.B., 2008. 5 turnover and retention research: a glance at the past, a closer review of the present, and a venture into the future, The Academy of Management Annals, 2(1), 231-274, http://doi.org/10.1080/19416520802211552

Jaros S., 2007. Meyer and Allen Model of Organizational Commitment: Measurement Issues, The Icfai Journal of Organizational Behavior, 6(4), 1-20.

Johns G., 2001. The Psychology of Lateness, Absenteeism, and Turnover: Handbook of Industrial, Work and Organizational Psychology, London: SAGE.

Keller S.B., Ozment J., 2009. Research on personnel issues published in leading logistics journals, The International Journal of Logistics Management, 20(3), 378-407, http://doi.org/10.1108/09574090911002832

Kim T., Chang K., 2014. Turnover Intentions and Organizational Citizenship Behaviours in Korean Firms: The Interactional Effects of Organizational and Occupational Commitment, Asia Pacific Business Review, 20(1), 59-77, http://doi.org/10.1080/13602381.2011.640538.

Kline R., 2011. Principles and Practice of Structural Equation Modeling, 3rd Edition. Guilford Press. New York.

Larkin I.M., 2015. Job Satisfaction, Organizational Commitment, and Turnover Intention of Online Teachers in the K-12 Setting, Doctor of Education in Instructional Technology Dissertations. Available on the Internet: https://digitalcommons.kennesaw.edu/cgi/viewcontent.cgi?article=1003&context=instruceddoc_etd (26/01/2019)

Lee T.W., Hom P.W., Eberly M.B., Mitchell T.R., 2017. On the Next Decade of Research in Voluntary Employee Turnover, Academy of Management Perspectives, 31(3), 201–221, http://doi.org/10.5465/amp.2016.0123.

Maloni M.J., Campbell S.M., Gligor D.M., Scherrer C.R., Boyd E.M., 2017. Exploring the effects of workforce level on supply chain job satisfaction and industry commitment, The International Journal of Logistics Management, 28(4), 1294-1318, http://doi.org/10.1108/IJLM-10-2016-0235.

Maslić Seršić D., 1999. An empirical test of Meyer and Allen's three-component model of organizational commitment in a Croatian context, Review of psychology, 6(1-2), 17-24.

McInerney D.M., Ganotice F.A., King R.B., Marsh H.W., Morin A.J.S., 2015. Exploring commitment and turnover intentions among teachers: What we can learn from Hong Kong teachers, Teaching and Teacher Education, 52, 11-23, http://doi.org/10.1016/j.tate.2015.08.004.

Meyer J.P., Allen N.J., 1984. Testing the “side-bet theory” of organizational commitment: Some methodological considerations, Journal of Applied Psychology, 69(3), 372–378, http://doi.org/10.1037//0021-9010.69.3.372.

Meyer J.P., Allen N.J., Gellatly I.R., 1990. Affective and continuance commitment to the organization: Evaluation of measures and analysis of concurrent and time-lagged relations, Journal of Applied Psychology, 75(6), 710–720, http://doi.org/10.1037/0021-9010.75.6.710.

Min H., 2004. An examination of warehouse employee recruitment and retention practices in the USA, International Journal of Logistics Research and Applications, 7(4), 345–359, http://doi.org/10.1080/13675560412331282948.

Min H., 2007. Examining sources of warehouse employee turnover, International Journal of Physical Distribution & Logistics

Management, 37(5), 375-388, http://doi.org/10.1108/09600030710758437

Mowday R.T., Steers R.N., Porter L.W., 1979. The measurement of organisational commitment, Journal of vocational behaviour, 14(2), 224–247, http://doi.org/10.1016/0001-8791(79)90072-1.

Niewiadomski P., 2020. Corporate maturity desiderata in the face of the COVID-19 pandemic – the digital plane of logistics microfoundations. LogForum 16 (4), 503-519, http://doi.org/10.17270/J.LOG.2020.495

Odważny F., Wojtkowiak D., Cyplik P., Adamczak M., 2019. Concept for measuring organizational maturity supporting sustainable development goals. LogForum 15 (2), 237-247, http://doi.org/10.17270/J.LOG.2019.321

Pepra-Mensah J., Adjei N.L., Yeboah-Appiagyei K., 2015. The Effect of Work Attitudes on Turnover Intentions in the Hotel Industry: The Case of Cape Coast and Elmina (Ghana), European Journal of Business and Management, 7(14), 114-121.

Robbins S.P., Judge T.A., 2010. Organizacijsko ponašanje [Organizational behavior], Paerson, Prentice Hall, Mate, Zagreb, Zagrebačka škola ekonomije i menadžmenta, 12th edition.

Robbins S.P., Judge T.A., 2017. Organizational Behavior, Paerson, Prentice Hall, 17th edition.

Rossiter J. R., 2002. The C-OAR-SE procedure for scale development in marketing. International Journal of Research in Marketing, 19(4), 305-335. Available on the Internet: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.831.735&rep=rep1&type=pdf (30/05/2019)

Schreiber J.B., Nora A., Stage F.K., Barlow E.A., King J., 2006. Reporting structural equation modeling and confirmatory factor analysis results: A review, The Journal of educational research, 99(6), 323-338, http://doi.org/10.3200/JOER.99.6.323-338.

Schwepker Jr. C.H., 2001. Ethical climate's relationship to job satisfaction, organizational commitment, and turnover intention in the salesforce, Journal of Business Research, 54(1), 39-52, http://doi.org/10.1016/s0148-2963(00)00125-9.

Shuck B., Reio T., 2014. Employee engagement and well-being: A moderation model and implications for practice, Journal of Leadership & Organizational Studies, 21(1), 43-58, http://doi.org/10.1177/1548051813494240.

Sishuwa, Y., Phiri, J., 2020. Factors Influencing Employee Retention in the Transport and Logistics Industry. Open Journal of Social Sciences, 8(6), 145-160.

Treuren G., 2013. The relationship between perceived job alternatives, employee attitudes and leaving intention, Anzam, 1-18. Available on the Internet: https://www.anzam.org/wp-content/uploads/pdf-manager/111_ANZAM-2013-243.PDF (06/08/2020)

Vandenberghe C., Bentein K., Stinglhamber F., 2004. Affective commitment to the organization, supervisor, and work group: Antecedents and outcomes, Journal of Vocational Behavior, 64(1), 47–71, http://doi.org/10.1016/S0001-8791(03)00029-0.

Vandenberghe C., Pannacio, A., 2015. Delving into the motivational bases of continuance commitment: Locus of control and empowerment as predictors of perceived sacrifice and few alternatives, European Journal of Work and Organizational Psychology, 24(1), 1-14, http://doi.org/10.1080/1359432X.2013.844126.

Vitasek K., 2013. Supply Chain Management Terms and Glossary, Council of Supply Chain Management Professionals, SCVisions.com.

Wayne S.J., Shore L.M., Liden R.C., 1997. Perceived organizational support and leader-member exchange: A social exchange perspective, Academy of Management Journal, 40(1), 82–111, http://doi.org/10.5465/257021.

Williams B., Onsman, A., Brown T., 2010. Exploratory factor analysis: A five-step guide for novices, Australasian Journal of Paramedicine, 8(3), http://doi.org/10.33151/ajp.8.3.93.

Yamazakia Y., Petchdee S., 2015. Turnover Intention, Organizational Commitment, and Specific Job Satisfaction among Production Employees in Thailand, Journal of Business and Management, 4(4), 22-38, http://doi.org/10.12735/jbm.v4i4p22.

Yong A.G., Pearce S., 2013. A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis, Tutorials in Quantitative Methods for Psychology, 9(2), 79-94, http://doi.org/10.20982/tqmp.09.2.p079.

ROLA ORGANIZACYJNEGO ZAANGAŻOWANIA KIEROWNICTWA W OBRĘBIE LOGISTYKI W ŁAŃCUCHACH DOSTAW ŻYWNOŚCI

STRESZCZENIE. **Wstęp:** Ze względu na zmieniające się warunki, wynikające z globalnej pandemii oraz dynamicznie zmieniającej się rzeczywistości, w której działa łańcuch dostaw żywności, pracownicy logistyki stają się bardzo ważnych zasobem. Przedsiębiorstwa są zmuszone do ciągłego monitorowania i estymowania poziomu zadowolenia zatrudnionych. Celem pracy jest zbadanie wpływu zaangażowania organizacyjnego na zmianę nastawienia wśród pracowników logistyki przedsiębiorstw działających w obrębie łańcucha dostaw żywności. Choć wpływ ten jest raczej niepodlegający dyskusji, to głównym celem jest określenie siły korelacji i zdefiniowanie dominującego czynnika wpływającego na zmianę nastawienia.

Metody: Podstawowa analiza empiryczna została przeprowadzona na próbie 121 zatrudnionych pracujących na stanowiskach logistycznych w 5 przedsiębiorstwach działających w łańcuchach dostaw żywności w Chorwacji. Skala zmian nastawienia oraz zaangażowania organizacyjnego zostały użyte do zmierzenia efektu wpływu zaangażowania organizacyjnego na zmianę nastawienia pracowników. Dla przeprowadzenia analizy regresji i modelowania strukturalnego SEM, zostało użyte oprogramowanie SPSS 21.0 oraz AMOS 21.0.

Wyniki: W wyniki przetestowania proponowanego modelu strukturalnego, otrzymano wyniki zmiany nastawienia w wysokości 43,4%, a po uwzględnieniu typu aktywności oraz miesięcznego poziomu pensji jako zmiennych kontrolnych, 44,5%. Silny, bezpośredni, istotny i negatywny wpływ organizacyjnego zaangażowania na zmianę nastawienia pracowników został udowodniony, podczas gdy nie wykazano istotnego wpływu dla standardowego zaangażowania. Zmienne kontrolne poprawiły model ale bez istotnego wpływu na zmianę nastawienia.

Wnioski: Praca wypełnia lukę w prowadzonych badaniach i zwraca uwagę na istotność zaangażowania organizacyjnego dla pracowników logistyki, podkreślając istotę zaangażowania emocjonalnego. Zostało potwierdzone, że emocjonalna więź w obrębie organizacji pomaga utrzymać zatrudnionych. Inwestycja organizacji w budowaniu i wzmacnianiu długoterminowego emocjonalnego zaangażowania wymaga sporo czasu i konieczności wśród kierownictwa umiejętności interpersonalnych, które mogą być lekceważone w obrębie działalności logistycznej skupionej na poprawie przepływów.

Słowa kluczowe: działalność logistyczna, łańcuch dostaw żywności, zaangażowanie organizacyjne, modelowanie strukturalne

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ORIGINAL PAPER

INVENTORY MANAGEMENT STRATEGIES OF FOOD MANUFACTURING INDUSTRIES IN A DEVELOPING ECONOMY

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ABSTRACT. **Background:** Among the various food chain processes, inventory is regarded as the most important, complex and expensive. Inventory practically accounts for over 70% of food processing firms overall capital assets in both developed and developing economies. As such, its proper management is key to promoting the performance, growth and competitiveness of food processing firms and their supply chains. However, in developing economies notably Ghana, the strategies adopted by food processing firms in managing their inventories remains scanty and unclear. Thus, the aim of this article is to investigate the different inventory management strategies of manufacturing industries with focus on food processing firms in a developing economy in case of Ghana.
Methods: The study adopted the quantitative approach, descriptive design, and backed by the theory of constraints. It collects data through structured questionnaires from 104 food processing firms in Ghana and analysis was done using descriptive statistics (i.e. mean and standard deviation).
Results: The study's results revealed that food processing firms in developing economies notably Ghana most prefer the Economic Order Quantity during inventory management; followed by Strategic Supplier Partnership and the Activity Based Costing strategies respectively.
Conclusions: This study's findings contribute largely to empirical studies on inventory management of food processing firms in developing economies. The findings also inform policies and practices associated with inventory management, while facilitating the adoption of relevant inventory management strategies in food processing industries.

Key words: inventory management strategies, just-in-time, economic order quantity, strategic supplier partnership, vendor managed inventory, activity based costing.

INTRODUCTION

The increasingly competitive nature of manufacturing industries championed by globalisation, technological advancements and demand fluctuations has highlighted the need for efficient inventory management [John et al. 2015]. Inventory management has become a vital operational weapon for firms that intend to survive competitive pressures in their manufacturing industries [Kolawole et al. 2019]. Inventory (either raw materials, semi-finished and or finished products) is key to manufacturing firms' survival as it constitutes about 70% of their current assets [Koumanakos 2008]. Failure to properly manage inventory could have severe consequences on firms' operational performances. Also, poorly managed inventory creates huge gaps in internal controls leading to financial risks: theft and fraud schemes [Panigrahi 2013]. It could also expose firms to production and delivery delays, countless faulty products and product shortages.

The goal of inventory management is to strengthen internal controls to ensure optimal and quality inventory while providing value to customers [Sunday and Joseph 2015]. Proper management strikes a balance between too little and too much inventory [Elsayed and Wahba 2013]. Inventory below or above optimal levels could affect a firm's

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productivity by increasing production costs. The theory of constraints suggests that manufacturing firms are exposed to inventory constraints arising from thefts, expiries, shortages and long lead times which could obstruct their entire systems [Gupta and Boyd 2008]. Such firms can only overcome inventory constraints and improve performance by adopting appropriate inventory management strategies [Chen and Paulraj 2004]. These strategies enable firms to monitor stock levels, forecast future demands and make proper replenishment plans [Weiss 2014]. Research has revealed common inventory management strategies to include Activity Based Costing, Economic Order Quantity, Just-In-Time, Vendor Managed Inventory and Strategic Supplier Partnership [Stevenson 2005, Khan and Siddiqui 2018].

Arguably, food processing firms hold the most delicate inventory type in terms of ease of inventory perishability [Khan and Siddiqui 2018]. Given the relatively shorter shelf life and ease of contamination of their inventory, food processing firms, in various economies are predominantly exposed to high product expiries and shortages [Taylor 2017] as compared to other firms such as automobile and plastics/rubber producers. Thus, inventories kept by food processors require proper inventory strategies to protect them from bacterial contaminants and lead poisons to minimise production cost. Although some strategies have been recognised, the extent to which these strategies are adopted by Ghana's food processing firms remains unknown. This has misled firms into adopting irrelevant inventory management strategies exposing them to high inventory wastages, unnecessary shortages and production delays. Food processing firms in Ghana could also be exposed to product quality issues, longer lead times and high production costs [Koumanakos 2008]; a situation which could have rippling effects on their overall performance levels and contributions to economic development.

Although inventory errors associated with processed foods could negatively influence firm performance and invariably affect end-consumers' health, studies on inventory management strategies focusing on developing economies notably Ghana remains limited. Previous studies [Panigrahi 2013, Munyao et al. 2015, Chan et al. 2017] have focused on composite of manufacturing firms other than specific classes [Opoku et al. 2020] notably food processing firms. This present study addresses this research gap by investigating the key inventory management strategies adopted by the food processing firms in Ghana and how they individually contribute to inventory management. Findings would help address the menace facing food processing firms while informing policies and practices of such firms during inventory management.

The remaining issues in this paper is structured as follows: Section 2 outlines the study's material and methods used; Section 3 presents the results and discussion with support from relevant studies and Section 4 ends the paper with conclusions and suggestions for future studies.

MATERIALS AND METHODS

The study adopted the quantitative approach and descriptive research design due to its research objectives. The quantitative approach uses descriptive and or inferential statistics to describe issues in a given study [Creswell 2014]. It also allows a study to collect and analyse data in quantitative terms to generate better objective conclusions for generalisation of findings across a target population. The descriptive design also provides accurate representation of persons, events or situations [Saunder et al. 2012]. It is advantageous in producing good amount of responses from a large group and it can also be used with greater confidence.

The study was carried out within the scope of the Ghana's manufacturing sector; focusing on food processing firms. The sector is a key part of Ghana's industrial set-up [Ackah et al. 2014]; thus, a core of industrial activities which deal with a vast range of inventory. Food processing firms primarily converts raw materials or into finished goods to meet end users' needs. There are about 142 food processing firms located within Tema, Accra and Kumasi metropolises of Ghana (Association of Ghana Industries 2018]. As such, the study's population comprised 142 food processing firms. Using the census technique, information was obtained from every unit to ensure higher degree of accuracy and reliability of findings. This technique provides a fair representation of members. The respondents included production, operations and procurement or purchasing managers/officers due to their direct involvement in inventory related activities.

To achieve the study's purpose, structured questionnaire was used to gather primary data where each person is asked to respond to the same set of questions in a predetermined order. It is also suitable for a quantitative study because it helps in obtaining objective responses for statistical analysis [Saunders et al. 2012]. The questionnaire was self-administered and obtained valid response rate of 71.84%. Table 1 further presented how the study's variables were measured to achieve the research objectives. These measurement indicators were used in constructing the study's structured questionnaire. All the measurement items were based on extensive reviews of related literature of which the indicators were put on a five-point scale ranging from "1 - least agreement" to "5 - highest agreement".

Table 1. Measurement of Variables and Sources

Variables	Measurement items	Sources
Activity Based Costing	Item classification, selective control, fund allocation, focus and periodic review	Pokorná [2016]
Economic Order Quantity	Demand, lead time and fixed orders are known and constant, procedure for determining cost components, preparation toward inventory shortages	John et al. [2015]
Just-In-Time	Proper layout of production systems, on-time supplies, communication flow, adherence to production schedules, customers' specifications	Chen and Hua Tan [2011]
Strategic Supplier Partnership	Supplier involvement, information sharing, supplier agreement, frequency of meetings and supplier capacities	Qrunfleh and Tarafdar (2013)
Vendor Managed Inventory	Supplier agreement, supplier capacity, access to information, supplier review and supplier control	Mulandi and Ismail [2019]

Source: own construct

Data obtained through survey-based researches require editing, sorting, coding, error checking and mathematical calculations. Data cleaning and screening were subsequently done to check for missing values and data consistency. Analysis was done using descriptive statistical tools comprising mean and standard deviation. The mean score, for instance, is widely used as a standard measure of central tendency [Creswell 2014]. The mean score was reported using a mean scale of 1 to 5 with mean scores of 1 to 2.9 indicating 'low', while 3 to 5 indicate high. It is, therefore, suitable for ranking results based on average scores. All the study's research objectives were analysed using this statistical tool and the result was presented in tables and discussed thereof.

RESULTS AND DISCUSSION

The section presented the study's results and discussion based on its research questions.

Activity Based Costing (ABC) Strategy

This section presented the description of the Activity Based Costing (ABC) strategy. The ABC strategy has generally been described using item classifications, selective control, allocation of funds, focus on valuable items and periodic review or re-categorisation. As such, the section specifically described how each indicator is adopted by food processing firms in Ghana. The result was presented in Table 2.

Table 2. Description of Activity Based Costing (ABC) strategy

Item/Indicator	Mean	Standard Deviation
Classification of items	4.16	.884
Selective control	4.08	.889
Allocation of funds	4.27	.808
Focus on valuable items	3.47	1.019
Periodic review and re-categorisation	3.75	1.122

Source: field survey

From Table 2, all the firms, 102(100.0%) agreed that they strictly allocate funds for managing inventories based on the value attached each inventory item. This result was rated 'high' because it had a mean score of 4.27 which is between 3 and 5. The standard deviation statistic of 0.808 indicates that the data points are gathered closely around the mean value confirming it as a great value. The result implies that, the firms studied apportion funds to manage inventories based on how valuable the item is. Highly valued items require more funds to manage unlike less valuable items. The result also indicated that, the firms' studied, 85(100.0%) classify their items in order of importance (M=4.16). The standard deviation score of 0.884 indicates that the mean value is great because its distribution is spread around it. This implies that, the firms studied engage in item classification which aids in apportioning funds and control. One of the major assumptions of this strategy is item classification where firms classify items on the basis of value.

Also, all the firms, 102(100.0%), had selective control over their inventory items (M=4.08; SD=0.889). The implication is that food processing firms control their inventories based on the value attached to them. Thus, highly valuable or key items could be given maximum control as compared to less valuable or routine items. The result also revealed that, the firms studied periodically review and re-categorise their inventory items (M=3.75; SD=1.122). Fluctuations in customers' demands coupled with unpredicted nature of business environments have called for firms to frequently re-categorise their items in order to meet demand. Periodic review enables firms to monitor and evaluate their inventories to ensure effective management. Finally, the firms agreed that they focused more on valuable items than other items based on the ABC strategy (M=.3.47; SD=1.019). This implies that, highly valuable items receive total attention as compared to less valuable items. This is because, highly valuable items are the pivots with which production thrives; failure to provide maximum control could affect the overall success of the firm.

Economic Order Quantity (EOQ) Strategy

The section presented the description of EOQ as a strategy adopted by food processing firms in Ghana. This was achieved by discussing the contributions of each indicator to the strategy based on their average scores (see Table 3).

Table 3. Description of the Economic Order Quantity (EOQ) strategy

Items	Mean	Standard Deviation
Demand is known and constant	3.89	.900
Lead time is known and constant	4.24	.826
Place fixed orders	4.38	.707
Specific procedure for determining cost components	4.32	.694
Preparation toward inventory shortages	3.94	1.106

Source: field survey

From Table 3, all the firms, 102(100.0%), agreed that they place fixed orders whenever inventory is below optimal level within specified time frame. This helps these firms to properly manage their inventories as fixed quantities are ordered at all times. The result was rated 'high' because it had a mean score of 4.38 with standard deviation statistic of 0.707; indicating that the data distribution is gathered closely around the mean value thus confirming it as a great value. The result implies that the firms understudy ensure that the same amount of quantity is ordered to achieve optimal inventories. Inventories below or above optimum levels are regarded as costs which could negatively affect firms' profitability levels. The firms also agreed that they have fixed and well-established procedures for determining cost components associated with inventory management over a given period (M=4.32; SD=0.739); implying that these firms do not make unnecessary expenditure on their inventories as it could tie up a large portion (70%) of their total current assets.

The study's result also revealed that, the firms studied ensure that lead time is known and constant over a specified period of time (M=4.24; SD=0.826). The result has the implication that, the food processing firms ensure continuous production because they know when to place orders and receive them within a given time frame. This minimises production delays and help in meeting customers' demands on time. The study revealed that the firms prepare adequately toward inventory shortages (M=3.94; SD=1.106). Production wastages are largely associated with increased production costs; failure to prepare adequately towards this menace could have adverse impact on profit levels. Firms which are predominantly exposed to wastages during production are likely to spend more funds replenishing their inventories as compared to waste-conscious firms. Also, food processing firms ensure that customer demands for their products are known and constant over time (M=3.89; SD=0.900). The result implies that, the firms have implemented proper systems to ensure that the demands of their customers are constantly known and predetermined over a given time frame.

Just-In-Time (JIT) Strategy

This section examines how the following dimensions: on-time delivery from suppliers, proper layout of production systems, quick communication among chain actors, strict adherence to production schedules and reliance on customers' specifications best describes the Just-In-Time (JIT) strategy. Using descriptive statistics, the result was presented in Table 4.

Table 4. Description of JIT strategy

Item	Mean	Standard Deviation
On-time delivery	3.65	1.088
Proper layout	3.52	1.191
Communication flow	3.61	1.059
Adherence to production schedules	3.75	1.164
Customers' specifications	2.68	1.293

Source: field survey

In terms of the Just-In-Time (JIT) strategy, all the firms agreed that they strictly adhered to production schedules (M=3.75; SD=1.293). The result implies that, the firms studied strictly follow production schedules in order to avoid or minimise production delays, production errors and wastages while ensuring customer satisfaction. Firms which strictly follow production schedules are generally able to meet customers' demands at the right time in the right quantum and at the right place thereby increasing their profit levels. Also, the firms agreed that they have a proper layout (men, machine, material, information) that supports their production systems (M=3.65; 1.088) while eliminating waste. They also emphasis on quick communications with key suppliers during production (M=3.61; SD=1.059). Communication is one of the key elements for competitive and sustainable businesses. As such, ensuring quick and faster communication with key suppliers leads to on-time receipt of goods while minimising unnecessary errors and mistakes.

Further, it was revealed that food processing firms mostly rely on on-time supplies from key suppliers to ensure smooth production (M=3.52; SD=1.191). Thus, on-time receipt of needed inventories enables food processors to meet production levels, customers' demands while ensuring maximum outputs. Arguably, delays in receiving the needed raw materials from suppliers could lead to production delays and invariably frequent failure to meet customers' demands and this could force them to consider substitutes. However, the study's result revealed that, the firms' studied do not rely on customer specifications when making production plans. This indicator had a lowest mean score of 2.68 with a standard deviation score of 1.293. Food processing firms' emphasis on product standardisation other than product customisation requires strict adherence to customer specifications. Arguably, the nature of activities coupled with ease of perishability of inventories does not allow them to produce on basis of customer specifications.

Strategic Supplier Partnership (SSP) Strategy

Manufacturing firms have been found to describe SSP strategy to inventory management based on supplier involvement, information sharing, supplier agreement, frequency of meetings and supplier capacities. Using the mean and standard deviation scores, Table 5 revealed how each indicator best describes the SSP strategy within the firms' studied.

Table 5. Description of Strategic Supplier Partnership (SSP) Strategy

Item/indicator	Mean	Standard Deviation
Early supplier involvement	4.27	.585
Complete information sharing	4.26	.675
Long-term agreements with suppliers	4.14	.758
Frequency of meetings	3.79	1.001
Supplier capacities	3.84	1.089

Source: field survey

From Table 5, all the firms agreed that they use early supplier involvement (M=4.27; SD=0.585) as a key criterion for describing the Strategic Supplier Partnership strategy. The result implies that the food processing firms ensure that key suppliers are involved right from product design stages through to final production. This is to ensure that their key suppliers have in-depth knowledge about the nature of inventory needed and its associated quantity, quality time and place of delivery. Indicates mean score is great because its data distribution is gathered closely around it. Also, the firms' studied emphasise on complete information sharing when describing the SSP strategy (M=4.26; SD=0.675). The result implies that, key suppliers have complete description of the inventory needed thus reducing possible wastages and/or shortages during production. Failure to proper share information with key suppliers could lead to supply delays, wrong deliveries thus failing to meet customer demands; invariably affect overall production levels and firm survival.

The food processing firms were found to establish long-term agreements with key suppliers (M=4.14; SD=0.758); leading to efficient resource integration to ensure proper inventory management. The result implies that food processing firms ensure that they enter into long term agreements with key suppliers to promote effective collaboration during production. Also, the firms studied consider the capacities of key suppliers as key criterion for describing SSP strategy (M=3.84; SD=1.089). Supplier capacity focuses on supplier's ability to meet requirements in terms of product quality, on-time supplies in right quantity while meeting set environmental standards. This implies that, the firms studied ensure that key suppliers have the required capacities to meet their needs in order to remain competitive. Finally, the firms ensure that they organise meetings frequently with key suppliers (M=3.79; SD=1.001) in order to ensure effective exchange of vital information during inventory management. Frequent meetings and interactions among parties ensure effective information exchange, aid understanding of what needs to be accomplished while allowing each partner to carry out required activities with minimal supervision.

Vendor Managed Inventory (VMI) Strategy

Table 6 describes how supplier agreement, supplier capacity, complete access to information, periodic review by suppliers and supplier control over inventory best explains the VMI strategy.

Table 6. Description of Vendor Managed Inventory (VMI) strategy

Item/Indicator	Mean	Standard Deviation
Supplier capacity	4.35	.612
Complete access to information	3.88	1.062
Supplier control over inventory	3.78	1.228
Agreement with suppliers	3.74	1.207
Periodic review by suppliers	3.49	1.191

Source: field survey

From Table 6, all the firms agreed that they consider supplier capacity as key criterion for describing the VMI strategy (M=4.35; SD=0.612). The result implies that, having adequate knowledge of suppliers' operational capacity promotes confidence and trust in their abilities to properly manage inventories on behalf of the focal firm. Also, the firms give key suppliers complete access to needed information (M=3.88; SD=1.062). Allowing key suppliers to have access to vital information exposes them to the nature of inventory to be kept and how to properly manage them. Firms that fail to provide needed information may stand the risk of exposure to poor inventory management as the suppliers may fail to know which inventory require more control and attention. The study also revealed that, food processing firms allow their key suppliers to have complete control over the inventories they keep at their premises (M=3.78; SD=1.228). The result implies that the firms allow their key suppliers to properly manage inventory with minimal interferences. One of the key assumptions of the VMI strategy is key suppliers having total control over items they keep. Failure to allow to completely control the inventories could lead to conflicting interest which could invariably affect the effectiveness of inventory management.

Table 6 further indicated that, the firms ensure that they establish long-term agreements with their key suppliers (M=4.14; SD=3.74). This leads to efficient integration of assets between the actors thus promoting the exchange of valuable resources aimed at inventory management. The study's result also revealed that the firms studied consider the level of supplier agreement as a criterion for describing the SSP strategy (M=3.74; SD=1.207). Finally, the result revealed that the firms' key suppliers were allowed to periodically review inventories without their permission at all times (M=3.49; SD= 1.191). The result implies that, food processing firms which allow their key suppliers to manage inventories on their behalf also gives them the opportunities to conduct periodic reviews to ensure constant optimum inventories. However, they do not necessarily give these suppliers the permissions at all times to conduct such reviews. This in turn ensures faster reviews with minimal influence and interference from the focal firms.

Ranking the Inventory Management Strategies

This section aimed at examining the ranking the various inventory management strategies as adopted by the food processing firms in Ghana. This was geared towards identifying the key strategy adopted by these firms during inventory management. The result was analysed using descriptive statistical tools such mean and standard deviation scores and presented in Table 7.

Table 7. Ranking Inventory Management Strategies

Strategy	Mean	Standard Deviation	Ranking
Economic Order Quantity (EOQ)	4.15	0.847	1st
Strategic Supplier Partnership	4.06	0.822	2nd
Activity Based Costing (ABC)	3.95	0.944	3rd
Vendor Managed Inventory (VMI)	3.85	1.06	4th
Just-in-Time (JIT)	3.44	1.159	5th

Source: field survey

From Table 7, it could be deduced that, the economic order quantity (EOQ) strategy was the most adopted and used with the highest mean score of 4.15 with a standard deviation score of 0.847. It, therefore, ranks 1st among the other inventory strategies used by the food processing firms in Ghana. This means that, the firms adopt the EOQ strategy the most during inventory management. The result implies that, food processing firms in Ghana place fixed orders whenever their inventories fall below specified optimum levels. They also have specific procedures for determining the cost components associated with inventory whereas they ensure that lead time and customer demands are known and constant over time. Finally, they adopt this method in order to prepare adequately toward inventory shortages. The use of this strategy has widely been supported by the theory of constraints which suggests that firms need to adopt relevant strategies such as EOQ during inventory management in a bid to address inventory constraints. Rao and Mangal [2018] concluded that EOQ is key to ensuring successful inventory management. Atnafu and Balder [2018] also found EOQ to significantly improve firm performance and competitiveness.

The result was followed by Strategic Supplier Partnership (SSP) strategy (M=4.06; SD=0.822) which ranked 2nd among the other strategies. This means that, SSP is one of the key strategies adopted by food processing firms during inventory management. The result implies that, majority of the food processing firms in Ghana involve their key suppliers during inventory management while sharing vital information with them during regular meetings. Also, these firms have formal agreements with their key suppliers which give them priorities over competing firms. The finding also implies that food processing firms ensure that their key suppliers have adequate capacities to handle their inventories. The result has largely been supported by Mukopi and Iravo [2015] who concluded that strategically collaborating with suppliers allow Kenya's sugar manufacturing firms to acquire high-value goods even in times of supply uncertainties. Khan and Siddiqui [2018] stressed that strategically partnering with suppliers could have a positive impact on supply chain performance. The theory of constraints also emphasises on the need for firms to collaborate with key suppliers as a strategy to manage possible constraints such as inventory.

Activity Based Costing (ABC) (M=3.95; SD=0.944) was also among the most used inventory management strategies adopted by food processing firms in Ghana (i.e. ranked 3rd). The result implies that, the firms studied manage their inventories through item classification where all their items are properly classified for easy identification. Also, the firms ensure selective control over their inventories where highly important or valuable items are given maximum control over less important items. The firms also allocate funds on the basis of item value which are periodically done. Thus, items are periodically re-categorised to ensure that highly valuable items are constantly detected and well managed. Krumwiede and Charles [2014] added that, ABC strategy also ensures proper utilisation of resources and physical control over inventory. Al-Qudah and Al-Hroot [2017] found the ABC strategy to improve firm profitability by 47.22 percent. Opoku et al. [2020] found that ABC to contribute to bettering operational performance.

The study further revealed vendor managed inventory (VMI) (M=3.85; SD=1.060) as the 4th ranked strategy adopted by food processing firms in Ghana during inventory management. The result implies that, during inventory management, these firms allow their suppliers to manage inventories at their premises by focusing on supplier capacities, how key suppliers can assess relevant information and supplier agreements. Also, they sometimes allow key suppliers to control some inventories especially in instances where their warehouses are full. The firms also allow suppliers to periodically review inventories and replenish them as and where necessary. According to Stadtler [2015], with this strategy, suppliers agree to take the responsibility for making key decisions on the amount and timing of inventory replenishment on behalf of the focal firm. In a similar vein, Wambua et al. [2015] found that VMI reduces inventory-carrying costs, stock out issues while ensuring better forecasts. However, this strategy may not be popular among Ghana's food processing firms due to their reluctance in allowing key suppliers to manage their inventories. This could be due to fear of failure on the part of key suppliers to deliver inventories as and when needed, lack of trust, poor technologies to managing inventories effectively and inadequate supplier capacities including inadequate warehouse spaces.

Finally, the Just-In-Time (JIT) strategy was found as the least used inventory management strategy with the lowest ranking (i.e. 5th). This is because, the result had the lowest mean with standard deviation scores (M=3.44; SD=1.159). The result implies that, even though the food processing firms in Ghana adopt the JIT strategy, it is the least used among the other strategies. Thus, some firms rarely adopt this strategy during inventory management and this could be argued to the complex nature of this strategy. This is because, firms which adopt the strategy constantly adhere to production schedules, on-time supplies, quick communication and well-structured layout. Also, such firms primarily produce on the basis of customer specification in order to minimise wastages and production errors which are mostly unlikely to be followed by food processing industries across the globe. Arguably, food processing firms would struggle to operate effectively on the basis of customer specification which emphasises on customisation. This could be because of how delicate their inventories are coupled with the high perishability rate if not consumed within a limited time period. These factors could make adopting the JIT strategy to managing inventories extremely difficult especially for firms in this industry. Processing foods solely on customer demands and requirements, for instance, could have severe health implications on end users. According to Biggart and Gargeya [2002], Just-In-Time traces its origins from the automobile industry specifically the Toyota production system; thus, it is unsurprising if it is not popular among food processing industries in a developing economy such as Ghana.

CONCLUSIONS

Based on the study's results, the made some conclusions. The study concluded that all the strategies identified contributed in diverse ways to ensuring effective inventory management of the food processing firms in Ghana. For instance, the ABC strategy is effective in managing inventories of food processing firms in Ghana by emphasising on item categorisation, selective control and selective allocation of resources and funds. The SSP strategy contributes to inventory management of food processing firms in Ghana by ensuring early supplier involvement, complete information sharing while establishing long-term agreements with key suppliers. The study also concluded that the EOQ and SSP strategies are the most used and important strategies for managing inventories among food processing firms in Ghana. On the other hand, the study concluded that, the JIT strategy is the least adopted for managing inventories of food processing firms in Ghana. However, due to its importance, some firms may be embracing it and thus, it could increase in importance over a given time period. With respect to these conclusions, the results could be used to facilitate the implementation of relevant strategies aimed at ensuring effective inventory management in food processing industries.

It seems clear that food processing firms need to place much emphasis on Economic Order Quantity and Strategic Supplier Relationship strategies in order to ensure effective inventory management to improve performance levels. The study, therefore, recommended that management of food processing firms should manage inventories by constantly monitoring customer demands, lead times and production costs. They should also involve their key suppliers during inventory management right from the design stage to the end of the inventories' useful life. Secondly, the study's result exposes management to the significance of adopting relevant strategies during inventory management. This will inform policies and practices associated with inventory management. Proper inventory management could lead to improved firm performance with respect to high product quality, speed, flexibility, dependability while minimising production costs. The study's results will also assist management of food processing firms in Ghana to concentrate on relevant strategies aimed at ensuring proper inventory management. It is vital for food processing firms to compete effectively while remaining sustainable in today's unhealthy business environment; achievable through proper inventory management as inventories account for over 70 percent of these firms' total current assets.

The study also made some theoretical contributions by providing empirical evidence with respect to inventory management strategies adopted by manufacturing firms including food processing industries in developing economies notably Ghana. The study was conducted within the framework of theory of constraints. Despite the immense contributions of inventories to the food processing sector in Ghana, studies related to inventory management strategies have not received much recognition in the country. However, previous studies have proven that by giving relevant attention to inventory strategies, valuable proof of their associated benefits could be derived in the food processing sector in Ghana. This could help improve the overall performance levels of firms the sector and invariably increase its contributions to economic development of the country. The study's findings may also help to overcome the limited literature on inventory management strategies within the food processing sector in developing economies notably Ghana. However, the study was limited to only one class of manufacturing sector (i.e. food processing sector) in Ghana; thus, the study cannot be generalised to all classes of firms in Ghana's manufacturing sector. Future studies could look at all or other classes of firms (i.e. plastics/rubber, metal/aluminium, pharmaceuticals/chemical, etc.) in the manufacturing and service industries. The study relied on the cross-sectional approach and as such, future research could consider using the longitudinal approach in order to provide better understanding of issues associated with inventory management. The mixed approach could then be employed to obtain in-depth information through both qualitative and quantitative means.

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REFERENCES

Ackah C., Adjasi C., Turkson F., 2014. Scoping study on the evolution of industry in Ghana (2014/075). WIDER Working Paper. http://hdl.handle.net/10419/97115

Al-Qudah L.A.M., Al-Hroot Y.A.K., 2017. The Implementing Activity-Based Costing Technique (ABC) and its impact on profitability: A Study of Listed Manufacturing Companies in Jordan. International Journal of Economics and Financial Issues, 7(2), 271-276.

Association of Ghana Industries, 2018. Fortune for Africa. Accra, Ghana: Association of Ghana Industries.

Atnafu D., Balda A., 2018. The impact of inventory management practice on firms' competitiveness and organizational performance: Empirical evidence from micro and small enterprises in Ethiopia. Cogent Business & Management, 5(1), 1503219. http://doi.org/10.1080/23311975.2018.1503219

Biggart T.B., Gargeya V.B., 2002. Impact of JIT on inventory to sales ratios", Industrial Management & Data Systems, 102, 4, 197-202. http://doi.org/10.1108/02635570210423235

Chan S.W., Tasmin R., Aziati A.N., Rasi R.Z., Ismail F.B., Yaw L.P., 2017. Factors influencing the effectiveness of inventory management in manufacturing SMEs. In IOP Conference Series: Materials Science and Engineering, 226, 1, 012024.

Chen Z.X., Tan K.H., 2011. The perceived impact of JIT implementation on operations performance. Journal of Advances in Management Research, 8 (2), 213-235. http://doi.org/10.1108/09727981111175957

Creswell J.W. 2014. A concise introduction to mixed methods research, Sage Publications, New York, NY.

Elhamma A., 2015. Perceived benefits of ABC implementation in Moroccan enterprises: Results of an empirical study. American Journal of Business, Economics and Management, 3(2), 24-35.

Elsayed K., Wahba H., 2013. Reinvestigating the relationship between ownership structure and inventory management: A corporate governance perspective. International Journal of Production Economics, 143(1), 207-218. http://doi.org/10.1016/j.ijpe.2013.01.011

Gupta M.C., Boyd L.H., 2008. Theory of constraints: a theory for operations management. International Journal of Operations & Production Management, 28(10), 991-1012. http://doi.org/10.1108/01443570810903122

John N., Etim J., Ime T., 2015. Inventory management practices and operational performance of flour milling firms in Lagos, Nigeria. International Journal of Supply and Operations Management, 1(4), 392-406.

Khan A., Siddiqui D.A., 2018. Information sharing and strategic supplier partnership in supply chain management: a study on pharmaceutical companies of Pakistan. Asian Business Review, 8(3), 117-124. https://ssrn.com/abstract=3397101

Kolawole A.D., Akomolafe A.B., Olusipe B.J., 2019. Inventory Management: An Impetus for Increased Profitability in Manufacturing Firms. International Journal of Accounting, Finance and Risk Management, 4(4), 1-6.

Koumanakos D.P., 2008. The effect of inventory management on firm performance. International Journal of Productivity and Performance Management, 57(5), 355-369. http://doi.org/10.1108/17410400810881827

Krumwiede K.R., Charles S.L., 2014. The use of activity-based costing with competitive strategies: impact on firm performance. Advances in Management Accounting (pp. 113-148), New York, NY: Emerald Group Publishing Limited. http://doi.org/10.1108/S1474-787120140000023004

Munyao R.M., Omulo V.O., Mwithiga M.W., Chepkulei B., 2015. Role of Inventory Management Practices on Performance of Production Department. A Case of Manufacturing Firms. International Journal of Economics, Commerce and Management, 3(5), 1625-1656.

Mulandi C.M., Ismail N., 2019. Effect of inventory management practices on performance of commercial state corporations in Kenya. International Academic Journal of Procurement and Supply Chain Management, 3(1), 180-197. http://www.iajournals.org/articles/iajpscm_v3_i1_180_197.pdf

Opoku R.K., Fiati H.M., Kaku G., Ankomah J., Opoku-Agyemang F., 2020. Inventory Management Practices and Operational Performance of Manufacturing Firms in Ghana. Advances in Research, 1-18. http://doi.org/10.9734/air/2020/v21i1030246

Panigrahi C.M.A., 2013. Relationship between inventory management and profitability: An empirical analysis of Indian cement companies. Asia Pacific Journal of Marketing & Management Review, 2(7), 23-37. https://ssrn.com/abstract=2342455

Pokorná J., 2016. Impact of Activity-Based costing on financial performance in the Czech Republic. Acta Universitatis agriculturae et silviculturae mendelianae brunensis, 64(2), 643-652. http://doi.org/10.11118/actaun201664020643

Qrunfleh S., Tarafdar M., 2013. Lean and agile supply chain strategies and supply chain responsiveness: the role of strategic supplier partnership and postponement. Supply Chain Management: An International Journal, 18(6), 571-582. http://doi.org/10.1108/SCM-01-2013-0015

Rajeev N., 2008. Inventory management in small and medium enterprises. Management Research News, 31(9), 659-669. http://doi.org/10.1108/01409170810898554

Rao V.M., Mangal D., 2018. Economic order quantity-a tool for inventory management-a case study. International Journal of Supply Chain and Inventory Management, 3(1), 56-65. http://doi.org/10.1504/IJSCIM.2018.098238

Saunders M., Lewis P., Thornhill A., 2012. Research methods for business students (6e éd.). Harlow, England.

Sunday O., Joseph E.E., 2017. Inventory Management and SMEs Profitability. A Study of Furniture Manufacturing, Whole-sale and Eatery Industry in Delta State, Nigeria. Journal of Finance, 5(3), 75-79. http://doi.org/10.12691/jfa-5 -3 -1

Stadtler H., 2008. Supply chain management: An overview, In Supply chain management and advanced planning, Springer, Berlin, Heidelberg. 9-36.

Taylor S.L., 2017. Food allergies-A public health dilemma how did we get here? Where are we going? Food Protection Trends, 37(6), 462-463.

Wambua B.J., Okibo W.B., Nyang'Au A., Ondieki S.M., 2015. Effects of Inventory Warehousing Systems on the Financial Performance of Seventh Day Adventist Institutions: A Case of Adventist Book Centers (ABC), Kenya. International Journal of Business and Management, 10(4), 259-268. http://doi.org/110.5539/ijbm.v10n4p259

Weiss D., 2014. Internal controls in family-owned firms. European Accounting Review, 23(3), 63-482. http://doi.org/10.1080/09638180.2013.821814

STRATEGIA ZARZĄDZANIA ZAPASAMI W PRZEMYŚLE SPOŻYWCZYM W KRAJACH ROZWIJAJĄCYCH SIĘ

STRESZCZENIE. **Wstęp:** Wśród wielu różnych procesów zachodzących w łańcuchach dostaw produktów żywnościowych, zarządzanie zapasami uznaje się za jednej z najważniejszych i najbardziej złożonych procesów. Zapasy pochłaniają ponad 70% zasobów w firmach spożywczych zarówno w krajach rozwijających się jak i rozwiniętych. W związku z tym właściwe zarządzanie tymi zapasami jest kluczowe dla zwiększenie konkurencyjności i polepszenia wyników finansowych firmy. Jednak w wielu rozwijających się krajach, między innymi w Ghanie, strategie zarządzania, stosowane przez firmy spożywcze dla zarządzania zapasami, pozostają niejasne i nieprecyzyjne. Celem tej pracy jest analiza różnych strategii zarządzania zapasami, z głównym naciskiem na firmy spożywcze, dla rozwijającej się gospodarki, na przykładzie Ghany.

Metody: Zastosowano podejście ilościowe jak i schemat opisowy, oparty na teorii ograniczeń. Dane do badań zebrano przy użyciu ustrukturyzowanej ankiety od 104 firm spożywczych, działających w Ghanie. Analiza danych została wykonana przy użyciu narzędzi statystycznych (m.in. wyliczając średnią i odchylenie).

Wyniki: W wyniku przeprowadzonej analizy, stwierdzono, że w krajach rozwijających się, na przykładzie Ghany, w większości przypadków preferowaną metodą postępowania w zarządzaniu zapasami jest metoda ekonomicznej wielkości zamówienia. Kolejnymi metodami, preferowanymi przez ankietowanych jest oparcie się o strategicznego dostawcę oraz strategia oparta o kalkulację kosztów.

Wnioski: Wyniki uzyskane w czasie tej pracy określają empiryczne podejście w zarządzaniu zapasami w firmach spożywczych w krajach rozwijających się oraz prezentują politykę i praktycznie stosowane strategie zarządzania zapasami w tych firmach.

Słowa kluczowe: strategie zarządzania zapasami, Just-in-time, ekonomiczna wielkość zamówienia, dostawca strategiczny, zarządzanie zapasem kupującego, kalkulacja kosztów

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ORIGINAL PAPER

CYBER SECURITY IN SUPPLY CHAIN MANAGEMENT: A SYSTEMATIC REVIEW

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ABSTRACT. **Background:** Cyber security of supply chain is a part of its safety measure that focuses on the management of the required cyber security that includes information technology systems, software, and networks. Supply chain management has a high risk of being threatened by cyber terrorism, malware and data-theft. Common supply chain cyber security activities are done to minimize risks including sole-purchase from trusted vendors, and disconnection of critical machines from external networks.

Methods: The main data sources for this study are research articles published from 2010 to 2020 in a peer-reviewed journal in the Web of Science and Scopus database. This study uses a systematic survey approach that is guided by PRISMA Statement, where the current study shows the trend of cyber research security in supply chain management.

Results: The final screening shows 41 identified related articles that are related to cyber security in supply chain management. This study also examined the publishing trends related to cyber security in supply chain management for both WOS and Scopus databases. The analysis shows that the highest publishing value was in 2019, coming from the Scopus database. In addition, four elements are covered in this study namely: (i) network security; (ii) information security; (iii) web application security and (iv) internet of things (IoT).

Conclusions: In brief, some suggestions are proposed to provide guidance for future researchers to study deeper about cyber security in supply chain management.

Key words: systematic review, supply chain, cyber security, network security, information security.

INTRODUCTION

Today, supply chain is becoming more complex and global. It is now increasingly dependent on information technology to increase its efficiency and to support communication and coordination between network suppliers, manufacturers, distributors, and even transportation service providers. Simultaneously, if information technology is not appropriately secured, it will increase supply chain vulnerability to cyber attacks [Kirk, 2014]. Raghavan, Desai and Rajkumar [2017] claimed that cyber security is frequently debated in the business industry from various angles, as recent violations show that every sector is exposed.

Furthermore, supply chain management needs to be carefully planned to get the right product, in the right quantity, and in the right place at the right time to reach the customers, and necessarily at the right price as claimed by [Mangan, Lalwani 2016]. As such, organizations digitize their operations to improve process efficiency and cost optimization [Shivajee et al., 2019]. Additionally, Shivajee et al. [2019] explained that the application of effective information technology tools ensures the organization's continued growth. Prominently, it regulates a set of techniques used to increase the security

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and integrity of a programme, network, and data from unauthorized and harmful access. Likewise, it refers to the process and technological body [Seemma, Nandhini, Sowmiya, 2018].

According to Miorandi et al. [2012], the supply chain is now consolidated between organizations through digital communication links due to digitization. In the supply chain, all members become the weakest because of the information and security arrangements that are shared throughout the supply chain. Meanwhile, Li et al. [2015], through their analysis found that information exchange, agility, and visibility increase through digital technology. However, there are some threats and risks that arise in this supply chain.

There are investigative reports made on data breaches where small organizations are often the target of cyber attacks due to their size in the supply chain. As such, larger companies are at risk of being exposed to specific threats, which have contracts with these small organizations to produce particular products [Verizon, 2014]. There is no denying that there is an increase in the number of attackers, but the tools available to the potential attackers are also becoming more sophisticated and active [Kizza, 2013; Koien, Oleshchuk, 2013]. Hence, Taneja [2013] highlighted that the use of the cyber medium and the internet could achieve its full potential if it thrives from cyber vulnerabilities and threats.

Yeboah-Ofori and Shareeful Islam [2019] described that cyber security within the supply chain provides organizations with secure network facilities to meet business objectives as a whole. Obviously, technological integration helps increase business processes, production productivity, and even reduce distribution costs. However, the increasing interdependence between the various supply chain stakeholders has created many challenges, including the lack of third-party audit mechanisms and cyber threats. This has also led to attacks such as design specification manipulation, changes, and manipulation during distribution activities. Hackers are also seen targeting web applications, as they have many networks. Thus, careful attention and monitoring can be done through firewalls and intrusion detection systems. In detail, the web application layer needs to be set up to ensure that it is safe from unauthorized users by developing high-quality security mechanisms for software development [Ge, Paige, Polack, Chivers, Brooke, 2006]. Web applications are an essential type of service provider and communication channel for their users. Vulnerability on the internet can have a detrimental effect and in turn, it affects all sensitive data.

The systematic literature review is an analysis of research questions formulated using systematic methods that aims to collect secondary data and efforts to identify, select and synthesize related studies to answer the research questions. To build a relevant systematic overview, the current article is guided by this key research question: "What is the focus field of cyber security in supply chain management?" This study's concentration is to explore areas that have been explored by previous studies in the context of cyber security in supply chain management, and this study also attempts to identify the trends of articles published in the last 10 years (2010-2020). Therefore, the focus of this study is to study this problem systematically.

METHODOLOGY

For the present study, the method used to obtain related articles of cyber security in supply chain management is discussed. Researchers have used key sources to search for associated articles from the Web of Science (WOS) and Scopus databases. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) approach, the researchers conducted systematic reviews such as eligibility criteria and exclusions, process revision like introductory steps, examination and qualification. Next, it is followed by data abstraction and article analysis.

Research Design

Systematic literature review is outlined on the basis of important criteria from the

PRISMA checklists. Additionally, PRISMA's statement allows the search for terms related to cyber security in supply chain management. This is important to ensure that researchers have taken measures to reduce bias in design and revision response.

Sources of Data

For the present study, the researchers relied on two major journal databases: Web of Science (WoS) and Scopus. As claimed by Zhu [2020], WoS and Scopus are two of the world's leading and competing citation databases. The web-based Web of Science was launched in 1997, and the database was renamed as the "Web of Science Core Collection" in around 2014. Additionally, the Science Citation Index Expanded, Social Sciences Citation Index and Arts and Humanities Citation Index was originally developed in 1997 and its gradual coverage developed ever since [Liu, 2019; Rousseau et al., 2018]. According to Cision [2017], it was initially produced by the Institute of Scientific Information (ISI) and is now operated by Clarivate Analytics. Furthermore, the Web of Science's acceptable content is determined by the evaluation and selection process based on the following criteria: impact, influence, timelinessness, peer review, and geographical representation [Reuters, 2010].

Meanwhile, Scopus is an abstract database and a collection of Elsevier launched in 2004. All journals covered in the Scopus database, regardless of who they are published below, are reviewed annually to ensure that the high quality standards are maintained. Search in Scopus also incorporates patent database search. In addition, Scopus also provides four types of quality measurements for each title: h-Index, CiteScore, SCImago Journal Rank and Source Normalized Impact per Paper [Kulkarni, Aziz, Shams, Busse 2009].

Systematic Review Process

Based on Figure 1, four stages are involved in the systematic review process. The first stage is to identify the keywords used for the search process. Researchers refer to previous studies and the keywords "cyber security" and "supply chain" or "supply chain management" were used. The following are the requirements for the Scopus database: TITLE-ABS-KEY ("cyber security") AND TITLE-ABS-KEY ("supply chain" OR "supply chain management"). For the WoS database, the following terms are used: TS = ("cyber security") AND TS = ("supply chain" OR "supply chain management"). In the first stage of identification, after a careful screening, 33 duplicate articles were deleted. The second stage was screening; 153 articles were worth reviewing, and 82 articles were issued. The third level was eligibility, where the full articles were accessible. After careful examination, the amount of 74 articles was excluded for not focusing on cyber security in supply chain management, and they were not conceptual papers. They did not focus on the areas studied by the researchers. Next, the final stage that was surveys that showed 41 articles used for further analysis (Figure 1).

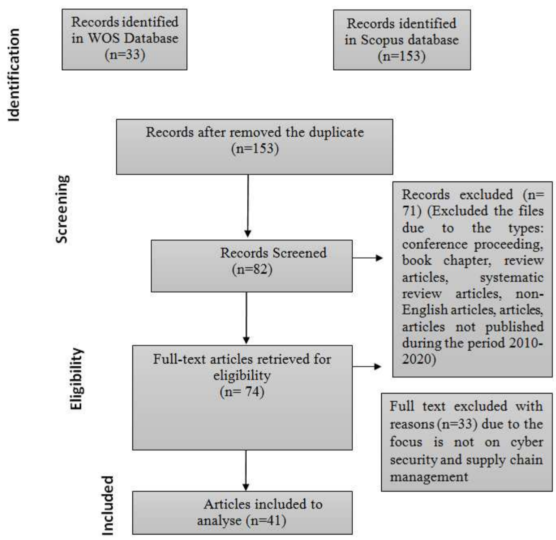

Fig. 1. Flow of the Systematic Review

Data Abstraction and Analysis

For data abstraction and analysis, the remaining articles were evaluated and analyzed by the researchers. The focus was on specific studies that could answer the research questions. The data was extracted using in-depth article reviews to obtain information related to the focus of each article.

Result and Discussion

The present study shows an overview of 41 articles that met the criteria set by the researchers for the purpose of the systematic review.

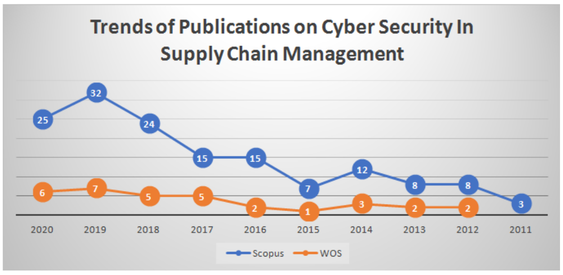

Fig. 2. Trend of Publications

The present study aims to systematically analyze the existing literatures on the outcomes of cyber security in supply chain management. The outcome should be entirely determined at the beginning of the supply chain management's activities to ensure that the outcomes were accessible. Referring to Figure 2, it was a trend of publication on cyber security in supply chain management. Compared to the two databases of Scopus and World of Science (WOS), the trend graph shows that most publications in the Scopus database were high. Next, 2019 shows the highest year data for published articles for these two databases where 32 articles were published in the Scopus database while 7 articles were published in the WOS database. Based on the researchers' observations, the trend of publications related to cyber security in supply chain management increased little by little every year starting in 2011, where there were only 3 publications in the Scopus database. In the following year, 2012 and so on, the number of publications increased unevenly, but related publications were still published. Overall, the publishing trend for this topic is growing and begins to be explored by researchers.

Analysis on Field of Study Covered in WOS and Scopus Databases

In the analysis of the entire final articles selected after screening, the researchers identified areas of studies related to cyber security in the context of supply chain management (Refer Figure 3). When most companies and businesses think about security, they often think about securing their digital networks, software, and assets from cyber attacks and data breaches. But, for the supply chains of whether traditional manufacturers or service providers, or data supply chains trusted by most large companies, they are also vulnerable to security risks. This is seen in many big data breaches through third parties. In practice, every company or business has a place in the supply chain, where the supply chain continues to grow on the flow of information such as the flow of goods and services. Therefore, it is not surprising that supply chain security is a very complex and continuously evolving function. Next, this shows that business executives pay more attention as the risks faced by information across the supply chain become increasingly apparent.

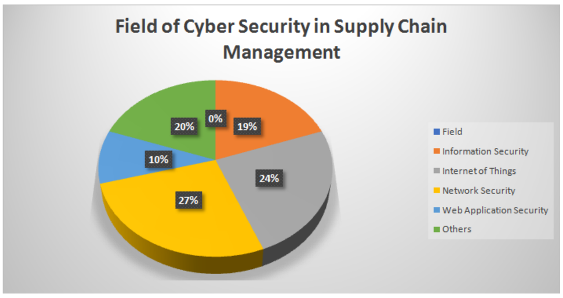

Fig. 3. Field of Study

Network Security

According to Figure 3, it shows that 27% of past studies were in network security (e.g. [Klos, Richardson, Corporation, 2013; Kshetri Voas, 2019; Pandey, Singh, Gunasekaran, Kaushik, 2020; Tamy, Belhadaoui, Rabbah, Rifi, 2020]. According to Gaigole and Kalyankar [2015], network security is an essential element for personal computer users as well as organizations. Besides, safety is the main concern due to the widespread use of the internet. There is no denying that the internet itself can pose some security threats. This can be explained when the intellectual property can be easily accessed through the internet, and there are many types of attacks that can be transmitted over the network. There are differences in network security management for all types of situations, and it is necessary because the increased daily use of the internet includes home or office use, where it requires underlying security. However, large businesses require high maintenance, capable software, and sophisticated hardware to prevent hackers and scammers [SANS Technology Institute, 2020]. On the other hand, Gaigole and Kalyankar (2015) highlighted that network security should be a priority for the entire network, in order to stay awake and protected. Network security does not only focus on computer security at each end of the communication network, but it should also be monitored when sending data, as communication channels should not be vulnerable. This is because it will pose a greater threat. Hackers may intend to hack communication channels, obtain, manipulate data, and disseminate false information within the network.

Information Security

Next, Figure 3 shows that 19.5% of the past studies were in the field of information security [e.g. Boyson, 2014; Fernández-Caramés, Blanco-Novoa, Froiz-Míguez, Fraga-Lamas, 2019; Ram, Zhang, 2020]. Information security refers to a set of strategies for managing the tools, policies, and processes involved in detecting, preventing, and documenting. In addition, it is also to respond to threats to digital and non-digital information. The purpose of developing an information security programme is to protect the integrity, availability, and confidentiality of a business's data and information technology system. Among other things, it is also to ensure that sensitive information is disclosed only to the authorities, avoid manipulating invalid data, and confirm that the appropriate authorities can access the data when needed [Jain, Parashu, 2017]. The development of information security programmes aims to protect the integrity, availability, and confidentiality of business data systems and information technology.

Web Application Security

As reported in Figure 3, there were 9.8% previous studies in web applications [e.g. Osborn, Simpson, 2017, 2018; Polatidis, Pavlidis, Mouratidis, 2018]. Jain and Parashu [2017] explained that protection is required on any software used by the user. Each of these applications may contain holes or vulnerabilities in which an attacker can infiltrate user requests. Besides, application security includes software, hardware, and procedural methods to protect applications and avoid external threats. Among other things, aspects of application security also include actions taken during the development life cycle to protect applications from possible risks through vulnerabilities. It covers the design, development, use, upgrading, or maintenance of applications. Moreover, the security rules found in security forms and practices in the proper use of applications can minimize the risk of manipulating applications to steal data, hacking keywords to gain access, and controlling the data contained. Pandey and Singh [2020] classify cyber security risks into three categories: cyber security, supply risk, operational risk and demand risk. Cyber physical system has pushed global innovation into the daily operations of SC professionals. Web applications are an important type of service provider and communication channel for users. Vulnerability on the internet can create harmful effects and affect all sensitive data. Moreover, the main reason for this is that developers have limited programming skills and lack awareness of the importance of cyber security [Durai, Priyadharsini, 2014].

Internet of Things

The internet of things shows 24.4% of the past studies focusing on this area [e.g. Ardito, Petruzzelli, Panniello, Garavelli, 2019; Cheung, Bell, 2019; Gajek, Lees, Jansen, 2020; Urquhart, McAuley, 2018]. According to de Vass, Shee, and Miah [2018], the Internet of Things (IoT) is the next generation in an embedded ICT system connected to the internet network in a digital environment to integrate the supply chain, and logistics process to run smoothly. Additionally, the emerging IoT integration into the current ICT system can be unique because of its ingenuity.

Their study also found that IoT can positively and significantly impact the integration of internal processes, customers, and suppliers, which affects supply chain and organization performance. Mostafa, Hamdy, and Alawady [2018] highlighted that IoT is a new technology that enables the connection of several objects by collecting real-time data and sharing it; the information generated can then be used to support automated decision-making. Phase and Mhetre [2018] described that IoT infrastructure operates by assembling, delivering information to track the position, quality, and timely delivery of goods. IoT today is used to track goods and predict the situation to help protect and reduce losses. Multifaceted algorithms happen due to the different supply chains. Lastly, 19.5% of the statistics showed about other fields.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the 41 final articles screened in the present study, the researchers found that future studies can meet some constraints. First and foremost, cyber security is an essential factor in today's supply chain management, but most studies do not explain it further. Researchers suggest that future studies explore more about web security elements other than those discovered in this study, namely web application security, internet of things, network security, and information security. By exploring other elements in future studies, they can explain more about the importance of establishing cyber security in supply chain management. Secondly, most past studies relied on keyword searching. This technique is the most commonly used form of text search on the web. Most search engines query and retrieve their texts using keywords [Rahman, 2013]. Nevertheless, another searching method includes citation searching. As claimed by Fasco [2004], savvy searching means citation searching. This search technique has long been used for decades. Moreover, Wright, Golder and Rodriguez-Lopez [2014] claimed that citation searching is an additional search method for systematic review and it is useful to confirm findings in other reviews. Hence, future studies are proposed to use this technique to explore more search articles in the field of cyber security in supply chain management.

CONCLUSION

In brief, this study presents a systematic review of existing literatures on the results of cyber security in supply chain management by reviewing study publications in the last ten years. The reviews were sourced from two databases namely Scopus and WoS, that produced 41 articles related to the field. This survey provides scholars' views on the importance of cyber security in supply chain management. From the present study, it shows that the trend of cyber security research in supply chain management is increasing and getting more attention from scholars. This present study discovered four main elements in cyber security: i) network security; ii) web application security; iii) internet of things; and iv) information security. Lastly, the majority of the past studies focused on network security. Therefore, many studies related to cyber security are needed in the future to provide more understanding about the importance of cyber security for supply chain management in an organization or business.

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REFERENCES

Ardito L., Petruzzelli A. M., Panniello U., Garavelli A.C., 2019. Towards Industry 4.0: Mapping digital technologies for supply chain management-marketing integration. Business Process Management Journal, 25(2), 323–346. http://doi.org/10.1108/BPMJ-04-2017-0088

Boyson S., 2014. Cyber supply chain risk management: Revolutionizing the strategic control of critical IT systems. Technovation, 34(7), 342–353.

http://doi.org/10.1016/j.technovation.2014.02.001

Cheung K.F., Bell M.G.H., 2019. Attacker–defender model against quantal response adversaries for cyber security in logistics management: An introductory study. European Journal of Operational Research. http://doi.org/10.1016/j.ejor.2019.10.019

de Vass T., Shee H., Miah S.J., 2018. The Effect of "Internet of Things" on Supply Chain Integration and Performance: An Organisational Capability Perspective. Australasian Journal of Information Systems, 22, 1–29. http://doi.org/10.3127/ajis.v22i0.1734

Durai K.N., Priyadharsini K., 2014. A Survey on Security Properties and Web Application Scanner. International Journal of Computer Science and Mobile Computing, 3(10), 517–527.

Fasco P., 2004. Citation Searching. Online Information Review, 28(6), 454–460.

Fernández-Caramés T.M., Blanco-Novoa O., Froiz-Míguez I., Fraga-Lamas P., 2019. Towards an Autonomous Industry 4.0 Warehouse: A UAV and Blockchain-Based System for Inventory and Traceability Applications in Big Data-Driven Supply Chain Management. Sensors (Basel, Switzerland), 19(10). http://doi.org/10.3390/s19102394

Gaigole M.S., Kalyankar M., 2015. The Study of Network Security With Its Penetrating Attacks and Possible Security Mechanisms. International Journal of Computer Science and Mobile Computing, 4(5), 728–735.

Gajek S., Lees M., Jansen C., 2020. IIoT and cyber-resilience: Could blockchain have thwarted the Stuxnet attack? AI and Society, (0123456789). http://doi.org/10.1007/s00146-020-01023-w

Ge X., Paige R., Polack F., Chivers H., Brooke P., 2006. Agile Development of Secure Web Applications. In The 6th International Conference on Web Engineering, 305–312. Palo Alto.

Jain J., Parashu R.P., 2017. A Recent Study over Cyber Security and its Elements. International Journal of Advanced Research in Computer Science, 8(3), 791–793.

Kizza J., 2013. Guide to Computer Network Security. Springer.

Klos S., Richardson J., Corporation S., 2013. Support Better Cyber Security.

Koien G., Oleshchuk V., 2013. Aspects of Persona Privacy in Communications-Problems, Technology and Solutions. River Publishers.

Kshetri N., Voas J., 2019. Supply chain trust. IT Professional, 21(2), 6–10. https://doi.org/10.1109/MITP.2019.2895423

Mostafa N.A., Hamdy W., Alawady H., 2018. Impacts of Internet of Things on Supply Chains: A Framework for Warehousing. Social Sciences (Special Industry 4.0 Implication for Economy and Society), 84, 1–10. http://doi.org/10.3390/socsci8030084

Osborn E., Simpson A., 2017. On small-scale IT users' system architectures and cyber security: A UK case study. Computers and Security, 70, 27–50. http://doi.org/10.1016/j.cose.2017.05.001

Osborn E., Simpson A., 2018. Risk and the Small-Scale Cyber Security Decision Making Dialogue - A UK Case Study. Computer Journal, 61(4), 472–495. http://doi.org/10.1093/comjnl/bxx093

Pandey S., Singh R.K., 2020. Cyber Security Risks In Globalized Supply Chains: Conceptual Framework. Cyber Security Risks. http://doi.org/10.1108/JGOSS-05-2019-0042

Pandey S., Singh R.K., Gunasekaran A., Kaushik A., 2020. Cyber security risks in globalized supply chains: conceptual framework. Journal of Global Operations and Strategic Sourcing, 13(1), 103–128. http://doi.org/10.1108/JGOSS-05-2019-0042

Phase A., Mhetre N., 2018. Using IoT in Supply Chain Management. International Journal Pf Engineering and Techniques, 4(2), 973–979.

Polatidis N., Pavlidis M., Mouratidis H., 2018. Cyber-attack path discovery in a dynamic supply chain maritime risk management system. Computer Standards and Interfaces, 56, 74–82. http://doi.org/10.1016/j.csi.2017.09.006

Rahman M., 2013. Search Engines Going Beyond Keyword Search: A Survey. International Journal Pf Computer Applications, 75, 1–8.

Ram J., Zhang Z., 2020. Belt and road initiative (BRI) supply chain risks: propositions and model development. International Journal of Logistics Management. http://doi.org/10.1108/IJLM-12-2019-0366

SANS Technology Institute. (2020). Predictions and Trends for Information, Computer and Network Security. Retrieved from https://www.sans.edu/cyber-research

Seemma P. ., Nandhini S., Sowmiya M., 2018. Overview of Cyber Security. International Journal of Advanced Research in Computer and Communication Engineering, 7(11), 125–128. http://doi.org/10.17148/IJARCCE.2018.71127

Tamy S., Belhadaoui H., Rabbah N., Rifi M., 2020. Cyber security based machine learning algorithms applied to industry 4.0 application case: Development of network intrusion detection system using hybrid method. Journal of Theoretical and Applied Information Technology, 98(12), 2078–2091.

Taneja M., 2013. An Analytics Framework to Detect Compromised IOT Devices Using Mobility Behaviour. In ICT Convergence (ICTC) on. IEEE, 38–43.

Urquhart L., McAuley D., 2018. Avoiding the internet of insecure industrial things. Computer Law and Security Review, 34(3), 450–466. http://doi.org/10.1016/j.clsr.2017.12.004

Wright K., Golder S., Rodriguez-Lopez R., 2014. Citation Searching: A Systematic Review Case Study of Multiple Risk Behaviour Interventions. Medical Research Methodology, 14(73), 1–8.

Zhu J., 2020. A Tale of Two Databases: The Use of Web of Science and Scopus in Academic Papers. Forthcoming in Scientometrics.

BEZPIECZEŃSTWO CYBERNETYCZNE W ZARZĄDZANIU ŁAŃCUCHEM DOSTAW

STRESZCZENIE. Wstęp: Bezpieczeństwo cybernetyczne łańcucha dostaw jest częścią postępowania mającego na celu zapewnienie bezpieczeństwa, które skupia się na zarządzaniu bezpieczeństwem systemów technologicznych, oprogramowania i sieci. Zarządzanie łańcuchem dostaw jest zagrożone cyberatakami terrorystycznymi, złośliwym oprogramowaniem oraz kradzieżą danych. Działania obejmujące bezpieczeństwo cybernetyczne mają na celu minimalizację ryzyk, między innymi zakup tylko do zaufanych dostawców czy niepodłączanie krytycznych urządzeń od zewnętrznych sieci.

Metody: Praca oparta jest na przeglądzie publikacji naukowych z latach 2010-2020 w podlegających recenzji czasopismach z baz Web of Science i Scopus. Zastosowano metodo liczne podejście zgodne z zasadami PRISMA, ukazując trendy w dziedzinie bezpieczeństwa cybernetycznego w zarządzaniu łańcuchem dostaw.

Wyniki: Wyselekcjonowano 41 publikacji, których tematyka obejmuje bezpieczeństwo cybernetyczne w zarządzaniu łańcuchem dostaw. Przeanalizowano trendy w dziedzinie bezpieczeństwa cybernetycznego w zarządzaniu łańcuchem dostaw. Przeprowadzona analiza wykazała, że najwięcej publikacji ukazało się w 2019 w bazie Scopus. Dodatkowo, wyodrębniono cztery główne elementy badań: bezpieczeństwo sieci, bezpieczeństwo informacji, bezpieczeństwo aplikacji sieciowych oraz Internet rzeczy.

Wnioski: Sformułowano kilka sugestii, które mogą być wskazówkami do dalszych badań nad bezpieczeństwem cybernetycznym w zarządzaniu łańcuchem dostaw.

Słowa kluczowe: przegląd danych, łańcuch dostaw, bezpieczeństwo cybernetyczne, bezpieczeństwo sieci, bezpieczeństwo informacji

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ORIGINAL PAPER

AUTOMATIC SIMULATION MODELLING OF WAREHOUSES

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ABSTRACT. **Background:** The goal of the paper is study on the possibility of using automation in simulation modeling of various types of warehouses, enabling quick verification of projects carried out in the area of storage. The paper outline the problem of simulation modeling of a complex storage system based on the concept of drawer racks designed by the company Zrembud located in Cieszyn, Poland. In order to properly evaluate the usefulness of the concept, the mechanism for modeling of both the drawer racking system and the highly popular row racking system was developed and adjusted to user without advanced simulations skills. The mechanism described in the paper is the part of the methodology of warehouse automatic simulation modeling.

Methods: Based on the structural analysis of rack types and the spatial relations of their components, modeling in the LogABS program was concluded. Modeling was performed in the DES (Discrete-Event System) environment. Data structures are necessary to automate the generation of warehouses. The engine code was written in C ++ programming language.

Results: The result of implementing the mechanism is the automatic generation of two storage systems, adapted to the user's requirements, in one simulation model. The first results of the analyzes for the generated structures determine the size of the storage area necessary to accommodate a certain number of storage units, as well as the level of complexity of the operation of both systems, which translates into the time of transport and loading activities.

Conclusions: The presented mechanism is the basis for the methodology of automatic simulation modeling of warehouses. It allows significant reduction in simulation models building duration, and thus a significant reduction in the time of projects consisting in verifying the concept of spatial arrangement in various projects related to the storage area. The proposed tool is innovative and useful for practitioners specializing in simulation modeling and specialists in warehouse design. Due to the organization and simplification of data structures, it can be implemented in various simulation modeling environments. Also after implementation, it can be used by people who do not have advanced simulation skills.

Key words: rapid warehouse design, automated simulation modeling, drawer racks, simulation, warehouse.

INTRODUCTION

Nowadays, due to the limited amount of space, high cost of maintaining warehouses, limited access to a qualified workforce and high availability of outsourcing services related to the provision of commercial technical solutions, enterprises are exploring innovations in the field of storage. Due to the widespread automation, the cost of developing new solutions is constantly declining. The e-commerce industry became interesting phenomenon requiring efficient processing of a large number of orders for individual customers. The high volume of warehouse traffic is conducive to investing in semi or fully automated storage and picking systems.

One of such solutions is the innovative design of a semi-automatic storage system using racks placed on metal frames (called drawers). Such storage system is based on single or double sections of racks rotated 90 degrees relative to corridor. Each double rack (drawer) can move perpendicular to the transport corridor. The structure of the rack (the number of storage levels and the number

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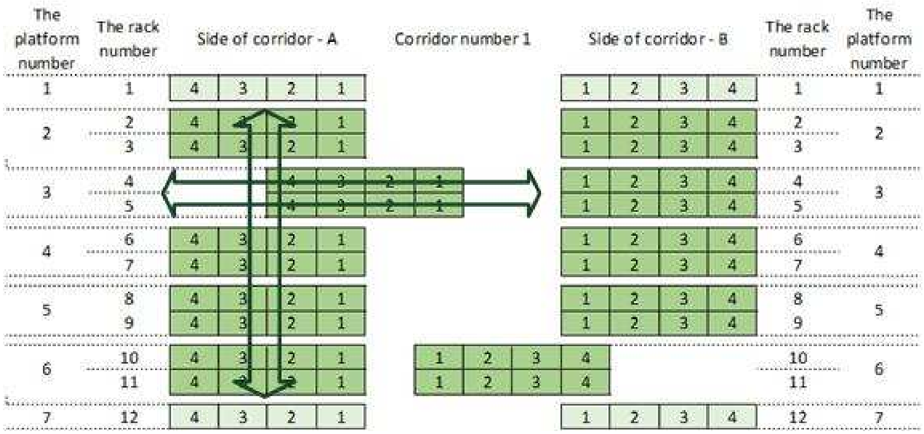
of storage places on single level) can be freely modified depending on the users' requirements. The layout of the drawer rack warehouse is shown in Figure 1.



Source: own work

Fig. 1. The drawer rack system with directions of AGV movement

Figure 1 shows the arrangement of single and double racks in a drawer warehouse. The figure also indicates the platforms, racks and storage areas numbering. In the drawer racking system, single racks are placed at the ends of the rows of racks and do not need to be slid out - forklifts have permanent access to it. On the other hand, access to loads in double rack system is limited, so in order to get access to stored items, it is necessary to lift the platform (metal frame) with the racks and slide it out.

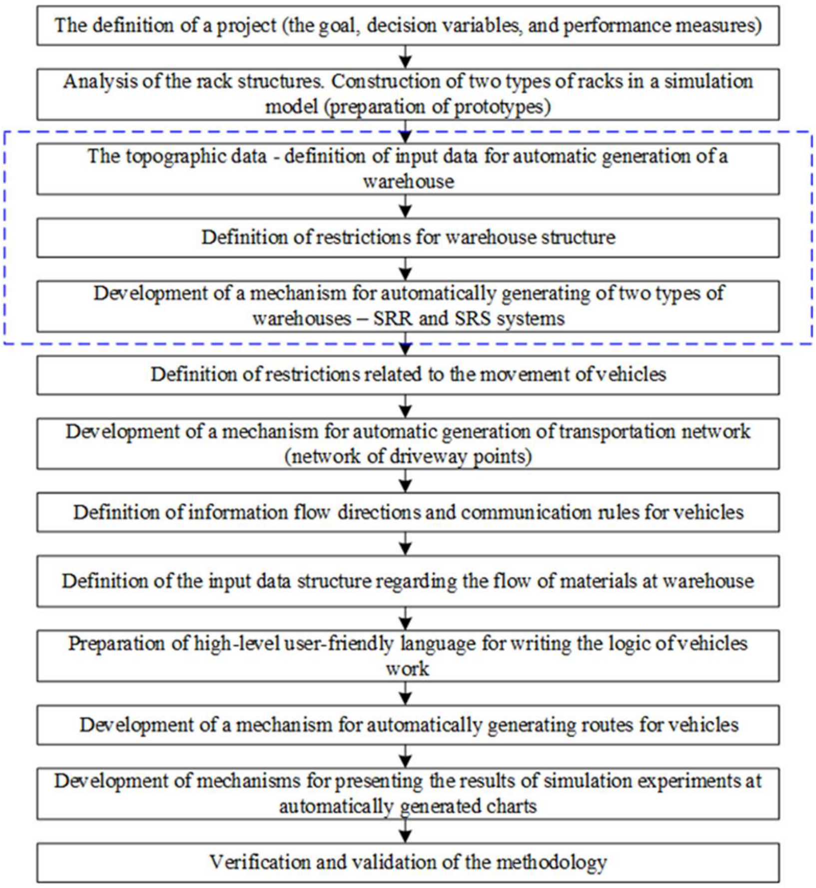
Source: https://zrembud.com.pl/nowe-systemy-regalowe/

Fig. 2. The prototype of drawer rack system

Moving the rack placed on a metal frame is feasible through the use of an automatic guided vehicle (AGV - called Transfer Unit in this case). It moves under the lowest shelving level (in directions marked by vertical arrow at Fig. 1) , and as a result it can reach any drawer, lift it, as well as slide it in and out when necessary (in directions marked by horizontal arrow at Fig. 1). The drawer-rack mechanism is described by Bartkowiak et al. [2019] in more detail. Researchers use data, ideas, rules and technical restrictions from the Zrembud company

The performance of the proposed solution is simulated and compared with the most standard systems, namely single depth row storage. The model is built in the Discrete Event System (DES) environment and uses the ABS simulation. The use of simulation results from the need to verify the designed system of AGV and forklifts management taking into account their communication and cooperation. The simulation allows to efficiently test the designed concepts related to both, the forklifts management and the implementation of safety restrictions. The preparation of a simulation model also allows observing the system in a virtual environment and refining the concept prior to its implementation. A particularly important stage in the design of the new shelving system is the development of a methodology for the automatic generation of drawer and traditional warehouses in order to compare such systems, and determine conditions when the SRS system has an advantage over the row racking system.

The stages of building the methodology of simulation modeling of storage systems are presented in Figure 3.



Source: own study

Fig. 3. The stages of building the methodology of automatic simulation modeling of storage systems

The implementation of the first two stages was the definition of the project and preparation of information and structures to build an automatic warehouse generation mechanism. The implementation of the steps marked in the diagram is the process of building the mechanism, which is the subject of this article. The next steps concern the definition of communication and cooperation rules between AGV and forklifts, and then the construction of a mechanism for automatic management of their work. The last stages of building the methodology include the development of mechanisms for generating charts (in order to analyze the results), as well as the process of its verification and validation.

The main goal of the paper is study on the possibility of using automation in simulation modeling of various types of warehouses, enabling quick verification of projects carried out in the area of storage.

The additional goals of the paper are:

- the presentation of automated drawer racks concept and its originality,
- basis for mechanism of automatic modeling of warehouse,
- presentation of implementation of described mechanism.

Main contribution is to develop the basis for the methodology for automatic building of simulation models of warehouses, that enables rapid warehouse design. Presented mechanism, as part of mentioned methodology, is dedicated to the user without advanced simulations skills and knowledge of simulation methods.

The paper is organized in five sections. Section 2 content the literature review about AS/RS systems and methods of assessment of warehouse performance. In section 3 authors describe the analysis of the rack structure - necessary step in building the mechanism for automatic generation of drawer rack system (SRS) and row racking system (SRR) in the warehouse. Section 4 describes mechanism for automatic generation of warehouses. Section 5 includes conclusions and further works.

LITERATURE REVIEW

The efforts of the companies to substitute manual picking with semi-or fully-automated systems are becoming increasingly popular. Designing new solutions related to the automation of picking processes is a great challenge due to the costs of developing and verifying such solutions. Kunc and Pawlewski [2019] provide the description of most popular non-automatic and semi-automatic solutions for warehousing.

In the existing facilities the amount of space is limited. It causes the developing of compact storage systems in order to improve the utilization of resources [Revillot-Narvaez et al. 2019]. Xu et al. [2019] describes how to designate the optimal size of a multi-deep AS/RS warehouse system. Tappia et al. [2019] provides analytical model that enables to measure the throughput times and order picking performance in integrated warehousing and picking systems. Hu et al. [2018] presents a hybrid algorithm for minimize the time of the retrieval and storage operation in AS/RS system.

The important research of De Koster et al [2008] contains the synthesis of approaches for optimal design of racks in a multi-deep compact automated storage and retrieval system (AS/RS). They consider several storage strategies, including the full-turnover-based storage, two class-based storage and the random storage.

This approaches allow transporting units manipulation in three-dimensional space along three reference axis X, Y, and Z. The movement is possible by implementing a mechanized devices to perform the repetitive tasks of loading, storage and unloading parts in racks.

Researchers use different methods to analyze the performance of fully and semi-automated warehouses. The most popular are dynamic simulation models. However, the study of AS/RS systems also adapts the static approaches.

The use of simulation involve the DES (discrete-event system) approach [Hrusecka et al. 2018], Petri nets [Gerini 2019], Agent-based approach [Ribino 2018], and others.

The static approaches includes travel-time models with empirical [Xu et al. 2020], statistical [Revillot-Narvaez et al. 2019] and continuous approaches.

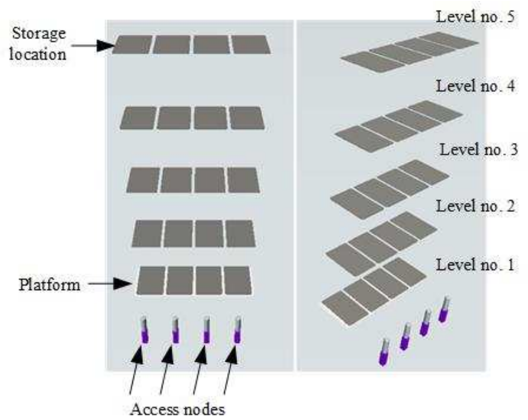
Nowadays researchers are searching opportunities to automatically build simulation models [Garrido and Saez, 2019, Burduk, Grzybowska, Safonyk, 2019, Indrajitsingha et al., 2019].

ANALYSIS OF THE RACK STRUCTURE

Creating a mechanism for automatic warehouse generation requires analysis of the rack structure and building racks in a simulation model (prototypes). It is the base to specify restrictions related to the structure of the rack and extract the parameters necessary for automatic generation of the warehouse.

In both systems, the rack consists of the platform (which is the basis of the structure), a group of storage places (shown as gray rectangles) and access nodes representing the stopping points for the forklifts (determining the distance of the forklifts from the rack when moving in the warehouse, as well as during manipulation).

In the case of the SRR system, the pallet places are arranged in a row on many levels relative to the rack floor, along the corridor. The SRR rack built in the simulation model is shown in Figure 4.

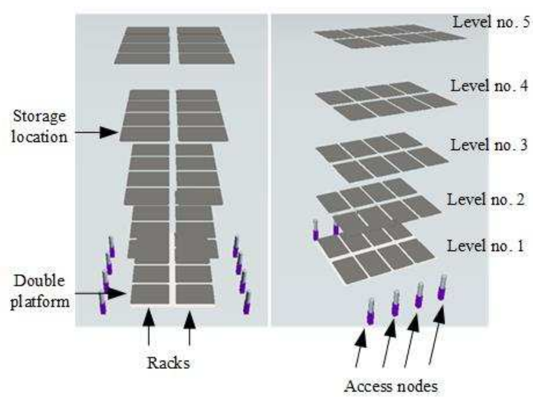


Source: own study with use LogABS simulation program

Fig. 4. The SRR rack built in the simulation model

Modeling a SRS rack requires consideration of both single (placed on the edge of each row of racks) and double (located in a row between the extreme racks) rack structures. Single racks are static racks, the structure of which do not differ from the traditional racks implemented in the SRR, except for the fact of placing them above the floor (placement of the rack on a metal frame) and the arrangement of these racks across (rotated 90 degrees) relative to the corridor.

A double rack (called drawer) consists of two racks placed on a platform. In the simulation model, a double shelf is a single, wide platform, on which two rows of storage places (two racks) are placed on many levels relative to the floor of the shelf, across the corridor. The double rack of the SRS system built in the simulation model is shown in Figure 5. On both sides of the drawer there are access nodes for the forklifts.



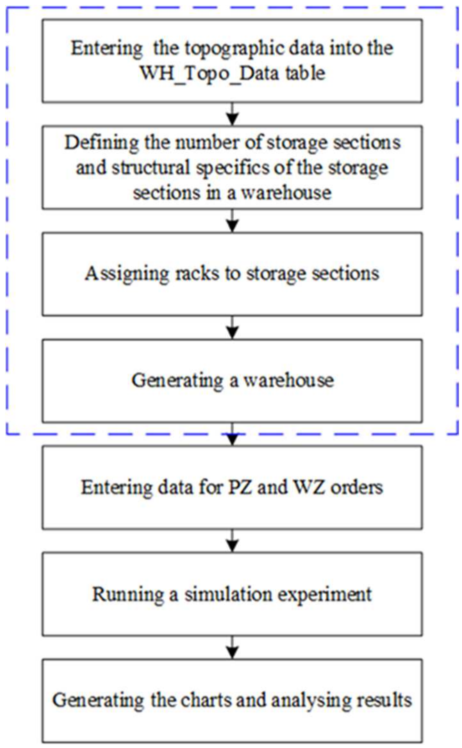
Source: own study with use LogABS simulation program

Fig. 5. The drawer rack built in the simulation model

At the current stage of mechanism development, the simulation model does not reflect the frame or metal structure of the rack. However, the distance between the base of the rack and the floor, the dimensions of the pallet places consistent with the size of the pallet and the distance between the pallets in the horizontal and vertical plane are modelled.

METHODOLOGY AND MECHANISM FOR THE AUTOMATIC GENERATION OF WAREHOUSE

The mechanism for automatic generation of warehouse structures described in this publication is part of the methodology for automatic building simulation models of storage systems shown in Figure 3. Automatic generation of a warehouse is a stage of this methodology, whose implementation is conditioned by the implementation of the steps indicated in Figure 6.



Source: own study

Fig. 6. The stages of methodology for automatically building simulation models of storage systems

The methodology also includes the definition of material flow data, automatic processing of this data, generation of forklifts and AGV executers operation routes, and the management of vehicles work taking into account spatial dependencies and communication. The methodology also includes generating graphs showing the results of simulation experiments. The implementation of these stages is related to the stages of methodology construction shown in Figure 3 and is the subject of other publications.

The use of the mechanism for automatic warehouse generation requires entering a number of data into the following tables:

– WH_Topo_Data - defines the most important data regarding the warehouse structure
– WH_SRS_Section_XXX and WH_SRR_Section_XXX, where XXX is the section identification number. These tables describe the specificity of the storage section, i.e. the types (determining the most important parameters) of the racks.
– WH_Assign_Sections_SRS and WH_Assign_Sections_SRR in which defined sections are assigned to the addresses in the warehouse (rack name).

The topographic data

The structure of the SRS and SRR storage systems is described in the WH_Topo_Data table. Structural data of SRS and SRS reference warehouses with an exemplary capacity of 3480 pallet places are presented in Figure 7.

	SRS	SRR
X coordinate of the first rack	80.78	83.89
Y coordinate of the first rack	35.90	-10
Numer of rows of racks	6	11
Number of racks in one row	12	12
The way of corridors generation	0	0
Corridor width	3.80	3.10
Width of a platform with a single rack (rack at the edge of row)	1.20	1.20
Width of a platform with a double rack	2.60	0
Width of AGV vehicle (Transfer Unit)	2.60	0
Length of platforms	3.60	3.60
Distances between racks	0.10	0.10
Distances between storage places on the Y axis	0.20	0.10
Distances between storage places on the X axis	0.08	0.08
Numer of forklifts	2	2
The maximum number of forklifts in a single corridor	1	2
The distance from rack (to load item)	1	1
The distance from rack (to wait for end of AGV movement)	3	0
The maximum hight of warehouse	8	10
Number of storage sections	2	2

Source: own study

Fig. 7. The view on the window with WH_Topo_Data table

The table is used to define the values of parameters regarding the structure of SRS (in the first column) and SRR (in the second column) warehouses. The first line specifies the X and Y coordinates of the first rack, i.e. the coordinates of the point from which the mechanism will start generating the entire warehouse. The next two lines define the number of rows of racks and the number of platforms (with racks) in one row of racks. The fifth row specifies how to generate rows of racks relative to the first corridor. The value 0 means that the first corridor has an even number of rows of racks (the racks are located on both sides of the corridor) while the value 1 means that the racks are placed only on one side of the corridor. The next row specifies the corridor width, i.e. the distance between the rows of racks. The next three parameters determine the width of the platforms with single and double racks, as well as the width of the AGV executer (also the station to which it is assigned). In the "Length of platforms" line, the user can specify the platform length, which mean width of the row of racks. In the next three lines the distance between racks next to each other and the distance between storage places (pallet places) in two reference axes must be specified. The next data concern the number of forklifts and restrictions on the capacity of the corridor (the number of forklifts that can remain in the corridor at the same time).

The next two lines specify the distances that the forklift must keep from the rack while waiting for the AGV end its movement and when loading from/ unloading to / the rack. These values directly influence the process of generating controlling markers at the right distance from the racks. Determining the maximum height of the warehouse is aimed at implementing additional functionality in the warehouse, i.e. enabling checking (after definition of the warehouse sections using the "Check Compliance" button - see Figure 8) whether the defined racks with the load will fit in the determined usable height. The last line allows to specify the number of storage sections (number of rack types).

Define the storage sections

The warehouse consists of sections. A section is a set of drawers with the same dimensions and structure. The number of sections is defined in the WH_Topo_Data table, and each section is defined in a separate table. Figure 8 shows the table defining the structure of an example section.

WH_SRS_Section_001 | Check Compliance | Help

	SRS
Width of a single storage place in X axis	0.80
Length of a single storage place in Y axis	1.20
The number of storage places within a single storage level	4
The number of storage levels	5
Height of platform	0.72
Height of L1	1.86
Height of L2	1.86
Height of L3	1.85
Height of L4	1.85
Height of L5	1.90

Source: own study

Fig. 8. The view on WH_SRS_Section_001 table filled with sample data

The WH_SRR_Section_XXX table (defining the structure of the section in the SRS warehouse) has the same structure as WH_SRR_Section_XXX table (defining the structure of the section in the SRR warehouse). The tables defining the sections are selected from the drop-down list at the top of the window. The user must complete all tables for the sections he has defined.

The first two lines of the table determine the size of a single storage place on the rack. All storage places within one rack have the same size. The next two lines define the number of storage levels on the rack and the number of storage places on single level. Then it is necessary to determine the height of the metal frame on which the rack stands. The following lines specify the height of the storage levels. Their number is adjusted depending on the defined number of levels.

Assign Sections to Platforms

After defining the section types for both kinds of warehouses, they should be assigned to the platforms (on which the racks stand) in the "Assign Sections to Platforms" window. The window is shown in Figure 9.

SRS

	AdrZR	AdrLogABS	Section
	1A_01	S1A_01	1
Row 2	1A_02	S1A_02	1
Row 3	1A_03	S1A_03	1
Row 4	1A_04	S1A_04	1
Row 5	1A_05	S1A_05	2
Row 6	1A_06	S1A_06	2
Row 7	1A_07	S1A_07	3
Row 8	1A_08	S1A_08	4
Row 9	1A_09	S1A_09	5
Row 10	1A_10	S1A_10	5
Row 11	1A_11	S1A_11	4

SRR

	AdrZR	AdrLogABS	Section
	1A_01	R1A_01	2
Row 2	1A_02	R1A_02	2
Row 3	1A_03	R1A_03	2
Row 4	1A_04	R1A_04	2
Row 5	1A_05	R1A_05	2
Row 6	1A_06	R1A_06	2
Row 7	1A_07	R1A_07	3
Row 8	1A_08	R1A_08	4
Row 9	1A_09	R1A_09	2
Row 10	1A_10	R1A_10	2
Row 11	1A_11	R1A_11	1

Source: own study

Fig. 9. The "Assign Sections to Platforms" window filled with sample data

The "Assign Sections to Platforms" window is divided into two parts. Both parts contain tables listing all rack addresses (platform names) in Zrembud (first column) and LogABS program (second column) notations.

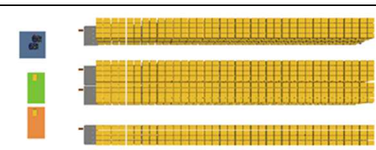
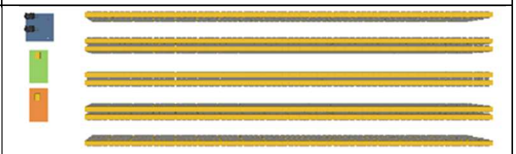
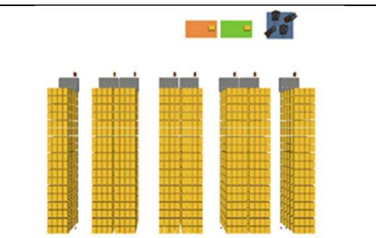
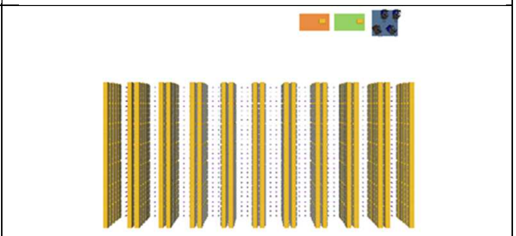
The first, left part of the window contains a list of shelves for the Drawer Storage System (SRS). The second part (right side of the window) contains a table with a list of shelves for the Single Depth Row Storage System (SRR).

In the third column of each table, the user can assign previously defined section type numbers to each rack in a warehouse. It should be remembered, however, that the section types for SRS and SRR have been defined separately, therefore the section type "1" will mean a different rack structure for the drawer storage system and for the row storage system. When entering values into the third table column on the left side of the window, use the section type numbers defined for the drawer storage system. Similarly, when entering values into the third table column on the right side of the window, use the section type numbers defined for the row storage system.

The automatic generation of warehouse

After filling up the tables, user can generate any type of warehouse by using the "Generate SRS" button (in order to generate the Drawer Storage System) or "Generate SRR" button (in order to generate the Row Storage System). After pressing the button, the warehouse in the simulation model will be generated automatically. The user can also delete the warehouse if it needs to be modified. The modification consists in correcting the data in the tables. Examples of generated warehouses are shown in Table 1. The most important parameters of warehouses is presented in Table 2.

Table 1. Simulation models of SRS and SRR systems

E.no.	SRS	SRR
1		
2		

Source: own work with use of LogABS program

Table 2. Parameters of generated SRS and SRR systems

	Experiment no. 1		Experiment no. 2	
Parameter	**SRS**	**SRR**	**SRS**	**SRR**
Number of rows of racks	4	8	8	20
Number of racks within a single row	19	18	10	7
Total width of storage area[m]	48	66	25	25,5
Total length of storage area [m]	22,5	22,5	44,86	56,6
Storage area [m^2]	1080	1485	1121,5	1433,3

Source: own work

Each warehouse has a capacity of 2880 loading units, the same dimensions of storage places, the same number of storage levels, he same number of locations at each level, and one dimension with the same or approximate value. The difference in the size of warehouses area is significant and amounts 27.3% and 22.3%.

CONCLUSIONS AND FURTHER RESEARCH

The result of the research described in the publication is a mechanism, which shows the ability to automatically generate warehouses of various types in the simulation environment. Presented mechanism enables the user without advanced simulation skills to generate a simulation model with two different types of storage systems. Operation of the tool requires only filling a few tables with information through simple, user-friendly interface. Generating the warehouse after filling in the tables takes several seconds. The user can also automatically delete the warehouse to correct the data in the tables and generate the warehouse again. This is an important stage in the methodology in automatic building simulation models of storage systems, which results in generated exemplary warehouses shown at figure 9.

Further development of the research includes the implementation of subsequent stages of the methodology in simulation technology, as well as the development of the methodology itself by developing a tool for determining the stock rotation for pallet places at SRS system and the allocation of indexes in the warehouse (assigning SKU to pallet places depending on their stock rotation). To increase the usability of the methodology, it is planned to expand the mechanism for automatic storage generation, which consists in extending the range of available storage systems with other types of racks. The methodology also assumes the definition and implementation of a number of variants for setting buffers for inbound and outbound materials, which also requires the development of an automatic warehouse generation mechanism. The most complex stage of methodology development is preparation of logic for management of AGV and forklifts movement. This logic has to involve many decision-making processes for proper handling orders related to warehouse stocking (PZ) and shipments (WZ), taking into account the rules of AGV's and trolleys movement and their cooperation. An important stage of the planned methodological evolution is the development of mechanisms enabling the implementation of resource and process cost accounting.

The initial results of simulation experiments show that the SRS system allows the storage of the same number of loading units in area smaller by over 22% compared to the SRR type warehouse. It does not change the fact that the complexity of the SRS system operation may result in a longer duration of internal transport orders.

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REFERENCES

Bartkowiak T., Kunc T., Kluska K., Myszkowski A., Pabiszczak S., 2019. Novel approach to semi-automated warehouse for manufacturing: design and simulation, IOP Conference Series: Materials Science and Engineering, 591, 012040-1 - 012040-10, http://doi.org/10.1088/1757-899X/591/1/012040

Burduk A., Grzybowska K., Safonyk A., 2019. The use of a hybrid model of the expert system for assessing the possibility of manufacturing the assumed quantity of wire harnesses. LogForum 15(4), 459-473, http://doi.org/10.17270/J.LOG.2019.360

De Koster RMBM, Le-Duc T., Yugang Y., 2008. Optimal storage rack design for a 3-dimensional compact AS/RS, International Journal of Production Research, 46(6), 1495-1514, http://doi.org/10.1080/00207540600957795

Garrido J., Saez J., 2019. Integration of automatic generated simulation models, machine control projects and management tools to support whole life cycle of industrial digital twins, IFAC-PapersOnLine, 52(13), 1814-1819, http://doi.org/10.1016/j.ifacol.2019.11.465

Gerini C, Sciomachen A., 2019. Evaluation of the flow of goods at a warehouse logistic department by Petri Nets, Flexible Services and Manufacturing Journal, 31(2), 354-380, http://doi.org/10.1007/s10696-018-9312-3

Hrusecka D., Adla R., Krayem S., Pivnicka M., 2018. Event-B Model for Increasing the Efficiency of Warehouse Management, Polish Journal of Management Studies, 17(2), 63-74, http://doi.org/10.17512/pjms.2018.17.2.06

Hu HN., Li L., Lv ZJ., 2018. A Novel Hybrid Algorithm for Order Picking Optimization in Automated Warehouse, 2018 37TH Chinese Control Conference (CCC), 3216-3220, http://doi.org/10.23919/ChiCC.2018.8484006.

Indrajitsingha S.K. , Samanta P.N. , Raju L.K. , Misra U.K., 2019. Two-storage inventory model for deteriorating items with price dependent demand and shortages under partial backlogged in fuzzy approach. LogForum 15 (4), 487-499, http://doi.org/10.17270/J.LOG.2019.344

Pawlewski P., Kunc T., 2019. Using Agent Base Simulation to Model Operations in Semi-automated Warehouse, De La Prieta F. et al. (eds) Highlights of Practical Applications of Survivable Agents and Multi-Agent Systems. The PAAMS Collection. PAAMS 2019. Communications in Computer and Information Science, 1047, Springer, Cham. http://doi.org/10.1007/978-3-030-24299-2_5

Ribino P., Cossentino M., Lodato C., Lopes S., 2018. Agent-based simulation study for improving logistic warehouse performance, JOURNAL OF SIMULATION, 12(1), 23-41, http://doi.org/10.1057/s41273-017-0055-z

Revillot-Narvaez D., Perez-Galarce F., Alvarez-Miranda E., 2019. Optimising the storage assignment and order-picking for the compact drive-in storage system, International Journal Of Production Research, http://doi.org/10.1080/00207543.2019.1687951

Tappia E, Roy D., Melacini M., De Koster R., 2019. Integrated storage-order picking systems: Technology, performance models, and design insights, European Journal Of Operational Research, 274(3), 947-965, http://doi.org/10.1016/j.ejor.2018.10.048

Xu XH., Zhao XZ., Zou, BP., Gong YM., Wang HW., 2020. Travel time models for a three-dimensional compact AS/RS considering different I/O point policies, International Journal Of Production Research, 58(18), 5432-5455, http://doi.org/10.1080/00207543.2019.1659519

Xu XH., Zhao XZ., Zou BP., Li MZ., 2019. Optimal dimensions for multi-deep storage systems under class-based storage policies, Cluster Computing-The Journal Of Networks Software Tools And Applications, 22(3), 861-875, Special Issue: SI, http://doi.org/10.1007/s10586-018-2873-9

AUTOMATYCZNE MODELOWANIE SYMULACYJNE MAGAZYNÓW

STRESZCZENIE. Wstęp: W pracy przedstawiono problem modelowania symulacyjnego złożonego systemu magazynowania opartego o koncepcję regałów szufladowych zaprojektowaną przez firmę Zrembud posiadającą siedzibę w mieście Cieszyn w Polsce. Aby możliwa była ocena użyteczności koncepcji opracowano mechanizm do automatycznego modelowania zarówno systemu regałów szufladowych, jak i cieszącego się dużą popularnością systemu regałów rzędowych. Opisany w publikacji mechanizm jest częścią metodyki automatycznego modelowania symulacyjnego magazynów. Celem metodyki, a także zastosowania opisanego mechanizmu jest pełne zautomatyzowanie procesu modelowania symulacyjnego magazynów, prowadzące do minimalizacji czasu weryfikacji projektowanych koncepcji magazynów.

Metody: Na podstawie analizy struktury dwóch rodzajów regałów oraz relacji przestrzennych ich elementów składowych, odwzorowano je w modelu symulacyjnym. Opracowano struktury danych niezbędne do automatyzacji ich generowania. W artykule przedstawiono opracowany mechanizm automatycznego generowania dwóch rodzajów magazynów.

Wyniki: Wynikiem zastosowania mechanizmu jest automatyczne wygenerowanie dwóch systemów magazynowania, dostosowanych do wymagań użytkownika, w jednym modelu symulacyjnym. Pierwsze wyniki analiz dla wygenerowanych struktur określają wielkość obszaru magazynowania, niezbędnego do zmieszczenia określonej liczby jednostek transportowo-magazynowych, a także poziom złożoności obsługi obu systemów, przekładający się na czas realizacji czynności transportowych oraz ładunkowych.

Wnioski: Przedstawiony mechanizm stanowi podstawę metodyki automatycznego modelowania symulacyjnego magazynów. Pozwala on na znaczące skrócenie czasu budowania modeli symulacyjnych systemów magazynowania, a co za tym idzie znaczne skrócenie czasu projektów polegających na weryfikacji koncepcji zagospodarowania przestrzeni w rozmaitych projektach związanych z obszarem magazynowania. Proponowane narzędzie posiada duże znaczenie dla praktyków zajmujących się modelowaniem symulacyjnym oraz specjalistów projektujących magazyny. Dzięki uporządkowaniu oraz uproszczeniu struktur danych, może zostać ono wdrożone w różnych środowiskach modelowania symulacyjnego, a po wdrożeniu być stosowane przez osoby nieposiadające zaawansowanych umiejętności obsługi programów symulacyjnych.

Słowa kluczowe: modelowanie symulacyjne magazynu, automatyczne modelowanie symulacyjne, system regałów szufladowych, magazyn, symulacja

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ORIGINAL PAPER

SUPPLY CHAIN FINANCE AND CHALLENGES OF MODERN SUPPLY CHAINS

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ABSTRACT. **Background:** The cognitive goal of the article is to systematize the knowledge in the field of Supply Chain Finance (SCF) in the context of the leading contemporary trends and challenges of Supply Chain Management (SCM). For the purposes of the research objective, Walmart was selected for the case study as a model implementation example. In the authors' assessment, there is a need to discuss and organize knowledge about the co-existence of SCF with modern solutions such as sustainable finance or blockchain technology. The empirical goal is to assess the sustainable supply chain finances management (SSCF) in terms of shaping the financial condition of the company and its position on the market.
Methods: To achieve the research objective, it was necessary to critically assess the present SCF literature and actual trends implemented in companies, which was done using case study method. The case study form was chosen due to the limited state of knowledge in a research area and the selected company is a precursor in this aspect. The research procedure consisted of: data collection, data analysis, formulating generalizations, confronting the literature, processing of generalizations and study closure.
Results: Conducted research helped to develop the existing theory and systematize effects and identify potential opportunities from implementing sustainable supply chain finances management based on blockchain technology. Analysis of financial data proved that benefits exceed implementation costs.
Conclusions: First, it was possible to develop an open-ended SCF benefit set, distinguished on the basis of varied literature. Second, implementing blockchain technology in the supply chain and drive to make it sustainable can be complementary activities. In summary, the authors formulate recommendations for other companies and indicate the direction of further research.

Key words: supply chain finance, blockchain, sustainable supply chain.

INTRODUCTION

Today's supply chains are required to undergo constant change, which is caused by the management of companies searching for opportunities to gain a competitive advantage. Therefore, the importance of capital commitment awareness in the context of supply chain management has grown enormously [Chen, Cai, He, Chen, Zhao, Zou, Guo 2020]. These changes result mainly from companies following modern information technology while maintaining sustainable development. Consequently, it leads to the entire chain integration, and in some cases restructuring and creation of global logistics networks. Therefore, there remains a high potential for optimization, which affects the company's capital structure, risk level, operating costs, profitability, and ultimately market value [Gomm 2010].

Combining SCM with leading trends: blockchain implementation and considering sustainable issues results in both improving efficiency, transparency, and traceability and significant corporate financial savings [Kouhizadeh, Saberi & Sarkis 2020]. However, the use of this combination of tools in a supply

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chain strategy does not guarantee success, which is the result of many factors. The obstacle is the short presence of such a business strategy in practice and few described success stories. Therefore, the research problem of identifying the benefits of blockchain technology and sustainable finance for SCF has been addressed. To this end, the Walmart case study was analysed.

SYSTEMATISING KNOWLEDGE OF SCF

More and more research is being undertaken to link logistics and supply chain management (SCM) with the business value and financial performance [e.g. Gomm 2010, Wandfluh, Hofmann & Schoensleben, 2016, Li and Chen 2019]. As H.Ch. Pfohl [2006] writes, supply chain finance (SCF) enables the rationalisation of finances by creating cooperation between manufacturers, suppliers, customers and logistics intermediaries. The optimization of financing outside the company's borders is achieved by reducing the cost of capital and accelerating cash flows [Gelsomino et al. 2016; Wuttke et al. 2016]. SCF definitions focus on rationalization through solutions implemented by financial institutions or technology with the ultimate goal of aligning financial flows with products and information flows in the supply chain (SC) [Hofmann 2003; Camerinelli 2009; Lamoureux and Evans 2011; Wuttke et al 2013]. The main areas of SCF are order cycle management, working capital management and fixed asset financing [Gomm 2010]. On the other hand, as suggest Jan H. Jansen [2016] SCF is a paradigm shift about collaboration in the SC, creating value by having better working capital management and more tight cooperation of departments or even shift in a business culture especially for small and medium-sized companies. According to the Scopus base, currently (25.05.2020) there are 1726 scientific publications in which the term SCF appears. Most of the publications are written in China (South China University of Technology), then in the United States (Michigan State University) and Great Britain (University of York).

Financial Supply Chain Management (FSCM) is based on logistic tasks linked to procurement, production as well as distribution/marketing, functionally coordinated with financial, investment and accounting tasks of the company [Pfohl 2006]. The concept is geared to shaping the risk and profit of companies, which is measured by the value for shareholders [Gomm 2010]. SCF encompasses a wide range of providers-including platforms, marketplaces, logistics companies, insurers, international development entities, private investors, and investment funds [Hawser 2020]. According to the PwC [2018] report "SCF Barometer", the most popular SCF solution in most industries and regions of the world is currently reverse factoring. The following in terms of popularity are respectively dynamic discounting, asset-based lending, and inventory finance [Hawser 2020]. SCF, popular so far mainly among large companies, is starting to be applied also in small enterprises, which may result from use of technological solutions such as blockchain improving the transparency and thus the credibility.

PRESENT-DAY CHALLENGES OF SUPPLY CHAIN AND SCF

In recent years, both business and scientists' communities have been paying particular attention to the issues of ecology and sustainability. In line with this trend, keywords related to the supply chain most frequently undertaken by scientists are sustainable supply chain (own research based on Scopus for publications from 2015-2019). The relation between finance and sustainability in SC may take the form of assisting contractors in the process of implementing sustainable chain solutions that the chain leader wants to apply in own company and contractors. The challenge supply chains are facing is how to increase the efficiency of this relation [Rezende de Carvalho Ferreira et al. 2016].

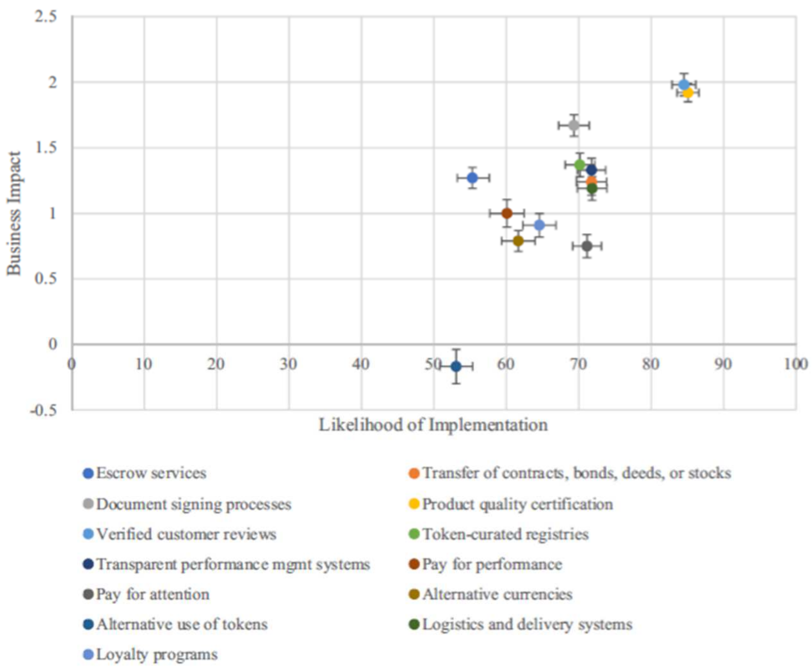
The first scientific studies on SSCF (Sustainable Supply Chain Finances) have already appeared, although there is a need to analyze the methods of measuring the benefits and costs of applying this concept [Tseng et al 2019]. Financial flows along the supply chain play a key role for sustainable development in this chain, yet both researchers and management do not seem to notice it, as the research shows [More and Basu, 2013; Basu and Nair, 2012]. However, the situation in this matter is changing dynamically. The first cases where SCF management methods have been applied are large retail chains, clothing manufacturers and consumer goods manufacturers. They are linked by a focus on consumers and pressure from them, which is one of the most important reasons for achieving sustainable development goals. By implementing the buyer's sustainability goals, the supplier gains direct discounts. The research by M. Tseng et al [2019] showed that SSCF improve the competitive advantage of companies and the most important aspects of improving results are boosting innovation, strategic competitive advantage, and financial attributes. An additional effect may be the improvement of long-term business relationships. Furthermore, to successfully apply SSCF, it is first necessary to improve the synchronization of financial decisions, learn about prices, costs and focus on product and service quality. New tools are emerging to support companies in this process [Transaction Banking 2020].

Another issue linking finances with the implementation of sustainable development objectives is so-called impact investing, i.e. investing financial resources, to create social and environmental changes (together with financial benefits) [Rezende de Carvalho Ferreira et al. 2016]. A noteworthy solution of the SSCF are green bonds, which can be issued by both the state and private sector entities. The idea is to finance a predefined target related to ecology and sustainability with emission funds [Al-Mheiri, Nobanee, 2020]. In the supply chain, this could be, for example, an investment in a closed loop, renewable energy sources or the elimination of certain materials or substances from the production process.

Another megatrend at SCM is progressing rapid digitization. The use of information systems in an integrated SC reduces its complexity and therefore the cost level. Businesses are therefore increasingly transferring their activities and processes, including the SCM process to a virtual environment, which contributes to the so-called Smart Supply Chains. Their core idea is building interconnected systems integrating technologies used by all partners in the supply chain, such as IoT, Big Data, Cloud Computing, 3D printing, big data analytics [Nowicka 2018]. The latest technology, including blockchain, is also used to optimize supply chain financing.

Blockchain is a decentralized and dispersed database in the open source model and a peer-to-peer (P2P) network, with no central computers and no centralized data storage. It is used, among others, to book transactions encoded in the form of cryptographic algorithms [Nakamoto 2009]. It enables secure exchange of monetary value and information leading to new cooperation between the SC entities [Chen, Cai, He, Chen, Zhao, Zou, Guo 2020] along the entire supply chain in both its physical (buyer-supplier or supplier-customer) and support (carrier-supplier or financial institution-buyer) tiers [Carter, Rogers, and Choi 2015]. Blockchain-based applications can also replace nonvalue adding intermediaries (e.g., call centers, e-commerce platforms). C. Durach et al. [2020] demonstrated in their research that there is a variety of implementation areas for blockchain in SC in terms of implementation probability and business impact. The results of their research are presented in Figure 1.

Inefficiencies in the processing of internal and external financial settlements in the supply chain are, in addition to low awareness, a major obstacle to the implementation of SCF. Despite the progressive computerization of processes in supply chains, the processing of financial transactions in most corporations remains in the traditional paper form [More and Bass 2013], leading to delays in payments, higher DSO (Days Sales Outstanding) and, as a result, increased demand for working capital. For many companies operating on minimum margins, even small delays can have a serious impact on their liquidity. Moreover, the flow of goods along SC is often not transparent enough. The development of blockchain technology can respond to these challenges [More and Bass 2013] by providing tamper-proof history of production, handling, maintenance, as well as digital ownership and packaging information, leading to increased transparency in the chain and intensified integration [Ghode et al. 2020]. In traditional business-to-business flows there is a high risk of falsification or distortion of e.g. information, documents, or cash. On the contrary, blockchain guarantees fairness and allows for secure authentication of logistics and spread of information in the network.



Source: Durach et. al, 2020

Fig. 1. Best blockchain application areas in SC transactions: Means of expected likelihood of implementation and impact on business

Source: Chen, Cai, He, Chen, Zhao, Zou, Guo 2020

Fig. 2. Role coordination in a blockchain-based platform for supply chain financing (BCautoSCF)

Research of J. Kim and S. Shin [2019] has shown that the characteristics of blockchain technology (information transparency, information invariability and smart contracts) have a significant positive impact on the development of partnerships in supply chain, which translates into company performance. First examples of implementation show that blockchain in SCF is a great opportunity for small and micro enterprises with a short credit history. Blockchain-based supply chain management platform for the Chinese market was launched in 2019 by DBS Bank to fill the gap in financing for logistics providers by increasing their creditworthiness. Using blockchain technology, it takes a few seconds to verify supplier transactions and 24 hours to receive financing [Hawser 2020].

The SCF concept was initially rapidly spreading in business, as the topic of scientific analysis it gained popularity later. It seems that the same is true for the combination of SCF with the trends discussed in this paper. The use of blockchain in SC is a new but fast-growing research area. According to Scopus (as of 22.07.2020), there are 915 publications with phrases: supply chain and blockchain, but:

- 70 for combination: supply chain + finances + blockchain
- 74: sustainable + supply chain + blockchain
- and only 3 with combination: sustainable + supply chain + blockchain + finance.

The most modern supply chains currently using SCF are characterized by the simultaneous application of modern technologies such as APIs and blockchain, the implementation of philosophy of greening supply chain and the consideration of the interests, including financial, of end-chain small companies. This is evidenced by the results of the Annual Awards for World's Best Supply Chain Finance Providers 2020 published by Global Finance [Hawser 2020]. Technology solutions such as distributed ledger technologies and application programming interfaces (APIs) increase the ability of banks to reach small entities at the end of the chain, usually ignored by commercial trade finance banks. Banks such as Paribas' GNP effectively compete among SCF solutions providers offering sustainable finance solutions.

SUSTAINABLE SUPPLY CHAIN FINANCE AND BLOCKCHAIN TECHNOLOGY - THE WALMART CASE STUDY

The company famous for optimizing the supply chain through innovation is the American supermarket chain Walmart Inc. founded in 1962 by S. Walton [www.walmart.com]. In 2019, Walmart began working on the application of blockchain technology to SCM. In the same year, he also started a sustainable supply chain finance project [Dimitrov 2019]. Being one of the world's largest retailers, Walmart owes its success to effective and efficient supply chain management. The store chain has been a precursor of partnerships with suppliers, treating them more like partners than competitors. As one of the first companies, over 10 years ago, it implemented RFID to track pallets with goods in every link of the supply chain. This venture has become a benchmark for other retail chains. Walmart contributed to the roll-out of the Electronic Scoreboard (RetailLink), which could be used by suppliers and carriers to measure their progress towards offering the highest quality customer service.

It is also characteristic of the Walmart chain to ensure that the supply chain is sustainable, which was manifested in the systematic implementation since 2005 a set of practices leading to greening supply chain, as shown in Table 1. These objectives are mostly still being pursued by Walmart, although some have been slightly modified or their role has increased.

Walmart's Sustainability Index Program (currently THESIS - The Sustainability Insight System) is a global database of product sustainability, created in cooperation with a scientific consortium. Ultimately, all products available for sale at Walmart [Quinn 2009] are to be included. Index collects and analyzes in one place information from various stages of product movement from sourcing materials to after-sales service. It helps to identify social and environmental hotspots - places in the chain that require action, and then presents potential solutions to diagnosed problems by category. Detailed ratings as well as the ranking position in various categories are visible to suppliers. All this encourages commitment to continuous improvement of products to make them more sustainable [Walmart Inc. 2018].

Table 1. Walmart's 8 practices for sustainable supply chain

Practice	Short description	Financial aspect
Identifying goals, metrics, and new technologies	Sustainability of all core suppliers and providers of all private-label products were evaluated by Walmart's assessment called "15 questions" Initiating the creation of the Sustainability Consortium - a collective of manufacturers, retailers, NGOs, and universities	With better information company can rationalize its supply chain and reduce costs. Scorecard is including also financial performance
Certifying environmentally sustainable products	Certifying products by outside organization results in verification of environmental performance, increased transparency, and better visibility of the entire chain	Growing trust in supply chain has positive impact on finances
Providing network partner assistance to suppliers	Consulting, trainings, and assistance for suppliers to achieve desired results	Win-win: short payback period, significantly lower costs for suppliers, achieving goals for Walmart
Committing to larger volumes of environmentally sustainable products	Making long-term quantity commitments to drive suppliers toward more sustainable practices	Building partnership and motivating sustainable investments keeping low cost
Cutting out the middleman	Buying directly there, where Walmart is selling raw product (e.g. apples but not cotton)	Buying directly from farmers increases both their and Walmart's income
Restructuring the buyer role	Facilitating more effective supplier relationship management by team-based approach that allows individuals to specialize in one narrow area and staff rotation (between roles)	Higher efficiency of purchasing process
Consolidating direct suppliers	Shifting power within the relationship from Walmart to the supplier may encourage him to invest in sustainability	Long-run profitability for the supply chain as a whole
Licensing environmental innovations	Proactive role of Walmart in promoting the spread of good ideas e.g. bringing best suppliers together in non-competitive working groups	Through licensing, suppliers can generate additional revenue streams and realize a quicker payback on their investments

Source: own work [Plambeck and Denend 2011]

A leading example of the SSCF is the network's partnership with the UK bank HSBC in China to promote greater sustainability in the SC by linking the funding rate to supplier sustainability references compared to the Walmart Sustainability Index [Hawser 2020]. The joint work resulted in the development of the WSIP/THESIS index and Project Gigaton [www.business.hsbc.com]. The supply chain financing program aims to promote sustainability by adjusting financial rates between supplier and enterprise. Under the program, suppliers who take sustainability initiatives and demonstrate progress in achieving their targets will have access to preferential funding rates from HSBC. Financial support can take a variety of forms, from standard green loans to innovative projects that fund suppliers to develop tools to reduce the negative environmental impact of their activities. Walmart's second initiative is the Project Gigaton launched in 2017 to reduce one billion tons of greenhouse gases by 2030. To achieve this goal, working with suppliers is crucial, as the entire life cycle of a product is analyzed to assess its environmental impact. All suppliers are invited to cooperate regardless of the products they offer or their current level of pro-sustainable activity, and their targets are set individually. To meet the program goal, Walmart also makes its own investments in renewable energy, including solar power generation in California and the purchase of wind power for stores in Texas [Quinn 2009].

According to N. Blyth, Global Head of Trade and Receivables Finance in HSBC [www.business.hsbc.com]: "Embedding sustainability in global supply chains is not only beneficial for the environment and society, but also for companies' bottom lines. As the world's leading international bank, HSBC is actively building new partnerships and frameworks to help deliver a more sustainable future for all." Walmart's management board is of a similar opinion, believing that focusing on sustainability throughout the supply chain stimulates innovation and generates added value for the company. Investing in sustainability can not only lead to higher productivity and cost reductions for suppliers, but also stimulate the development of employee creativity and high-tech activities [www.walmartsustainabilityhub.com].

Described above path of development chosen by the company's management has led to the implementation of another technological novelty - blockchain in the supply chain, despite this technology is currently unavailable for most companies and constitutes a huge challenge in logistics.

According to the VeChain platform, VET [www.vechain.org] Walmart China in June 2019 began work on a project to supervise the transport and food supply process throughout the supply chain via blockchain. For this purpose, the Walmart China Blockchain Traceability Platform [www.cointelegraph.com] was established, managed as a joint venture by Walmart China, VeChain, PricewaterhouseCoopers (PwC), cattle company Inner Mongolia Kerchin, and the China Chain-Store & Franchise Association. Initially, the blockchain-controlled supply chain is going to cover 23 product lines, then another 100 products from various categories will be included.

K. Feng, Chief Operating Officer of VeChain reported [www.prnewswire.com]: "It is expected that the Walmart China's traceability system will see traceable fresh meat account for 50% of the total sales of packaged fresh meat, traceable vegetables will account for 40% of the total sales of packaged vegetables, traceable seafood will account for 12.5% of the total sales of seafood by the end of 2020." Such an approach is evidence of gradual development of the project and testing the functioning of the supply chain based on new technology, which allows for constant correction of errors and deviations from the intended purpose.

The first work on the decentralized database was started in 2016 with IBM, which resulted in the creation of Distributed Ledger Technology (DLT), now to be synchronized with blockchain. DLT is a distributed database with registers replicated and shared between distributed geographical units. Since then, Walmart has been involved in several DLT-related patents, including the identification of the product withdrawn from the market, the tracking of meat products, the surveillance of supply drones, and the patenting of intelligent supply in the United States [www.cointelegraph.com].

Currently blockchain is also used by Walmart Canada. According to the company, all external freight forwarders are already using the platform, which has contributed to the security of supply chain operations. Walmart Canada has established a partnership with DLT Labs, resulting in a project called DL Asset Track. This is a new system that uses blockchain to track delivery, verify transactions, and automate payment and reconciliation between the company and suppliers to more than 400 stores in Canada. According to DLT Labs, the system has the advantage of being simple and intuitive to use, requiring only a web portal or mobile application. The project aims to increase the company's distribution efficiency by managing, integrating, and synchronizing all supply chain and logistics data in real time, linking data between Walmart Canada, shipping companies and suppliers.

According to J. Bayliss, Senior Vice President of Logistics and Supply Chain at the company [www.risnews.com]: "carrier partners move over 500,000 loads of inventory nationally, which creates an extraordinary volume of transaction data. This new dynamic and interactive blockchain technology platform is creating complete transparency between Walmart Canada and all of our carrier partners. Blockchain is enabling a material advance in our smart transportation network, with expedited payments, extensive cost savings and other benefits among our supply chain. Moreover, this degree of improved efficiency represents a powerful platform for us to continue to reduce our environmental footprint and continue our leadership in environmental sustainability." The use of blockchain technology will contribute to increase efficiency of the supply chain, which will result in cost reductions.

To verify that statement, we analyzed financial indicators from last 5 years, when the changes described above were carried out (Table 2.). Total revenues and total assets have been growing gradually since 2016, which may indicate the growing business activity. However, profitability (Net Margin, EBITDA, ROE, ROA) and liquidity (Quick ratio, Current ratio) have only been increasing since 2019 when the work on the implementation of blockchain technology began and the commitment to supply chain finance sustainability increased (project plans were already in place since 2016). Data from last 2 quarters of 2020 show continuation of growing trend. However, data from the next 5 years after implementation will be needed to clearly identify the impact of discussed changes on financial results.

Table 2. Walmart's financial measures

		2020	**2019**	**2018**	**2017**	**2016**
1	Total revenues*	523.964	514.405	500.343	485.873	482.13
2	Operating income*	20.57	21.96	20.44	22.76	24.11
3	Total assets*	236.50	219.295	204.522	198.825	199.581
4	Net Profit Margin	3.05%	1.30%	1.97%	2.81%	3.05%
5	EBITDA*	31.56	32.64	30.97	32.84	33.56
6	Return on Asset	6.29%	3.11%	4.84%	6.80%	7.31%
7	Return on Equity	19.08%	8.57%	12.53%	17.17%	17.90%
8	Current ratio	0.79	0.80	0.76	0.86	0.93
9	Quick ratio	0.22	0.23	0.20	0.22	0.24

Source: own work based on data from: https://www.macrotrends.net/stocks/stock-comparison [access 15.10.2020]

DISCUSSION

The SCF is now entering a new phase from a poorly researched innovation to a complete, mature, and increasingly widespread concept in SCM. Not only large industry leaders (although those still dominate, according to PwC research), but more and more small suppliers, even without a credit history, participate in SCF programs [Hawser 2018]. These changes force the search for innovative solutions within the SCF, and these focus primarily on technological innovations and the consideration of the sustainable aspect. As the future of SSCF, the blockchain technology is indicated, which will facilitate the configuration of mechanisms dedicated to the SSCF, open the way for more effective, sustainable and secure supply chain financing solutions and, consequently, contribute to their diffusion [Al-Mheiri, Nobanee, 2020].

The literature review shows that there are many articles on SCF and FSCM, while there are far fewer scientific publications on comprehensive supply chain finance management in the face of new logistics challenges, including technological innovation and environmental protection. However, as in the times of the financial crisis of a decade ago, there is a strong interest in this issue of business environment, as evidenced by the growing number of entities offering such services.

After analyzing Walmart's case study, it appears that implementing blockchain technology in the supply chain and sustainability are complementary activities. From Figure 1 we see that areas of blockchain implementation in the Walmart network such as verification of supplier information and SCF support are areas that generate big business impact. It can therefore be assumed that they bring measurable benefits to the company that exceed costs. The authors have defined such costs and the potential benefits, dividing them into the short and long term effects (Table 3.).

Table 3. Achieved and potential benefits and costs of implementing blockchain technology and SSCF in Walmart's SC

Short-term benefits (already achieved)	Strategic benefits (achieved over 5 years after blockchain implementation)	Main costs and obstacles
Increase trust & transparency to Walmart's end consumer	Minimize fraudulent products that either harm consumers and/or result in PR damage	Transparency is not always desirable – requires partner relations which is not always the most effective (according to transactional cost theory)
Direct insight into inventory and supply chain inefficiencies. Digitize essential certificates and documents to optimize information management, certify provenance, and ensure authenticity	Reducing negative environmental impact by: - reduction of unnecessary transport - ability to prove product is safe during a foodborne outbreak - the cost of human health and life	Time and resources used after incorporating blockchain into existing system for employees training program and implementation plan
fast identification of potential problems in the supply chain related to the circulation of information, goods and finance that can be quickly resolved	Build a more sustainable food system by detecting food fraud, increase safety, reduce spoilage & waste with analytics	Cost of implementation of new systems: reconstruction of the company's infrastructure and business processes can disrupt the operation of the entire enterprise or take human resources from other projects within the organization
automation of financial operations maintaining an appropriate level of transaction verification, secure management of distributed databases	Increased monetization from specific segments by validated organic beef vs. non-organic OR wild vs. farmed salmon	Some suppliers may not be able to adapt to a blockchain-based environment due to some shortages
Increase in revenue, decrease in costs: 89%, Enhancing traceability 81%, 79% Enhancing transparency (Source: report Insolar)	Create a global view of the provenance across Walmart's supply chain	
Gain halo effect from new tech potential	Prepare roadmap for future solutions	
Improve shelf-life management and waste of expired products	achieving added value through a combination of blockchain and SSCF resulting from preferential financing rates for green activities	
	increased transparency in the chain and intensified integration between suppliers as well as banks and financial institutions leading to higher performance of all chain due to motivated suppliers	

Source: Own elaboration based on https://academy.binance.com/pl/articles/blockchain-use-cases-supply-chain [access 15.10.2020].

The effectiveness of including sustainability and blockchain implementation into the SCF and the achievement of long-term goals, with regard to financing, may be a subject of the future research. Increasing the SC efficiency, together with the security of operations, can contribute to the reduction of activities that do not generate value for the company, thus minimizing the negative impact of its activities on the environment. The existence of an interface between supply chain finances, blockchain technology and concept of sustainable supply chain may be further investigated.

SUMMARY

The systematization of knowledge in the field of supply chain finance allowed to critically assess information in this area and to identify the most important theories and aspects related to finance in logistics. As a result, it was possible to analyze case study of Walmart and establishing cooperation with the British bank HSBC.

There is a considerable amount of English-language literature on sustainable supply chain finance, associated with the trend of "green logistics", but there was a lack of analysis and methods for measuring the benefits and costs of this concept.

On this basis, the following recommendations for enterprises were formulated regarding the current financial management of the supply chain:

1. Blockchain can be used to effectively shape sustainable supply chains. This technology enables, above all, the safe implementation of logistics processes by excluding disruptions in the flow of information throughout the supply chain.
2. Blockchain is an opportunity especially for complex chains with large disproportions in the bargaining power of entities where suppliers are small and micro businesses.

3. The future of the SCF may be the use of methods such as equity crowdfunding and venture capital in investments related to ecology and sustainability, e.g. the so-called impact investing.
4. Financial operations in global supply chains will force an increase in the SC transparency and fastening the process of chain integration, as well as support by specialized banking institutions.

Therefore, future research for SCF and sustainable finance should undertake methods of assessing supply chain financing measurement, and related indicators should be dynamically adjusted, quantified and calculated based on the development of different regions and different industries and related policies.

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REFERENCES

Al-Mheiri W., Nobanee H., 2020. Green Bonds: A Mini-Review, SSRN Electronic Journal, February http://doi.org/10.2139/ssrn.3538790.

Camerinelli E., 2009. Supply chain finance, J. Payments Strategy & Syst, 3 (2), 114–128.

Carter C.R., Rogers D.S., Choi T.Y., 2015. Toward the Theory of the Supply Chain. Journal of Supply Chain Management 51(2):89–97, http://doi.org/10.1108/09600030810882816

Chen J., Cai T., He W., Chen L., Zhao G., Zou W., Guo L., 2020. A Blockchain-Driven Supply Chain Finance Application for Auto Retail Industry. Entropy, 22(1), 95, http://doi.org/10.3390/e22010095.

Dimitrov, B., 2019. How Walmart And Others Are Riding a Blockchain Wave to Supply Chain Paradise, Forbes, www.forbes.com, dostęp: 24.05.2020.

Durach C., Blesik T., Düring M., Bick M., 2020. Blockchain Applications in Supply Chain Transactions. Journal of Business Logistics, 1–18, http://doi.org/10.1111/jbl.12238.

Frohlich M.T., Westbrook R., 2001. Arcs of integration: An international study of supply chain strategies, Journal of Operations Management, 19, 2, 185-200, http://doi.org/10.1016/S0272-6963(00)00055-3.

Gelsomino L.M., Mangiaracina R., Perego A., Tumino A., 2016. Supply chain finance: a literature review, International Journal of Physical Distribution & Logistics Management, 46, 4, 348-366.

Ghode D., Yadav V., Jain R., Soni G., 2020. Adoption of blockchain in supply chain: an analysis of influencing factors. Journal of Enterprise Information Management, http://doi.org/10.1108/JEIM-07-2019-0186.

Gomm M. L., 2010. Supply chain finance: applying finance theory to supply chain management to enhance finance in supply chains, International Journal of Logistics: Research and Applications, 13(2), 133-142, http://doi.org/10.1080/13675560903555167

Hawser A., 2020. New Leaders of Supply Chain Finance. Global Finance, 34, 2, 34-36.

Hofmann E., 2003. The flow of financial resources in the supply chain: creating shareholder value through collaborative cash management, In: ELA, ed. Eight ELA doctorate workshop. Brussels: ELA.

Hofmann E., Sertori Y., 2020. Financial Spillover Effects in Supply Chains: Do Customers and Suppliers Really Benefit? Logistics 2020, 4(1), 6, http://doi.org/10.3390/logistics4010006.

Jansen J. H., 2016. Supply Chain Finance "Is SCF ready to be applied in SMEs?", Vestnik, December 2016.

Kim J.-S., Shin N., 2019. The Impact of Blockchain Technology Application on Supply Chain Partnership and Performance, Sustainability, 11(21), 6181, http://doi.org/10.3390/su11216181.

Kouhizadeh M., Saberi S., Sarkis J., 2020. Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers, International Journal of Production Economics, 231, 107831, http://doi.org/10.1016/j.ijpe.2020.107831.

Lamoureux J., Evans T.A., 2011. Supply Chain Finance: A New Means to Support the Competitiveness and Resilience of Global Value Chains, Available at SSRN 2179944, http://doi.org/10.2139/ssrn.2179944.

Lee H. L., So K.C., Tang C.S., 2000. Value of information sharing in a two-level supply chain, Management Science, 46, 5, 626-643, http://doi.org/10.1287/mnsc.46.5.626.12047

Li S., Chen X., 2019. The role of supply chain finance in third-party logistics industry: a case study from China, International Journal of Logistics Research and Applications, 22(2), 154-171, http://doi.org/10.1080/13675567.2018.1502745.

More D., Basu P., 2013. Challenges of Supply Chain Finance: A Detailed Study and a Hierarchical Model Based on the Experiences of an Indian Firm, Business Process Management Journal, 19, 624-647, http://doi.org/10.1108/BPMJ-09-2012-0093.

Nakamoto S., 2009. A peer-to-peer electronic cash system. Bitcoin. URL: https://bitcoin.org/bitcoin.

Nowicka K., 2018. Supply Chain Management in era of Smart Industry. Gospodarka Materiałowa i Logistyka, 3, 6-8.

Transaction Banking, 2020. How to drive sustainability with supply chain financing. Open Insights by Nordea, https://insights.nordea.com/en/sustainable-finance/how-to-drive-sustainability-with-supply-chain-financing/ [15.04.2020].

Pfaff D., Skiera B., Weiss J., 2004. Financial supply chain management. Bonn: Galileo Press.

Pfohl H. Ch., 2006. Finansowe aspekty łańcucha dostaw: zorientowanie na koszt i wartość w logistyce [Financial Supply Chain: Cost and Value Orientation in Logistics], W: T. Janiak (red.), Najlepsze praktyki w logistyce. Polski Kongres Logistyczny “Logistics” [Best Practices in Logistics. Polish Logistics Congress], Instytut Logistyki i Magazynowania, Poznań.

Plambeck E. L., Denend L., 2011. The greening of Walmart's supply chain—revisited, Supply chain management review, 15(5).

Quinn, B., 2009. Walmart’s Sustainable Supply Chain. Green Connection. September, p. 24.

Rezende de Carvalho Ferreira C.M., Amorim Sobreiro V., Kimura H., Luiz de Moraes Barboza F., 2016. A systematic review of literature about finance and sustainability, Journal of Sustainable Finance & Investment, 6(2), 112-147, http://doi.org/10.1080/20430795.2016.1177438.

Tseng M.-L., Lim M. K., Wu K.-J., 2019. Improving the benefits and costs on sustainable supply chain finance under uncertainty. International Journal of Production Economics, 218, 308–321, http://doi.org/10.1016/j.ijpe.2019.06.017.

Wandfluh M., Hofmann E., Schoensleben P., 2016. Financing buyer–supplier dyads: an empirical analysis on financial collaboration in the supply chain. International Journal of Logistics Research and Applications, 19(3), 200-217, http://doi.org/10.1080/13675567.2015.1065803.

Wuttke D.A., Blome C., Foerstl K., Henke M., 2013. Managing the Innovation Adoption of Supply Chain Finance-Empirical Evidence From six European Case Studies, Journal of Business Logistics 34 (2), 148–166, http://doi.org/10.1111/jbl.12016.

Wuttke D.A., Blome C., Heese H.S., Protopappa-Sieke M., 2016. Supply chain finance: Optimal introduction and adoption decisions. International Journal of Production Economics, 178, 72-81, http://doi.org/10.1016/j.ijpe.2016.05.003.

Website: Walmart Inc., www.walmart.com, access: 24.05.2020.

Website: VeChain VET, www.vechain.org, access: 24.05.2020.

Website: www.cointelegraph.com, access: 24.05.2020.

Website: www.prnewswire.com, access: 24.05.2020.

Website: www.risnews.com, access: 24.05.2020.

Website: www.business.hsbc.com, access: 24.05.2020.

Website: www.walmartsustainabilityhub.com, access: 6.07.2020.

Website: www.macrotrends.net/stocks/stock-comparison, access 15.10.2020

FINANSOWANIE ŁACUCHA DOSTAW ORAZ WYZWANIA WSPÓŁCZESNYCH ŁAŃCUCHÓW DOSTAW

STRESZCZENIE. **Wstęp:** W ocenie autorek istnieje potrzeba zwrócenia uwagi oraz uporządkowania wiedzy w zakresie współistnienia zarządzania finansami łańcucha dostaw z nowoczesnymi rozwiązaniami, takimi jak zrównoważone finanse, czy technologia blockchain.
Metody: W ramach realizacji celu konieczna była krytyczna ocena obecnego dorobku literatury z zakresu SCF oraz aktualnych trendów wdrażanych w przedsiębiorstwach. Do osiągnięcia celu badawczego posłużono się studium przypadku przedsiębiorstwa Walmart, które pozwoli rozwinąć istniejącą teorię i dokładniej wyjaśnić kwestię osiąganych korzyści z wykorzystania technologii blockchain i zrównoważonych finansów do zarządzania łańcuchem dostaw. Posłużenie się studium przypadku jest uzasadnione ze względu na niewielki stan wiedzy w danym obszarze badań, a wybrana firma jest w tym aspekcie prekursorem. Procedura badawcza składała się z: gromadzenia danych, analizy danych, sformułowania uogólnień, konfrontacji z literaturą, opracowania uogólnień i zamknięcia badania.
Cel: Celem poznawczym artykułu jest usystematyzowanie wiedzy z zakresu Supply Chain Finance (SCF) w kontekście wiodących współczesnych trendów i wyzwań Supply Chain Management (SCM). Celem empirycznym jest analiza potencjalnych korzyści dla przedsiębiorstw z zarządzania zrównoważonym rozwojem finansów łańcucha dostaw.
Wnioski: Po pierwsze, możliwe było opracowanie zespołu korzyści służących do zarządzania finansami łańcucha dostaw. Zbiór ten wyróżniono na podstawie zróżnicowanej literatury i nie ma on charakteru zamkniętego. Po drugie, wdrożenie technologii blockchain w łańcuchu dostaw i dążenie do jego zrównoważania mogą być działaniami komplementarnymi. Podsumowując przeprowadzone rozważania, autorki formułują rekomendacje dla innych przedsiębiorstw i wskazują na kierunek dalszych badań.

Słowa kluczowe: finanse łańcucha dostaw, blockchain, zrównoważony łańcuch dostaw

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ORIGINAL PAPER

CHANGE READINESS AS A PROPOSED DIMENSION FOR INDUSTRY 4.0 READINESS MODELS

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ABSTRACT. **Background:** Change readiness at organizational level is a key competence needed for Industry 4.0 readiness, and one of the most important critical success factors for managers in implementing Industry 4.0 initiatives.
Methods: This paper conducts a critical literature review of 184 peer-reviewed academic journals and industry reports from 1990 to 2019, and identifies 30 Industry 4.0 readiness models.
Results: A closer review of dimensions from these Industry 4.0 readiness models reveal that change readiness as a model dimension has not been sufficiently addressed. Supporting the conceptualization and operationalization of this new dimension, the literature review in this paper presents six change related dimensions, specifically change commitment factor, change efficacy, change management, individual fear of change, organizational change readiness and change leadership.
Conclusion: This study after critical analysis of the literature proposes change readiness as a new dimension for Industry 4.0 readiness models. Furthermore, in terms of future research, change readiness as a new dimension for studying Industry 4.0 readiness models offers valuable implications for individuals and organizations.

Key words: change readiness, industry 4.0 readiness, fourth industrial revolution, critical analysis, literature review.

INTRODUCTION

Change readiness is a topic that helps in moving organizations from Point A to Point B. It is defined as the state of organization being ready for internal and external changes [Holt, Daspit 2015, Shea et al. 2014]. Change readiness is an important yet an under-studied concept with reference to Industry 4.0 readiness. Industry 4.0 readiness then is defined as the degree to which organizations are able to take advantage of Industry 4.0 technologies [Stentoft et al. 2020]. Hence, this paper considers Change Readiness as a prerequisite for Industry 4.0 readiness, in a way that developing readiness on internal and external changes helps in the preparation for Industry 4.0 readiness. There are different Industry 4.0 readiness models available in the literature, with various assessment dimensions which will be discussed later in this paper. However, there is a lack of research on studying change readiness as one of the main dimensions for the Industry 4.0 readiness assessment. This review paper hence proposes change readiness as a new dimension for Industry 4.0 readiness models, and justifies its need in the context of Industry 4.0, which is the main motivation for this paper.

The author De Sousa Jabbour highlighted that change readiness at organizational level is a key competence needed for Industry 4.0 readiness, and is an important research gap to be addressed [Jabbour, et al. 2018]. Schneider quotes that change readiness is a critical success factor for managers in implementing Industry 4.0, and hence should be explored further. Change readiness is one of the most

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daunting management and leadership task in achieving Industry 4.0 readiness [Schneider 2018]. Moreover, the subject of change readiness is scarcely studied with reference to Industry 4.0 readiness, despite its growing significance for organizations [Jabbour, et al. 2018, Schneider 2018]. The fact that business world is moving fast, and competitive advantage is getting less relevant is all because of the fast rate of change [Hatch 2011]. Change readiness can exist at three levels: individual level, team level and organizational level [Burnes, James 1995]. At individual level, employees in almost all cases create a resistance against it. At team level, team leadership maybe at fault in terms of the communication style or the communication message asking for the change. There is also a leadership gap that people think that they are ready, but they fail to deliver results in the change process. Burnes & James in 1995 observed low change resistance in open and participative teams [Burnes, James 1995]. At organizational level, climate of change is considered. In terms of the scope of this paper, change readiness is considered primarily at the organizational level, as Industry 4.0 readiness model operate on organizational level. Hence the concept of organizational change readiness is considered instead of individual change readiness. This review paper aims at closing these gaps, by proposing change readiness as a new dimension for Industry 4.0 readiness models.

In terms of impact, there are three important perspectives to be considered to understand the relevance of change readiness with Industry 4.0 readiness: political, economic and social impact. From the political perspective, governments are getting more anticipative on trends like Industry 4.0, Fourth Industrial Revolution and Society 5.0, which calls for changes to be done by organizations within, cascading from outside regulators and the government. From the economic perspective Industry 4.0 has immense effect on the micro and macro-economic indicators of the economy, which will then have a direct effect on company performance, and hence organizations need to realign their activities to contribute better towards the economy. Last, from social perspective, organizations have to realign their product and service offerings to match with the changing needs and wants of customers and consumers. Overall, citizens and communities will tend to be more powerful and will be exercising greater autonomy in making personal choices leading to societal preferences, which then will have substantial effect on organizations. This will change the way we interact with other individuals and organizations. Blockchain, for instance, will enable individuals to do banking on their own without a financial intermediary, swaying direct control of state authorities. On the other side, Industry 4.0 will further increase inequality in society [Bankole et al. 2015]. To address these political, economic and social challenges, developing change readiness for Industry 4.0 technologies is imperative.

The remaining paper is arranged in this sequence: next section presents the review methodology. Subsequently, the section after methodology states the findings, and then the last section concludes this paper with the contributions and the avenues of future research.

RESEARCH METHODOLOGY

A thorough literature search was conducted through four keywords: (a) change readiness, (b) Industry 4.0 readiness model, (c) Industry 4.0 readiness framework, and (d) Industry 4.0 readiness assessment. This resulted in a total of 272 papers extracted from over 13 sources, including Google Scholar, literary databases, Research Gate, Emerald, JSTOR, Sage, MDPI, Science Direct, Wiley, Springer Link, EBSCO Host, Taylor & Francis, Wiley, SCOPUS and Web of Science (WOS). After reading the abstracts individually, 88 articles were excluded as being out of scope, in terms of review objectives. Hence, a total of 184 papers were then analyzed in this review paper. The review methodology followed in this paper is replicable, hence can be updated in the future as the topic of Industry 4.0 readiness and change readiness evolves. The targeted 184 articles, spanned from 1990 to 2019. The concept of Industry 4.0 and Industry 4.0 readiness gained prominence from 2000, but the discussions on change readiness initiated from 1990. For the same reason, this review starts from 1990 instead of 2000. As majority of the literature exists in English, this review tends to be comprehensive in terms of available literature. Academic journals were given preference, followed by applied journals. Popular and most-cited industry reports and whitepapers have also been considered in this review. 132 (72%) of reviewed articles were quantitative, and the remaining 52 (28%) of articles were qualitative or mixed. The papers that did not provide full model of Industry 4.0 readiness model, or complete items of the questionnaires, or full description of model dimensions have also been counted in this review to ensure comprehensiveness. The highlights of the literature review can be seen in Table 1.

Table 1. Review highlights

Criterion	Highlights
Total Articles Reviewed	184
Timeline	1990 to 2019
Language	English
Context	Global (Eastern and Western, including Asian and Non-Asian)
Data Extraction	88 Scientific Journals
Keywords	Change readiness, Industry 4.0 readiness model, Industry 4.0 readiness framework, Industry 4.0 readiness assessment
Sources	Google Scholar, Literary Databases, Research Gate, Emerald, JSTOR, Sage, MDPI, Science Direct, Wiley, Springer Link, EBSCO Host, Taylor & Francis, Wiley, SCOPUS, WOS

FINDINGS

The findings from this review paper can be divided into three main sub-sections: change readiness, Industry 4.0 readiness models, and change readiness in the context of Industry 4.0. These findings are individually reiterated in this section.

Change Readiness

Change readiness is defined as the state of organization being ready for internal and external changes [Holt, et al. 2007]. Organizational change also depends on the way it is communicated or marketed in business, which can be in a format that can create a push or pull for change within an organization [Swanson, Berninger 1996]. There are various studies in the literature that focus on the individual and organizational benefits of developing change readiness. However, change readiness has not been studied extensively in an empirical manner [Weiner et al. 2008]. This section first describes the major findings on change readiness in terms of theoretical and empirical studies, and then it mentions certain change readiness tools and instruments.

Theoretical and Empirical Studies on Change Readiness

The concept of change readiness was first introduced by Jacobson in 1990 [Jacobson 1990]. This word was carried forward by Van De Ven & Poole through a combination of change theories [Van De Ven, Poole 2005]. Change readiness is a multilevel and multi-faceted construct (team, department, or organization). So, the statements of ‘I’ change to ‘We’ in questions or statements relating to change readiness. The first facet is ‘change commitment’ that refers to organizational members’ resolve to change together. The determinant of this facet is ‘change valence’ which is how much do the organizational members’ value change. The second facet is ‘change efficacy’ that refers to organizational members’ collective capability to change. The determinants of this facet are ‘task knowledge’, ‘resource availability’, and ‘situational factors’ (like timings and environment). Hence, organizational change readiness construct should measure both change commitment and change efficacy.

Moreover, change readiness is a shared psychological state in which organizational members feel committed to implement an organizational change [Weiner 2009]. Here collective behavior is not only advantageous, but necessary. As per some estimates, around 50% of projects fail due to lack of change readiness. Just like Lewin's three-stage model of change, strategists recommend creating readiness by 'unfreezing' the current situation, and then creating motivation to change, and lastly then ‘freezing’ the changes adopted or implemented. Change implementation like other forms of implementation is seen as a 'team sport', as issues escalate when some people show commitment and others don't.

Changes motivated in a certain direction show the highest level of change intention. Largely, change readiness is situational, as some organizational features impact more than others. It is interesting to note that correlation is often found in different areas of readiness. At one end, organizational members can be confident to succeed at change yet show less motivation, and the opposite side of that is also probable [Rollnick et al. 1992]. Leadership messages and actions are highly important to generate collective readiness. Organizational processes also have a huge contribution in this regard. Similarly, inconsistent messages derail change process. Change should also resonate well with core values to be durable. This support then is shown by managers, peers, opinion leaders, and senior management. Different people may value organizational change for different reasons. Apart from situational factors, there are various other contextual factors like organizational culture that can amplify or dampen the overall change initiatives [Cattell, Mead 2008].

Contrary to that, Kotter [1999] shared five components that can be applied to variety of change readiness initiatives within the organizations: discrepancy, efficacy, appropriateness, principal support and personal valence. 'Discrepancy' indicates the need of change. The second component 'efficacy' refers to the individual confidence that people have for the results to work for them, as also witnessed by expectancy theory of motivation. The third component 'appropriateness' refers to the agreement or disagreement that an individual might have on change and how convinced he or she is regarding the change in that situation. The fourth component 'principal support' refers to change commitment displayed by the top management, and the promises being made in the process. The fifth and the last component 'personal valence' refers to what's in it for them individually, and the cost benefit analysis individuals can do in their interest.

Moreover, Madsen in 2005 also assessed change readiness for change, but in connection with organizational commitment and social relationships [Madsen et al. 2005]. The need is of studying individual change readiness for organizational performance. The study findings showed direct and positive relationships between change readiness and organizational commitment. All organizations are continuously changing. Bernerth narrated that in learning organization, employees and the organization act as a single unit [Bernerth 2004]. The research on Human Resource Development (HRD) has been instrumental in this regard. The researchers only in the last decade have progressed on individual employee readiness in an organizational setting [Armenakis et al. 1993]. The problem is not that the change is critical, but it is complex [Swanson & Berninger 1996]. The author used argued that different organizational structures result in different response from individuals on change [Cummings et al. 2016]. Bernerth relates change readiness more with thoughts and intentions [Bernerth 2004]. Backer in 1995 illustrated that change readiness has to do with people's beliefs and attitudes [Backer 1995]. Likewise, majority of the studies consider change readiness as antecedent to resistance or support in people. The study by Riemann in 2016 covers broad developments on the topic of change readiness. The author uses organizational optimization as another word in connection by which organization upgrades itself by change of technology and processes [Riemann 2016]. Change readiness is also seen as a component of project management in certain cases [Gareis 1989].

There are two contemporary approaches on changes readiness: nomadic learning and open innovation. Nomadic learning is an organizational learning concept based on paradigm shift. Nomadic thinking, like an image of rhizome, is critical way of thinking. This is because change no longer is liner, logical and likely. The four ideologies of nomadic learning are: (i) insert as much reality as possible: this implies that there is no industry-academic gap. (ii) incorporate multiple perspectives: this makes collaboration important. (iii) strong interconnection between action and conceptualization: this implies that there should be no gap of doing and becoming, as reality is not separate from conception. and (iv) make the learning horizontal: this implies that no knowledge is complete, and there could be other horizontal learning areas which are different from your horizontal understanding. Secondly, Verbano analyzed open innovation in small firms, and discovered three unique open innovation profiles [Verbano et al. 2015]. The three open innovation profiles are selective low open, unselective open upstream, and mid-partners integrated open. Christensen in his book 'How Will You Measure Your Life?' encourages companies to be innovative and change ready [Christensen 2015]. He coined this phenomenon as 'innovator´s dilemma', concerning about successful firms that can lose ground once the new technologies and changes are in place.

Tools and Instruments on Change Readiness

A learning organization is one in which employees learn and embrace continuous change. The authors Holt and Daspit studied various change readiness instruments, mostly in quantitative methods [Holt et al. 2007]. Despite the inadequacies, the authors suggested that instruments in literature can be combined to create a comprehensive model with four factors: change content, change process, internal context, and individual differences. In other words, readiness for change is affected by the content, the context, the process, and the individuals. Also, readiness is to be studied from cognitively and emotional perspective both. As change is carried by individuals, individual change readiness is an important factor to be studied. The instrument developed can be used before change and after change. This study provided specific factors on readiness.

The study by Solberg devised a new tool for organizational change readiness called the Change Process Capability Questionnaire (CPCQ) [Solberg et al. 2008]. The tool is built to ascertain organizational capability for managing change, which is a slightly different measure from change readiness. Ingersoll et al define organizational capability to manage change as a state of preparedness for change, based on organization's previous history of change, and its future plan to sustain that change. It was also discovered in the research process that organizational culture as a contextual factor is very important for organizational change. Good evidence-based outcome is required to establish this tool as a guiding tool for change transformation.

An important contribution was made by Bouckenooghe on the topic of organizational change readiness as well [Bouckenooghe et al. 2009]. The author developed a new instrument as Organizational Change Questionnaire, with involvement of Climate of Change, Processes, and Readiness (OCQ–CPR). Climate of change is a word used in company's internal context. The result of the survey resulted in three readiness-for-change dimensions, five climate-of-change dimensions, and three process-of-change dimensions. Organizations are more receptive and open to change than ever, but people are sceptical as always to change [Kotter 1999]. Few validated measures that assess change are by Holt, Armenakis, Harris, & Field. Readiness for change is important along with the process. Previous scales were developed to measure perception instead of attitudes. Other instruments are the Organizational Climate Measure (OCM) by Patterson & Williams and the Readiness for Organizational Change Measure (ROCM) by Holt [Patterson, Williams 2005]. However, issue with the OCM is around organizational climate. Similarly, ROCM is not generalizable. This tool has three angles: emotional dimension of change, cognitive dimension of change, and intentional dimension of change. Hence, readiness is studied as a triadic attitude concept.

Organizational change readiness is crucial for policy implementations [Shea et al. 2014]. However, there are very few research-based methods available to measure this. One of the prominent and recent ones is Organizational Readiness for Implementing Change (ORIC). ORIC measure is based on Weiner's Theory of organizational readiness for change. The study by Shea examined consequences that do not achieve intended results. Organizational readiness is the degree of organizational members' psychological and behavioral preparedness to implement organizational change. High ORIC measure shows that people and organizations are likely to change and hence will cooperate in the change process.

Conversely, low ORIC measure shows that people and organizations are unlikely to change and hence will hurt the change process. In literature review, most focus has been on individual readiness or preparedness, but ORIC measure puts primary focus on organizational change readiness.

Resulting from existing studies, Holt developed a new scale of Individual Readiness for Organizational Change (IROC) [Holt et al. 2007]. The findings suggest that change readiness is dependent on employee perception that (i) they can implement the change (change-specific efficacy), (ii) the change is fit for the organization (appropriateness), (iii) leadership is committed for the change (management support) and (iv) employees will benefit from the change (personal valence). Lewin in 1947 proposed three stages of change as unfreezing, moving, and refreezing. Overall, change readiness assessment can be qualitative (observation and interviews) and quantitative (questionnaires). Qualitative methods provide richer information [Isabella 1990], whereas reliability and validity can be faster established with quantitative methods.

Industry 4.0 Readiness Models

Literature review reveals that there are several existing Industry 4.0 readiness models. The authors Felch & Sucky mentions that there are existing models which don't serve the need adequately or can be further developed, particularly in terms of business practice [Felch, Sucky 2019]. There has been a quick escalation in the number of Industry 4.0 readiness in the recent few years. Furthermore, these readiness models as self-assessment tools help a company identify its current standing and the change that is necessitated. The comprehensive literature review conducted in this paper as per the methodology explained in the previous section results in 30 different Industry 4.0 readiness models from different academic and industry developers. These models mostly got popular and cited from 2016 onwards, as the area of Industry 4.0 is relatively new. Furthermore, 9 of 30 (30%) of existing Industry 4.0 readiness models were contributed by industry, whereas the remaining 21 of 30 (70%) of existing Industry 4.0 readiness models were contributed by academia. Summary of existing Industry 4.0 readiness models is shown in Table 2. This table is insightful in terms of dimensions, as number and names of dimensions of each model are illustrated juxtapose to the model name. As the table shows, the minimum dimensions used in the models are three, and maximum are 13. Most of the dimensions in different models are similar in names, nature or meaning. However, some dimensions are exclusive and unique to that model and its context only. Next section of this paper, will elaborate more on the dimensions.

Table 2. Existing Industry 4.0 readiness models with dimensions

S.No.	Model Name	Year	Dimensions Used	Source/ Reference
1	Industry 4.0 Readiness Evaluation for Manufacturing Enterprises	2018	8 Dimensions (Strategy, Leadership, Offered product and services, Customers, Company culture, People, Technical aspects (production), Critical areas of intervention)	[Basl & Doucek 2019]
2	Industry 4.0 Maturity Model	2018	3 Dimensions (Factory of the Future, People & Culture, Strategy)	[Bibby & Dehe 2018]
3	Future Readiness Level (FRL) / Industry 4.0 Future Readiness	2018	5 Dimensions (Technology Future Readiness Level (TFRL), Event Future Readiness Level (EFRL), Future Thinking Readiness Level (FTRL), Behavior Future Readiness Level (BFRL), Future Readiness Index (FRI))	[Botha 2018]
4	E-Business Industry 4.0 Readiness Model	2018	10 Dimensions (Integration of internal processes, use of analytical CRM software, electronic SCM, enterprise sending e-invoices, website with sophisticated functionalities, employees have remote access to IT system, portable devices to more than 20% employees, RFID use, enterprises using social media, cloud computing services)	[Demeter 2018]
5	Benchmarking Readiness I4.0	2018	3 Dimensions (Production & operations, digitalization, ecosystem)	Fraunhofer Institute

S.No.	Model Name	Year	Dimensions Used	Source/ Reference
6	SMEs Maturity Model Assessment of IR4.0 Digital Transformation	2018	7 Dimensions (Strategy & Organization, Smart factory, Vertical & horizontal integration, Distribution control, Smart product, Data driven services, Employees)	[Hamidi et al. 2018]
7	Readiness for Industry 4.0	2018	6 Dimensions (Technology, Management & Strategy, Employees & Communication, Organization of Production & Logistics, Interfirm Cooperation, Innovation Ecosystem)	[Horvat et al. 2018]
8	SSCM Assessment for Industry 4.0	2018	5 Dimensions (Management strategy & organization, collaboration, sustainable development, technology based smart products, business based smart operations)	[Manavalan & Jayakrishna 2018]
9	Industry 4.0 Business Model Innovations Tool	2018	3 Dimensions (Value creation, Value offer, Value capture)	[Muller 2018]
10	Industry 4.0 Maturity Model	2018	7 Dimensions (Digital business model and customer access, Digitalization of product portfolio, Digitizing horizontal and vertical integration of the value chain, Data and analysis as a key capability, Agile IT structure, Complaint handling security law and tax, Organization employees' digital culture)	Pricewaterhouse Coopers
11	Manufacturing Companies Industry 4.0 Adoption Model	2018	3 Dimensions (strategy, maturity, performance)	[Lin et al. 2018]
12	BMS Smart Industry Research Roadmap (Behavioral, Management, Social Sciences)- SIRM	2018	4 Dimensions (Technology, Business, Society, People)	University of Twente
13	ACATECH Industrie 4.0 Maturity Index	2017	4 dimensions (Resources, Information systems, Organizational structure, Culture)	Acatech
14	Enterprise 4.0 Assessment	2017	7 Dimensions (Structure, Design, Management, Culture, Process, Strategy, Employee Relationships)	[Baicu 2017]
15	Industry 4.0 Maturity Model-SPICE (Software Process Improvement and Capability dEtermination)	2017	5 dimensions (asset management, data governance, application management, process transformation, organizational alignment)	[Gökalp 2017]
16	Industry 4.0 Readiness Model for Tool Management	2017	9 Dimensions (Competencies, Database integration, Tool identification, Time horizon of data analytics, Location of data use, Determining the residual tool life, Degree of networking, IT Security, Degree of Standardization)	[Schaupp et al. 2017]
17	Three Stages Maturity Model in SME's towards Industry 4.0	2016	3 dimensions (Envision, Enable, Enact)	[Schumacher et al. 2016]
18	Design Business Modelling for Industry 4.0	2016	7 Dimensions (Learning & growth perspective, competitiveness perspective, innovation perspective, operational & process level, financial level, strategic level, socio-environmental level)	[Gerlitz 2016]
19	SIMMI 4.0 – System Integration Maturity Model Industry 4.0	2016	4 dimensions (Vertical Integration, Horizontal Integration, Cross-sectional Technology Criteria, Digital product development)	[Leyh et al. 2016]
20	Industry 4.0 Introduction Strategy	2016	3 Dimensions (I4.0 actual analysis, I4.0 target determination, I4.0 implementation)	Merz Consulting
21	Roadmap Industry 4.0	2016	13 Dimensions (Acceptance and application of new technology and media, Professional competence, Learning competence, Corporate strategy, HR Development strategy, Organization and democratization, Flexible working models, Health and safety, Information and communication, Employer branding, Change management, Process orientation, Knowledge management)	[Pessl 2017]
22	Assessment Model for Organizational Adoption of Industry 4.0 Based on Multi-criteria Decision Techniques	2016	6 Dimensions (Products and services, Manufacturing and operations, Strategy and organization, Supply chain, Business model, Legal considerations)	University of Warwick
23	Industry 4.0 Maturity Model	2016	9 dimensions (Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance, Technology)	[Yagiz Akdil et al. 2018]
24	Reference Architecture Model for the Industry 4.0 (RAMI4.0)	2015	6 Dimensions (Business, Functional, Information, Communication, Integration, Asset)	[Kannan et al. 2017]
25	Industry 4.0 Hindering Factors Model	2015	4 Dimensions (Cultural Market Obstructing Factors, Labor Market Obstructing Factors, Organizational Obstructing Factors, Technological Obstructing Factors)	Pricewaterhouse Coopers
26	IMPULS—Industrie 4.0 Readiness	2015	6 dimensions (Strategy & Organization, Smart Factory, Smart Operations, Smart Products, Data-driven Services, and Employees)	Verband Deutscher Maschinen- und Anlagenbau (VDMA)

S.No.	Model Name	Year	Dimensions Used	Source/ Reference
27	Industry 4.0 Barometer	2014	3 Dimensions (Strategy, Technology, IT Integration)	MHP (A Porsche Company)
28	Roland Berger Industry 4.0 Readiness Index	2014	Not Specified	Ronald Berger Consulting
29	Fraunhofer Industrie 4.0 Layer Model	2013	6 Dimensions (Business, Enterprise Transformation, Management, Human Resources, Information & Communication Technology, Production)	Pricewaterhouse Coopers
30	Industry 4.0 Readiness Model for Manufacturing	2006	7 Dimensions (Strategy, technology, manufacturing & operation, supply chain, employee, product, customer)	[Methavitakul & Santiteerakul 2006]

Source: Researchers' Own Illustration

Change Readiness in the Context of Industry 4.0

Change management is considered as one of the daunting leadership tasks. To start with, change has long been seen as a three-step process [Cummings et al. 2016]. The first step is called as 'readiness', in which people prepare their mind to support change. The second step is called as 'adoption', in which people are impacted with change. The third and final step is called as 'institutionalization', in which change is reinforced as a practice or habit. The change message in itself and the way it is communicated makes the change an easy or tough call [Armenakis et al. 1993]. The study by Armenakis and Harris focused on how to craft a change message in case the organization is going for change transformation or turnaround [97].

Drawing from literature review, technology readiness has been studied more commonly in the context of Industry 4.0 by Kuo [2013]. However, the subject of change readiness is scarcely studied with reference to Industry 4.0 readiness [Schneider, Castells 2010]. A learning organization is the one that learns, adapts, and changes quickly for accelerated learning, and hence change readiness is important. Kotter shared the perspective of 'efficacy' that can be applied to variety of change management initiatives within the organizations [Kotter 2000]. Efficacy implies the individual confidence that people have for the results to work in the process of change, in a volatile and uncertain environment like Industry 4.0. In similar vein, high organizational readiness for change exceeds job performance. Local needs, opportunities, and constraints are also important areas to look into before proceeding with the due change(s). This can be used as a base to further research organizational change readiness, rooting from determinants and consequences of change readiness. There are various important questions that are still unanswered like: the impact of different types of changes and types of organizations, readiness being necessary and relevant, readiness threshold to meet before or during change.

The first step for readiness for uncertain conditions (requiring change readiness) and volatile environment (requiring Industry 4.0 readiness) is preparing mind of people to support change (leading to people readiness). The study by Armenakis and Harris focused on how to craft a change message during the transition period (to test process readiness in terms of processes to follow or abandon) in case the organization is going for change transformation or turnaround (in an environment like Industry 4.0) [Armenakis et al. 1993]. The second step for readiness for uncertain conditions (requiring change readiness) and volatile environment (requiring Industry 4.0 readiness) is preparing actions or tasks of people in organizations to implement change (leading to process readiness). Holt and Daspit studied various quantitative readiness instruments, and suggested that readiness for change is impacted by products and services both [Holt & Daspit 2015]. The study by Van De Ven and Poole focused on how innovative products and services (product-service readiness) can pioneer or disrupt the market which is going for change transformation or turnaround (in an environment like Industry 4.0) [Van De Ven & Poole 2005].

The study by Brettel et al. [2014] describe the nine building blocks of business that should be continually changed or improved in the context of Industry 4.0: (i) value proposition: the value of products and services is based on individualizing offerings and accelerating time to market. (ii) customer segments: organizations under influence of Industry 4.0 can change existing and create new markets. (iii) channels: Industry 4.0 enables the seamless use of multiple social media and other online mediums. (iv) customer relationships: collaborative and intensified relations with customers have enabled customer service and customer care. (v) key resources: under Industry 4.0, the most valuable resource for business is value creation networks. (vi) key activities: under Industry 4.0 concepts, customer integration has significant role as customers become co-designers. (vii) key partners: customers are collaborative partners particularly through open source. (viii) revenue streams: physical and digital components work together to realize increased profitability. (ix) cost structure: under Industry 4.0, cost saving potential is immense, as it primarily reduces product and prototype development expenses.

Analyzing the model dimensions individually from all 30 existing Industry 4.0 readiness models as shown Table 2, it reveals that only study by Pessl [2017] has used 'change management' as a change related dimension in their Industry 4.0 readiness model. As shared in the introduction of this paper, change readiness is an important dimension. De Sousa Jabbour highlighted that change readiness at organizational level is a key competence needed for Industry 4.0 readiness, and is an important research gap to be addressed [Lopes de Sousa Jabbour et al. 2018]. Schneider quotes that change readiness is a critical success factor for managers [Schneider 2018]. Moreover, the results of this review paper reflect that the most common dimensions used in these models include dimensions like technology, people, strategy, leadership, processes and innovation. Also, technology as a dimension is used more frequently than other dimensions. It can be seen that change readiness is a new construct for Industry 4.0 readiness models, and for the same reason it is not explored much, as claimed in some past studies as well. However, the literature review reveals that concepts and constructs related to change readiness are not completely new, and they have been discussed in the literature as model dimensions, but not in the setting of Industry 4.0 readiness models. These change related dimensions with their literature references are listed in Table 3.

Table 3. Change related dimensions from the literature review

Change Related Dimensions	References
Change Commitment Factor	[Shea et al., 2014a]
Change Efficacy	[Holt et al., 200; Madsen et al., 2005; Shea et al., 2014b]
Change Management	[Pessl, 2017]
Individual Fear of Change	[Madsen et al., 2005]
Organizational Change Readiness	[Lopes de Sousa Jabbour et al., 2018]
Change Leadership	[Madsen et al., 2005; Schneider, 2018]

Source: Researchers' Own Illustration

CONCLUSIONS

Discussing the results presented in the previous section, it is evident that change readiness is an important dimension for Industry 4.0 readiness models. However, out of 30 Industry 4.0 readiness models, only one model by the author Pessl uses change as one of the dimensions [Gabriel, Pessl 2016]. Given the importance of change readiness, it is necessary to give change readiness a more detailed view in connection with Industry 4.0 readiness models. This is also a research gap as identified through this literature review. Therefore, this paper proposes change readiness as a relevant and significant new dimension for Industry 4.0 readiness models for future research. Next, this paper reveals six change related dimensions that can be studied as pertinent dimensions and sub-dimensions in developing the proposed new dimension of change readiness: (a) change commitment factor, (b) change efficacy, (c) change management, (d) individual fear of change, (e) organizational change readiness and (f) change leadership.

In conclusion, change is a highly valuable proposition in the context of Industry 4.0 readiness. Change is by nature episodic, but in Industry 4.0 it has become the norm. So, an organization needs to be ready for change throughout, and not just on junctures or particular events. This puts immense pressure on organizations to stay relevant in the age of Industry 4.0. Therefore, this paper critically analyses the literature that first shows the importance of exploring change readiness as a new dimension for future research, and then guides on the relevant literature and related dimensions that can be consulted in developing change readiness as a new dimension in Industry 4.0 readiness models.

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REFERENCES

Armenakis A.A., Harris S.G. Mossholder K.W., 1993. Creating Readiness for Organizational Change. Human Relations. http://doi.org/10.1177/001872679304600601

Backer T.E. 1995. Assessing and enhancing readiness for change: implications for technology transfer. NIDA research monograph.

Baicu A.V. 2017. Methods of Assessment and Training of a Company Towards the Enterprise 4.0. 28TH Daaam International Symposium On Intelligent Manufacturing And Automation 1065–1073. http://doi.org/10.2507/28th.daaam.proceedings.148

Bankole F.O., Osei-Bryson K.M., Brown I., 2015. The Impacts of Telecommunications Infrastructure and Institutional Quality on Trade Efficiency in Africa. Information Technology for Development. http://doi.org/10.1080/02681102.2013.874324

Basl J., Doucek P., 2019. A Metamodel for Evaluating Enterprise Readiness in the Context of Industry 4.0. MDPI Information 10(3): 89. http://doi.org/10.3390/info10030089

Bernerth J., 2004. Expanding Our Under-standing of the Change Message. Human Resource Development Review. http://doi.org/10.1177/1534484303261230

Bibby L., Dehe B. 2018. Defining and assessing industry 4.0 maturity levels–case of the defence sector. Production Planning and Control 29(12): 1030–1043. http://doi.org/10.1080/09537287.2018.1503355

Botha A.P., 2018. Rapidly Arriving Futures: Future Readiness for Industry 4.0. The South African Journal of Industrial Engineering 29(3): 148–160. http://doi.org/10.7166/29-3-2056

Bouckenooghe D., Devos G., Van H., 2009. The Journal of Psychology: Inter-disciplinary and Applied Organizational Change Questionnaire – Climate of Chan-ge, Processes, and Readiness: Development of a New Instrument. The Journal of Psychology.

Brettel M., Bendig D., Keller M., Friede-richsen N., Rosenberg M., 2014. Effectua-tion in manufacturing: How entrepreneurial decision-making techniques can be used to deal with uncertainty in manufacturing. Procedia CIRP. http://doi.org/10.1016/j.procir.2014.03.119

Burnes B., James H., 1995. Culture, cognitive dissonance and the management of change. International Journal of Operations and Production Management. http://doi.org/10.1108/01443579510094062

Cattell H.E.P., Mead A.D., 2008. The sixteen personality factor questionnaire (16PF). The SAGE Handbook of Personality Theory and Assessment: Volume 2 - Personality Measurement and Testing. http://doi.org/10.4135/9781849200479.n7

Christensen C.M., 2015. Surviving Disruption. HBR (December).

Cummings S., Bridgman T., Brown K.G., 2016. Unfreezing change as three steps: Rethinking Kurt Lewin's legacy for change management. Human Relations. http://doi.org/10.1177/0018726715577707

Demeter K., 2018. Assessing Industry 4.0 readiness: a multi-country industry level analysis. Corvinus 1: 1–10.

Felch V., Sucky E., 2019. Maturity Models in the Age of Industry 4.0 – Do the Available Models Correspond to the Needs of Business Practice ? Hawaii International Conference on System Sciences 6: 5165–5174.

Gabriel M., Pessl E., 2016. Industry 4.0 and Sustainability Impacts. ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering.

Gareis R., 1989. Management by projects: the management approach for the future. International Journal of Project Management. http://doi.org/10.1016/0263-7863(89)90013-6

Gerlitz L., 2016. Design Management As a Domain of Smart and Sustainable Enterprise: Business Modelling for Innovation and Smart Growth in Industry 4.0. Entrepreneurship and Sustainability Issues 3(3): 244–268. http://doi.org/10.9770/jesi.2016.3.3(3)

Gökalp E., 2017. Development of an Assessment Model for Industry 4.0: Industry 4.0-MM. Springer International Publishing 60: 1–2. http://doi.org/10.1016/j.csi.2018.05.002

Hamidi S.R., Aziz A.A., Shuhidan S.M., Aziz A.A., Mokhsin M., 2018. SMEs maturity model assessment of IR4.0 digital transformation. Advances in Intelligent Systems and Computing 739: 721–732. http://doi.org/10.1007/978-981-10-8612-0_75

Hatch M.J., 2011. Material and meaning in the dynamics of organizational culture and identity with implications for the leadership of organizational change. The Handbook of Organizational Culture and Climate. http://doi.org/10.4135/9781483307961.n19

Holt D.T., Armenakis A.A., Feild H.S., Harris S.G., 2007. Readiness for organizational change: The systematic development of a scale. Journal of Applied Behavioral Science 43(2): 232–255. http://doi.org/10.1177/0021886306295295

Holt D.T., Daspit J.J., 2015. Diagnosing Innovation Readiness in Family Firms. California Management Review 58(1): 82–96. http://doi.org/10.1525/cmr.2015.58.1.82

Horvat D., Stahlecker T., Zenker A., Lerch C., Mladineo M., 2018. A conceptual approach to analysing manufacturing companies' profiles concerning Industry 4.0 in emerging economies. Procedia Manufacturing 17: 419–426. http://doi.org/10.1016/j.promfg.2018.10.065

Isabella L., 1990. Evolving Interpretations As A Change Unfolds : How Managers. Academy of Management.

Jacobson R., 1990. Unobservable Effects and Business Performance. Marketing Science. http://doi.org/10.1287/mksc.9.1.74

Kannan S.M., Suri K., Cadavid J., Barosan I., Brand M., Van Den A.M., Gerard S., 2017. Towards industry 4.0: Gap analysis between current automotive MES and industry standards using model-based requirement engineering. Proceedings - 2017 IEEE International Conference on Software Architecture Workshops, ICSAW 2017: Side Track Proceedings 0: 29–35. http://doi.org/10.1109/ICSAW.2017.53

Kotter J.P., 1999. John P. Kotter on What Leaders Really Do. Harvard Business Review 1. http://doi.org/10.1016/S0090-2616(00)80020-0

Kotter J.P., 2000. Leadership engine. Leadership Excellence 17(4): 7.

Kuo Y.L., 2013. Technology readiness as moderator for construction company performance. Industrial Management and Data Systems 113(4): 558–572. http://doi.org/10.1108/02635571311322793

Leyh C., Schäffer T., Bley K., Forstenhäusler S., 2016. SIMMI 4.0 – A Maturity Model for Classifying the Enterprise-wide IT and Software Landscape Focusing on Industry 4.0. IEEE 8: 1297–1302. http://doi.org/10.15439/2016F478

Lin D., Lee C.K.M., Lau H., Yang Y., 2018. Strategic response to Industry 4.0: an empirical investigation on the Chinese automotive industry. Industrial Management and Data Systems 118(3): 589–605. http://doi.org/10.1108/IMDS-09-2017-0403

Lopes de Sousa Jabbour, A.B., Jabbour, C.J. C., Godinho Filho M., Roubaud D., 2018. Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Annals of Operations Research 270(1–2): 273–286. http://doi.org/10.1007/s10479-018-2772-8

Madsen S.R., Miller D., John C.R., 2005. Readiness for organizational change: Do organizational commitment and social relationships in the workplace make a difference? Human Resource Development Quarterly 16(2): 16(2), 213-234.

Manavalan E., Jayakrishna K., 2018. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. Computers & Industrial Engineering. http://doi.org/10.1016/j.cie.2018.11.030

Methavitakul B., Santiteerakul S., 2006. Analysis of key dimension and sub-dimension for Supply Chian of Industry to fourth Industry Performance Measurement. 2018 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI) 191–195. http://doi.org/10.17226/11517

Muller H., 2018. The CEO of Technology. Wiley.

Patterson M.E., Williams D.R., 2005. Maintaining research traditions on place: Diversity of thought and scientific progress. Journal of Environmental Psychology. http://doi.org/10.1016/j.jenvp.2005.10.001

Pessl E., 2017. Roadmap Industry 4.0 – Implementation Guideline for Enterprises. International Journal of Science, Technology and Society 5(6): 193. http://doi.org/10.11648/j.ijsts.20170506.14

Riemann T.O., 2016. Industry 4.0: How to Manage Transformation as the New Normal. The Palgrave Handbook of Managing Continuous Business Transformation 1–610. http://doi.org/10.1057/978-1-137-60228-2

Rollnick S., Heather N., Gold R., Hall W., 1992. Development of a short “readiness to change” questionnaire for use in brief, opportunistic interventions among excessive drinkers. British Journal of Addiction 87(5): 743–754.

Schaupp E., Abele E., Metternich J., 2017. Potentials of Digitalization in Tool Management. Procedia CIRP 63: 144–149. http://doi.org/10.1016/j.procir.2017.03.172

Schneider P., 2018. Managerial challenges of Industry 4.0: an empirically backed research agenda for a nascent field. Review of Managerial Science,12. Springer Berlin Heidelberg. http://doi.org/10.1007/s11846-018-0283-2

Schneider P.A., Castells M., 2010. The Information Age: Economy, Society and Culture. Journal of Marketing, 61. http://doi.org/10.2307/1252090

Schumacher A., Erol S., Sihn W., 2016. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. Procedia CIRP 52: 161–166. http://doi.org/10.1016/j.procir.2016.07.040

Shea C.M., Jacobs S.R., Esserman D.A., Bruce K., Weiner B.J., 2014. Organizational readiness for implementing change: A psychometric assessment of a new measure. Implementation Science 9(1): 1–15. http://doi.org/10.1186/1748-5908-9-7

Solberg L.I., Asche S.E., Margolis K.L., Whitebird R.R., 2008. Measuring an organization’s ability to manage change: The change process capability questionnaire and its use for improving depression care. American Journal of Medical Quality 23(3): 193–200. http://doi.org/10.1177/1062860608314942

Stentoft J., Adsbøll Wickstrøm K., Philipsen K., Haug A., 2020. Drivers and barriers for Industry 4.0 readiness and practice: empirical evidence from small and medium-sized manufacturers. Production Planning and Control 0(0): 1–18. http://doi.org/10.1080/09537287.2020.1768318

Swanson H.L., Berninger V.W., 1996. Individual differences in children’s working memory and writing skill. Journal of Experimental Child Psychology. http://doi.org/10.1006/jecp.1996.0054

Van De Ven, A.H., Poole M.S., 2005. Alternative approaches for studying organizational change. Organization Studies. http://doi.org/10.1177/0170840605056907

Verbano C., Crema M., Venturini K., 2015. The Identification and Characterization of Open Innovation Profiles in Italian Small and Medium-sized Enterprises. Journal of Small Business Management 53(4): 1052–1075. http://doi.org/10.1111/jsbm.12091

Weiner B.J., 2009. A theory of organizational readiness for change. Implementation Science 4(1): 1–9. http://doi.org/10.1186/1748-5908-4-67

Weiner B. J., Amick H., Lee S.Y.D., 2008. Review: Conceptualization and measurement of organizational readiness for change. A review of the literature in health services research and other fields. Medical Care Research and Review, hlm. 65. http://doi.org/10.1177/1077558708317802

Yagiz Akdil K., Ustundag A., Cevikcan E., Akdil K., Ustundag Á.E., Cevikcan Á.A., Ustundag A., Cevikcan E., 2018. Maturity and Readiness Model for Industry 4.0 Strategy Implementation of Industry 4.0 strategies require wide applications in companies. Springer International Publishing. http://doi.org/10.1007/978-3-319-57870-5_4

ZMIANA GOTOWOŚCI JAK PROPONOWANY WYMIAR MODELU GOTOWOŚCI NA INDUSTRY 4.0

STRESZCZENIE. **Wstęp:** Gotowość na zmiany na poziomie organizacyjnym jest kluczową kompetencją niezbędna dla gotowości do Industry 4.0 i jedną z najważniejszych krytycznych warunków powodzenia we wdrożeniu inicjatyw związanych z Industry 4.0.
Metody: Praca zawiera krytyczny przegląd publikacji 184 pracy podlegających recenzji z czasopism naukowych oraz raportów przemysłowych z okresu 190-2019 identyfikująca 30 modeli gotowości na Industry 4.0.
Wyniki: Analiza wymiarów modeli gotowości do Industry 4.0 wykazała, że zmiana gotowości, jako wymiar modelu, nie jest wystarczająco adresowana i eksponowana. W celu wspomożenia zdefiniowania i określenia nowego wymiaru, praca ta na podstawie dokonanego przeglądu literatury, proponuje zmianę sześciu powiązanych wymiarów, w szczególności współczynnika powiązania, skuteczności zmiany, zarządzania zmianą, indywidualna obawa przed zmianą, gotowość na zmianę organizacyjną oraz kierowanie zmianą.
Wnioski: W wyniku przeprowadzonej krytycznej analizie literatury, zaproponowano zmianą koncepcji gotowości na Industry 4.0 na nowy wymiary modeli gotowości na zmianę na Industry 4.0. Dodatkowo, w kontekście dalszych badań, zmiana gotowości na zmiany, jako nowy wymiar w analizie modeli gotowości na Industry 4.0 oferuje wartościowe konsekwencje dla jednostek jak również organizacji.

Słowa kluczowe: gotowość na zmiany, gotowość na Industry 4.0, czwarta rewolucja przemysłowa, analiza krytyczna, przegląd literatury

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ORIGINAL PAPER

MEDIATING ROLE OF SUSTAINABLE LEADERSHIP IN BUYER-SUPPLIER RELATIONSHIPS: AN SUPPLY CHAIN PERFORMANCE: AN EMPIRICAL STUDY

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ABSTRACT. **Background:** The field of the supply chain have narrowly focused upon the development of effecting buyer-supplier relationship to support social sustainability. Previously studies have analyzed the relationship between responsible leadership and environmental performance. This paper aims to test the impact of supplier relationship management on social performance under the moderating influence of sustainable leadership.

Methods: The purpose of this study is to examine the moderation role of sustainable leadership between buyer-supplier relationships and social performance improvements. Empirical data is collected from 224 respondents from different manufacturers. Partial least squares structural equation modeling (PLS-SEM) has been used for hypotheses testing.

Results: The findings indicate that those four aspects of sustainable leadership- go beyond self-interest, talk enthusiastically, focuses on coaching and teaching, and see novel ideas on sustainability issues individually enhance the firm social performance.

Conclusions: This study provides a starting point for understanding the sustainable leader's role and its impact on social performance outcomes. The study has some potential implications for the implementation of sustainability-related practices that need to be acknowledged. First, the findings enrich understanding of how sustainable leader (SL) affects the inter-firm relationship. Second, the research also gives a practical explanation that inter-firm relationships are contingent rather than pervasive. Thus, managers are advised to continuously explore best approaches that improve managers' behavioral skills and adopt best practices to enhance sustainability performance.

Key words: Buyer-supplier relationship; Social sustainability; Transformational leadership; Supply chain management.

INTRODUCTION

Recently, there is a growing academic interest in corporate social responsibility leadership for sustainable development in developing countries [Pureza and Lee, 2020]. The growing concern towards protecting social performance challenges such as child labor issues, health, and safety issues in the production area has shown increasing interest among researchers to take a proactive role. However, despite all the progress made to date examines how responsible leadership impact on sustainability performance [Afsar et al., 2020; Liao and Zhang, 2020], little research has examined how sustainable leadership influences on (Iqbal et al., 2020). Moreover, the role and impact on the sharing and maintenance of the exchange of information for firm performance outcomes have been ignored [Clifford Defee et al., 2010].

There is especially a lack of research about the interface between leadership and sustainable solutions [Wilson and McCalman, 2017]. So far, the present research has focused on leadership impact on learning sustainable practice [Gosling et al., 2014]. In this study, following [Hult et al., 2000], a sustainable

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leader refers to encourage and build and adopt social initiatives in their operations that deal with environmental and social concerns, lead to the emergence of new leadership styles as [Avery and Bergsteiner, 2011]. The sustainable leader explains the concept of sustainability and provides insights into the social change process in organizations' operational practices and societal wellbeing. Given that many of the inter-firm relationships on sustainability issues are interrelated in complex ways requires leadership to initiate and disseminate sustainable practices for customer relationship management [Awan et al., 2018c]. There are two most significant approaches to the management of the customer-supplier relationships, either adopting contract governance, in which exchange is regulated through a written agreement or relational governance, in which exchange is regulated on participation and flexibility [Poppo and Zenger, 2002]. Prior literature has substantially examined the proliferation of integration of leadership style across the inter-firm relationships in various forms to achieve mutual and desirable goals [Dubey et al., 2015] with the formal focusing on design and assessment of strategic sustainability [Kurucz, Colbert, Ldeke-Freund, Upward, & Willard, 2017] and sustainable leadership enhance performance and organizational resilience [Avery and Bergsteiner, 2011]. Little or a few research studies have adopted responsible leadership to understand the motivation for sustainable development practices [Muff et al., 2020].

Sustainable leaders have the potential to deliver long term value for both employees and society. Transformational leadership behaviors are of critical importance in affecting participative and formalization relationship [Hult et al., 2007]. There is still a limited understanding of how leadership styles in the supply chain are playing a role in the translation of the process [Blome et al., 2017]. The researcher has described the importance of leadership style for effective information exchange to improve firm performance [Birasnav et al., 2015] and attempt to initiate and establish common goals that may benefit all supply chain members [Clifford Defee et al., 2009]. For example, Hult et al. [2000] provided findings on transformational leadership's impact on customer-supplier linkages. Despite these understandings, the role of a leader in bolstering customer-supplier relationships remains unclear. However, existing literature appears to neglect the effect of sustainable leadership on sustainability performance [Iqbal et al., 2020].

Currently, research on leadership style remains disconnected to link inter-firm relationship to successful improvements in the social performance in two ways. First, the majority of earlier studies do not explore the role of leadership for the greater good of Wilson and McCalman [2017]. Second, previous studies have tended to investigate the question of which leadership has a high tendency to generate sustainability learning [Gosling et al., 2014] and environmental sustainability [Clifford Defee et al., 2010]. However, previous research studies to date have provided mixed findings on whether and how leadership style impact on sustainability performance. There remains a gap in the literature on which leadership styles play a role in the warrant of the success of the customer-supplier relationship.

To fill the research gap, this paper examines the moderating impact of sustainable leadership between customer-supplier relationships and social performance in a developing country. The research question is, does sustainable leadership moderate the relationship between customer-supplier relationships and social performance improvements. We address the research question using a sample of 540 export manufacturers from different industries in Pakistan. Following prior studies, our questionnaires were targeted at experienced senior managers. The present study contributes to the existing research and theory in three ways. First, our research study addressed this gap by linking sustainable leadership to social performance improvements. We integrate the resource-based view (RBV) to examine senior management behaviors as an intangible asset in facilitating customer-supplier relationships impact ton social performance. While previous research takes RBV perspective in explaining leader behavior that leverage resources individually to enhance their firm performance [Engelen et al., 2015]. Second, prior studies have suggested that responsible leadership influence on environmental performance [Liao and Zhang, 2020], little research has been investigated on how sustainable leadership effects firm social performance. This study extends the previous study on corporate social responsibility leadership's impact on sustainable development issues [Pureza and Lee, 2020]. Third, there are little or no previous studies that explore the relationship between sustainable leadership and sustainability performance [Iqbal et al., 2020]. Our results provide evidence that sustainable leadership can enhance the customer-supplier relationship by displaying teaching, coaching, and motivation behavior by understanding differences and inspire partners by adding meaningful initiatives. Sustainable leaders has the potential to support sustainable development initiatives [Gosling et al., 2017].

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Theoretical Perspective: Resource-based view

Leadership is a salient aspect of organizational capability research when it comes to anticipate and manage relationships. The inter-firm relationship can be viewed as superior assets of a firm that allows one to gain mutual performance gains and to solve the sustainability problems [Formentini and Taticchi, 2016]. To achieve firm performance, a key determinant is how firm resources create value in relationships. The resource-based view (RBV) advances that a firm's exchange partner offers new information, research and development opportunities, ideas and this relationship creates value in the relationships (Inkpen, 2000). RBV has been recently used within a multiparty international joint venture [Mohr et al., 2016]. With more effective capabilities, a firm can develop relationships and coordinate economic exchanges. According to RBV, the value derived from interaction depends on the capabilities of the leadership of supplier firms, the resources, and information shared with the buyer through their employees. The resources and capabilities that the firm uses to "achieve the maximum social benefit from a limited amount of resources available for social projects" [Pearce and Doh, 2005]. RBV stresses the importance of resources and capabilities, and it has played a significant role in explaining the competitive advantage of the firm [Barney et al., 2011]. As it has been suggested that leadership capabilities are rare resources in an organizational context, RBV describes how these capabilities are needed to be meet the firm objectives. Previous research viewed leadership as organizational specific capability Voola et al. [2004], which capability to understand the interest of collective and sacrifice for the greater good. RBV is viewed as a specific organizational capability. The conceptual framework of the study is shown in Fig. 1.

Hypotheses Development

Customer-supplier relationship management consists of joint planning, trust, monitoring, and governance mechanisms that foster a productive relationship between buyers and suppliers [Poppo and Zenger, 2002]. To provide a complete model of governing inter-firm relationships, a governance mechanism is often used [Poppo and Zhou, 2014]. Formal contracts or contract governance represents the fundamental structure; it entails specifying agreement for continuation and dispute resolution [Poppo and Zenger, 2002]. According to Pilbeam et al. [2012], contract governance is defined as "the extent to which decision making is regulated by explicit rules and procedures. Firms use a formal mechanism to encourage appropriate partner behavior by prescribing specific production processes and procedures that a supplier must follow [Stouthuysen et al., 2012]. While the analysis of governance mechanisms has drawn mainly from transaction cost economy (TCE), researchers, e.g. [Liu et al., 2009; Luo, 2002; Poppo and Zhou, 2014]. According to TCE (Williamson, 1985), view of a governance structure as controlling the opportunistic behavior. Despite the weakness of the contracts, it enables firms to protect individual rights, safeguard against opportunism, and coordinate firms' activities to achieve the desired goals of both parties [Lumineau, 2015; Zhou and Xu, 2012]. Customer-supplier relationship management through contract governance reflects the agreement inherent in social issues and in turn, a firm can mobile the resources to create opportunities and promote social performance improvements. The following hypothesis is proposed:

H1: Contract governance positively affects the improvement of social performance in export manufacturing firms.

Relational governance refers to the extent to which business exchanges are coordinated via social relations, trust, and shared norms [Heide and John, 1992; Poppo et al., 2008]. Relational governance relies on trust and relational norms. In developing a relationship, customer and suppliers enjoy a high degree of autonomy and choose the means of cooperation, whenever the opportunity arises [Poppo and Zhou, 2014]. According to resource base view, exchange of relationship with the partner is a valuable asset; past research has shown that relational mechanism is positively associated with relationship performance [Liu et al., 2009; Poppo and Zhou, 2014]. Jang, Zheng, & Bosselman [2017] also noted that leadership style to be positively related to the performance. Researchers have investigated whether contract or relational governance attempts to function effectively to improve social performance [Awan et al., 2018c]. The customer-supplier relationship ensures that firms can cope with social sustainability issues [Gimenez et al., 2012]. Previous empirical studies demonstrate a significant positive link between contractual and formal governance and performance outcomes [Venus Lun et al., 2015]. Awan [2019] observed that relational governance is positively associated with social performance improvement. Furthermore, there is an emerging consensus in the governance literature that relational governance is the basis for enduring and effective performance improvements. We argue that export manufacturers with relational governance encourage to set up a mutual understanding with partners the actions to be carried out for failure in the protection of social issues so that they have better practices to settle down issues. Following this, we posit:

H2: Relational governance positively affects the improvement of social performance in export manufacturing firms.

The moderating role of Sustainable Leadership

Sustainable leaders have the potential to deliver long term value for both employees and society and share a transformation (common) style of assuming social responsibility. Sustainable leadership refers to "any ethical behavior that has the intention and effect of helping groups of people address shared dilemmas in significant ways not otherwise achieved" [Bendell et al., 2017]. With the growing importance of social performance issues to transform a firm in terms of sustainable practices, leadership should envision real sustainability as an essential component of the organization's relationships [Efthimiou, 2017; Jones et al., 2017]. However, sustainability initiative management is not only an organizational management task but also part of a wider leadership style to create successful inter-firm relationships on social issues. For example, [Awan et al., 2018c] noted that leadership is important in relationship management across the supply chain initiatives has helped firms to achieve social performance objectives. More recently, there has been significant interest and focus on how leadership style affects the development of social performance. Consistent with this yearning for the implementation of ethical and sustainable solutions to system problems requires leadership for the greater good [Wilson and McCalman, 2017]. Essentially, firms with high customer integration focus and involvement occupy a unique position that provides exposure to new ideas and perspectives to improve social performance via a transformational leadership (TL) style [Awan et al., 2017]. Many previous studies highlight the importance of TL for improving firm performance [Aragón-Correa et al., 2007]. The extant literature on leadership has suggested that the TL approach may be effective and serves as a role model by showing they have won willingness to sacrifice for the good and interest of collective [Bass and Riggio, 2006]. However, a sustainable leader explains the concept of sustainability and provides insights into the social change process in an organization's operational practices. This shows that leadership characteristics enable him to understand the necessity to pay attention to the partner's interest to maintain long-term relationships. Leaders possessing the visionary and inspirational motivation characteristics have more willingness to take partners' need into consideration, and as a result, enhance performance [Birasnav, 2013]. Thus, we expect that the effect of contract governance on social performance improvements may vary under greater influence of the sustainable leadership style. Thus, we suggest:

H3a: The relationship between contract governance and social performance improvement is stronger for export firms with a greater influence on the sustainable leadership style.

Clifford Defee et al. [2009] argue that transformational leadership is likely to reflect cognitive stimulation and individualized consideration. As a result, much of the manufacturing sector has shifted towards an emphasis on inter-firm governance mechanism, along with an intensified focus on coordination and cooperation to demonstrate more performance outcomes [Gimenez et al., 2012]. Further, [Fredendall et al., 2005] suggests that visionary leadership embraces collaboration. [Hult et al., 2000] found that buyers show more commitment and can maintain a long-term relationship with suppliers. Defee et al. [2009] argue that TL positively affects the supply chain performance by motivating and encouraging pursuing company goals. Gosling et al. [2017] suggest that firms must take into account the supply chain leadership approach to increase collaboration and enhance learning. Further, Jones et al. [2017] light the importance of transformative leadership and the implementation of a sustainable system. With a more effective leadership style, a firm can develop relationships, and coordinate economic exchanges. The previous discussion in the literature shows that relational governance aims to balance relationship stability and develop more trust through information sharing. We argue that sustainable transformational leadership ensures and promotes cooperation, demonstrates the ability to seek different perspectives when solving social issues, and enthusiastically participate in the development of social issues. The sustainable leadership style may itself support prior agreements, expectations of cooperation by mutual understandings, and thereby improved social performance. Thus, we suggest:

H3b: The relationship between relational governance and social performance improvement is stronger for export firms with a greater influence on the sustainable leadership style.

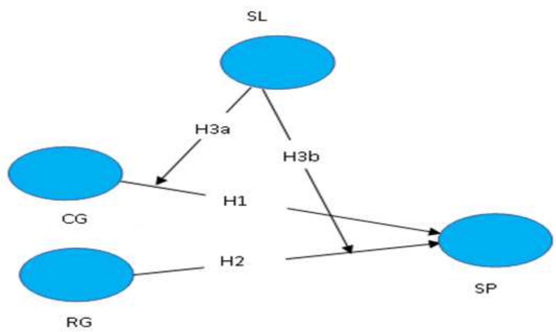

Fig. 1. Research model

METHODOLOGY

Data collection and Validation

The data was gathering using a structured survey method from the selected sample firms. We distributed survey questionnaires to the target respondents. Data for this study were collected from the top, middle, and operational level employees in different manufacturing industries in Pakistan. The list of sample firms was obtained from the Federal Chamber of Commerce and Industry online directory. The respondents in our target sample were within the export manufacturing firms, as export manufacturing has a major share in-country foreign exchange. Respondents were informed that participation in this study is voluntary, and data is being collected only for fully academic research. We collected data from senior managers from different industrial sectors. The sample comprised of 540 export manufacturing firms. In total, 224 usable questionnaires representing an overall response rate of forty-one percent were received. Respondents varied in education and hierarchical level. Respondents were asked to rate their level of leadership style. The unite of analysis was the ongoing relationship between the respondent firm and the selected partner. Accordingly, sustainable leadership constructs, as we slightly modified the items following the study objective with the help of pre-test of survey questionnaires. On average respondents had worked between 5 to 15 years is 48.21 percent, and more than 15 years are 38.83 percent, indicating that respondents are knowledgeable and familiar with the industry operations. 16.96 percent had a master's or higher and 29.46 percent had a bachelor's degree. Since respondents were senior-level supply chain managers from export manufacturing firms, they have an adequate level of English language proficiency. Firm's characteristics are presented in Table.1

Table 1. Firm's Characteristics

Industry type	f	%	**Education Level**	f	%
Surgical	56	25.00	Secondary	113	50.44
Sports	66	28.57	Bachelor	66	29.46
Leather wares	29	12.94	Master	38	16.96
Textile	73	32.58	Other	7	03.12
Titles	f	%	**[a]Firm size**	f	%
General Manager Operations	62	30.35	Less than 50	23	10.26
Managing Director	47	20.98	Between 51 and 250	105	46.87
Director Supply chain	68	30.35	More than 251	96	42.85
Director import and export	36	16.07	**Firm age**		
Other	11	04.91	Less than10	63	28.12
Experience	f	%	Between 11 and 30	113	50.44
Less than 5	29	12.94	Between 21 and 30	29	12.94
Between 5 &15	108	48.21	Greaterh than 30	19	08.48
More than 15	87	38.83			

[a]Firm size = measured in the number of employees, bFirm age = Number of years in the same business

Variable measurement

The study includes the scales followed by a systematic approach suggested by Churchill Jr [1979], adapted where possible and adopting from established measures which have been in previous research settings. Respondents were asked to rate all items in the questionnaire on a seven-point Likert scale 2 1 – Strongly disagree to 7 – Strongly agree".

Customer-supplier relationship management

A four-item scale developed by [Carey et al., 2011; Ferguson, 2005; Heide and Stump, 1995] was used to measure the customer-supplier relationship management practices by adopting Contract governance and relational governance Lusch and Brown [1996].

Sustainable leadership

We used a four-item scale of transformational leadership developed by Hult et al. [2000] in the context of buyer-supplier linkages. We adopted the scale by Hult et al. [2000] and modified in the context of our study following the recommendation of academicians in the process of a pre-test and validated the construct through the pre-test of the survey. The results of the measurement model provide adequate reliability and validity of the scale.

Social performance

The overall social performance was assessed by using items measure developed by [Awaysheh and Klassen, 2010; Kleindorfer et al., 2005]. The survey items are presented in Table 2.

Table 2. Constructs and measures

Construct	**Items**	**Measures**	
"To what degree do you agree or disagree with the following statements about". "1 – Strongly disagree 7 – Strongly agree)"			Factor loadings
Contractual Governance (CG)	CG1	"We have formal written agreements outlining social issues"	0.793
	CG2	"We have formal written agreements outlining how to Handel technical requirements"	0.766
	CG23	"We have formal written agreements that detail the rights and obligations of both parties"	0.915
	CG4	"We have formal written agreements that precisely state the legal remedies for failure to perform"	0.879
"To what degree do you agree or disagree with the following statements about" "1 – Strongly disagree 7 – Strongly agree"			
Relational Governance (RG)	RG1	"Our customer is involved early in the development of social initiatives"	0.682
	RG2	"Our firm has a mutual understanding of how to carry out solutions for failure in the protection of social issues"	0.776
	RG3	"Our firm has a mutual understanding of how to settle down issues with our customer on the social protection of our workers"	0.822
	RG4	"Our firm has a mutual understanding with customers the actions to be carried out when there are accidents at worker place"	0.754
"To what extent does each of the following statements you agreed or disagreed that your firm has improved performance. Please use the following scale to record an answer for each statement listed below (circle an answer for each item) 1: not at all, 2: a limited extent, 3: Slightly improve 4: Neutral, 5: a moderate extent, 6: a great extent, 7: a very great extent"			
Social Performance (SP	SP1	"We have Improved safety and health of existing employees"	0.729
	SP2	"We Improved the quality of life and basic health of the local community"	0.754
	SP3	"We have improved employee level of satisfaction with policies"	0.739
	SP4	"We have improved employee occupational health, safety, and labor conditions"	0.681
"To what extent do you agree, the decision-makers in your firm gave priority to seeking news opportunities for your firm, tried to develop a clear common view, leading and coordinated? Please use the following scale to record an answer for each statement listed below (circle an answer for each item).1 – Strongly disagree to 7 – Strongly agree"			
Sustainable Leadership (SL)	SL1	"They go beyond their self-interest for the good of social supply chain process"	0.756
	SL 2	"They talk enthusiastically about what needs to be accomplished in the social supply chain process"	0.804
	SL 3	"They spend time in coaching and teaching about the supply chain process"	0.811
	SL 4	"They seek different perspectives when solving purchasing problems"	0.765

Common method bias

Based on the guidelines of Armstrong and Overton (1977), non-bias was examined in this study by comparing the group of early respondents to late respondents. Following the recommendation by Vink et al. [2008], responses received within four weeks were considered early respondents and responses received after four weeks from the receiving the questionnaire were considered late respondents. The t-test performed at a 95% confidence level revealed no bias on early and late respondents. Since the present study used self-reporting survey measures from a single source, we used "Harman's one-factor" test to examine the potential threat of common method variance (CMV) by using exploratory factor analysis for all exogenous and endogenous variables [Podsakoff et al., 2003]. The result shows that no single factor account for most of the variance, the first factor extracted only accounts for 27.36% of the total variance. This provides support that CMV is not an issue. Prior to data collection, academician's experts were invited to review the questionnaire and then pretested among 12 manufacturing firms to gain clarity of content and improve readability and refine survey instrument to make it appropriately adapted to the local context in Pakistan.

Reliability and validity

To assess the model validity, the present study followed a two-step approach, as recommended by [Henseler et al., 2014], "coefficient of determination" (R2), "standardized root mean square" residuals (SRMR) [Henseler et al., 2014]. To avoid the multicollinearity issue, the variance inflation factor (VIF) values were lower than 2.16 for each of the indicators, showing the no auto-correlation issue in the data. The result of The factor analysis yielded items loadings of all constructs above the threshold value of .50, indicating unidimensionality [Hair Jr and Hult, 2016]. Cronbach's alpha of each construct exceeds (α >0.60) (Bagozzi and Yi, 1988); Composite reliability values (CR>0.70), establish the reliability and convergent validity of latent construct (Fornell and Larcker, 1981). The results of reliability and validity are presented in Table 3.

DATA ANALYSIS AND RESULTS

Analysis Methods

Partial least square (PLS) structural equation modeling approach was used, and PLS 3.2.1 Henseler et al. [2014] and PROCESS [Hayes and Krippendorff, 2007] software were used respectively for the measurement model and structural model analyses to test the theoretical model (Figure 1). PLS-SEM is very suitable for exploratory research [Hair et al., 2019] like ours, where the conceptual is more in line with theory building than theory testing. Whereas structural equation modeling (co-variance based) takes into account errors in measurement, and not situated for smaller sample size and non-normal distribution of variables [Hair Jr and Hult, 2016]. Several studies have to endorse model fit measures for PLS-SEM (Henseler et al., 2016). PLS model provides the predictive relevance of the model [Henseler et al., 2014].

Table 3. Constructs factor loadings, validity, and reliability

Items	Factoa r loadings	t-value	*AVE	**CR	***CA
Contractual Governance (CG):			0.706	0.905	0.872
CG1	0.793	9.44			
CG2	0.766	9.67			
CG3	0.915	12.55			
CG4	0.879	11.30			
Relational Governance (RG)			0.577	0.845	0.841
RG1	0.682	6.15			
RG2	0.776	8.27			
RG3	0.822	10.88			
RG4	0.754	8.36			
Social Performance (SP)			0.594	0.854	0.853
SP1	0.729	9.04			
SP2	0.754	9.54			
SP3	0.739	9.33			
SP4	0.681	6.55			
Sustainable Leadership (SL)			0.61	0.865	0.793
SL1	0.756	9.80			
SL2	0.804	11.73			
SL3	0.811	12.67			
SL4	0.765	9.77			

Note: *AVE: Average variance extract; **CR: Composite Reliability;***CA: Cronbach's alpha

The exogenous construct explains the study applies Chin (1998) recommendation to analyze the predictive accuracy by investigating the variance extracted in the endogenous construct. The value of (R2) falls between, 0.02 to 0.13 are considered weak, values between 0.13 and 0.26 are considered moderate, and finally, the values greater than 0.26 are considered substantial. The PLS examination appears that the structural model as a whole counts for about 58% of the variance in the firm social performance. Scale means standard deviations are presented in Table 4.

Table 4. Mean, Standard Deviation and Correlations

Items	Mean	S.D	SP	CG	RG	SL	FS	FA
SP	4.62	1.22	**0.770**					
CG	5.11	1.34	0.43**	**0.840**				
RG	4.85	1.26	0.29**	0.14*	**0.759**			
SL	4.08	0.92	0.32*	0.24*	0.36**	**0.781**		
[a] FS	2.18	0.83	0.07	0.04	0.16*	0.07	1	
[b] FA	19.26	8.01	0.05	0.12*	0.11*	0.08	0.35**	1

*Note: SD: Standard Deviation, CG: Contractual Governance, RG: Relational Governance, SP: Social performance, SL: Sustainable Leadership, FS: Firm Size, FA: Firm Age, **Correlation is significant at the p<0.01 level, *Correlation is significant at the p<0.05 level, a Logarithm of all employees and number of years in business.*

From a statistical explanatory modeling point of view, testing predictive accuracy is relevant and emphasized in PLS-SEM literature (Henseler et al., 2016). The predictive validity (predictive relevance Q2) was evaluated by applying the Stone-Geisser test using a blindfolding procedure with an omission distance 8 (Geisser, 1974). The Q2 greater than zero is regarded as predictive relevance for that particular construct. In this study, Q2 is 48.2% for endogenous latent constructs. The effect size relevance (f 2) is considered strong, moderate, and weak effect sizes 0.35, 0.15, and 0.02, respectively. As results reveal, 58% of social performance is together described by all the exogenous variables. The literature suggests some methods for testing moderation analysis effects.

Hypotheses Testing

PLS-SEM analysis was run to test the proposed conceptual model. The results show that CG has a significant positive effect on social performance (β =0.341, p<.05, t=5.207), which supports H1. RG also affects social performance (β =0.22, p<.05, t=3.534).The direct effect of sustainable transformational leadership has a positive effect on social performance. The significance is derived from 5,000 bootstrapped samples.

Table 5. Relationships between variables (direct effect and interaction effect)

Structural path	Coef. (*β*)	t values	95 % BC CI	Results
CG → SP	0.341	t=5.207	(0.112,0.352)	Supported
RG → SP	0.224	t=3.534	(0.007,0.336)	Supported
Interaction SL x CG	0.230	t= 3.544	(0.009,0.311)	Supported
Interaction SL x RG	0.193	t=2.256	(0.003,0.202)	Partial Supported

To test the moderating effect of sustainable leadership on the relationship between customer-supplier relationship and social performance improvement, we used SPSS PROCESS using bootstrapping for simple moderation following the guidelines by Preacher and Hayes (2008). The PROCESS macro V2.13 was then used to examine the moderation effect using a bias-corrected 95% bootstrap confidence interval (CI). 95% CI bias-corrected bootstrap for the interaction of TL and CG on SP does not contain zero, indicating interaction effects standardized root means square residual (SRMR) for the model is 0.051, indicating a good fit is assuming the cut-off 0.08 (Hu et al., 1995). The results findings are presented in Fig. 2. H3a and H3b state that sustainable leadership will moderate the relationship between CG and SP. The results of the analysis presented in the Table.5, show a significant interaction between CG x SL and RG x SL on SP (β =0.23, p<.05, t= 3.544) and (β =0.19, p<.05, t=3.256) respectively.

As table 5, indicates that the interaction between SL x CG is significantly positively related to social performance improvement, lending support for the H3a (β =0.230, t= 3.544). Since sustainable leaders (SL) involve in establishing customer-supplier relationships through formal governance mechanisms. SL is more attentive to exchange more quality information. However, H3b is supported since the interaction between SL x RG is significant and positively (β =0.193, t= 2.256). In line with the hypothesis, this implies that the relational mechanism affects social performance when the level of transformational leadership is high. Similarly, the marginal effect of relational mechanisms on social performance depends on sustainable leadership. Relational governance may play a marginal role in facilitating social performance improvements. Thus, the likelihood that the contract governance mechanism would enhance social performance when the firm could rely on sustainable leaders.

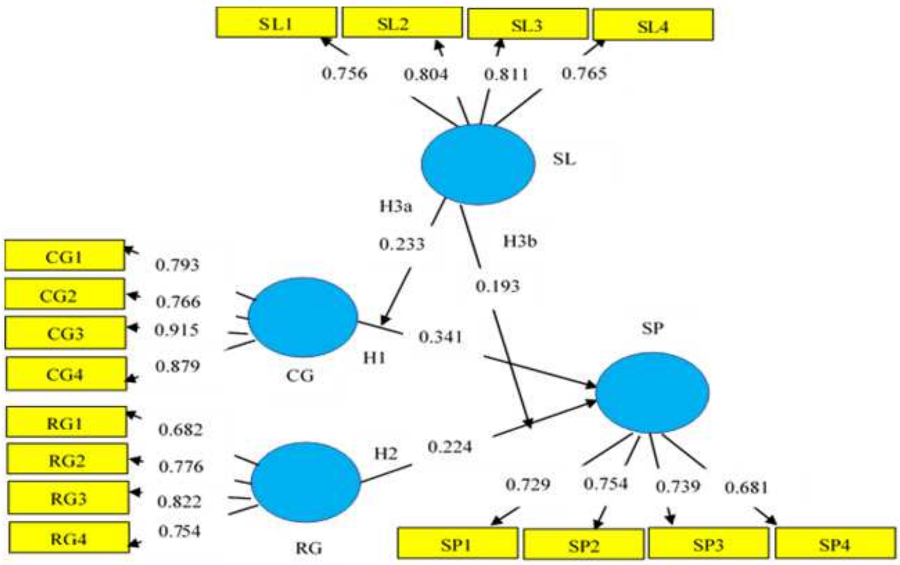

Fig. 2. PLS Path model and results

DISCUSSION AND CONCLUSION

This study argued that sustainable leadership (TL) style may act as an explanatory mechanism of the relationship between customer-supplier relationship management and social performance improvement (SPI). This study examines whether and how sustainable leadership may ensure that the positive effect of customer-supplier relationships impacts social performance improvements. Our result reveals that four aspects of sustainable leadership- go beyond self-interest, talk enthusiastically, focuses on coaching and teaching, and see novel ideas individually enhance the firm social performance.

The present study contributes to the literature by examining the association between sustainable leadership and sustainability performance. Although, prior studies have suggested that responsible leadership influence on environmental performance [Liao and Zhang, 2020], little research has been investigated on how sustainable leadership effects firm social performance. Our research study addressed this gap by linking sustainable leadership to social performance improvements. First, we integrate a resource based view (RBV) to examine senior management behaviors as an intangible asset in facilitating customer-supplier relationships impact ton social performance. While previous research takes RBV perspective in explaining leader behavior that leverage resources individually to enhance the firm performance [Engelen et al., 2015]. Our study findings are in line with the RBV that top management behaviors become a valueable resource, which makes it difficult to intimate by the competitors. Second, our study extends the previous study on corporate social responsibility leadership's impact on sustainable development issues [Pureza and Lee, 2020]. This research provides evidence by showing that sustainable leadership promotes the partner relationship. Second, our results contribute to sustainable leadership literature Tideman et al. [2013], by suggesting that SL may inspire and supports actions that go beyond self-interest and enthusiastically support sustainability initiatives towards a great world for today and future generations. Our results consistent with the findings of [Hult et al., 2007], the leadership style can appropriately manage the resources embedded with the partners for the social performance overall. Our study also contributes to the development of social performance, while previous research has shown that corporate social responsibility strategy is positively associated with social performance [Orazalin and Baydauletov, 2020]. Our study extends research on sustainability by enhancing our understanding of the leadership style that affects the customer-supplier relationship for social performance improvements. Consequently, it is suggested that transformational leaders can be interpreted as sustainability leaders, who possess adaptive leadership behaviors and who are likely to support buyer participation in a flexible relational exchange without any threat of punishment and understand when a partner has to be supported with the required resources. Third, our findings show that sustainable development requires leaders who's teaching and coaching are the most effective ways to foster change in organizational relationship dynamics. This study presents evidence for the importance of a transformational leader in buyer-supplier linkages context Hult et al. [2000]. The sustained capacity of SL is essential to success in implementing the governance mechanism that will sustain social performance. In this direction, SL constitutes the need for sustainable leaders, who can make a balance among what needs to be accomplished, and when to go beyond self-interest and take a different perspective on solving the differences. Thus, sustainable leaders look beyond self-interest, focuses on coaching and resolving differences in the customer-supplier relationship process to gain organizational objectives in the sustainability context. Sustainable leaders imbue the meaning of and shaping organizational sustainable development objectives during the social change process and provide crucial initiatives that serve the needs of the existing employees to grow and develop with the organization. The study is in line with the United Nations Sustainable Development Goals (UNSDGs) that highlight the need of improving health, safety, and labor conditions through sustainable development goal policy instruments (SDG17), which would be promising and support to redesign and enhance partnership building among international buyers from developed countries and suppliers from developing countries on the experience and resourcing strategies to support the achievement of the sustainable development goals.

This study provides a starting point for understanding the sustainable leader's role and its impact on social performance outcomes. Our study has some potential implications for the implementation of sustainability-related practices that need to be acknowledged. First, our findings enrich understanding of how sustainable leader (SL) affects the inter-firm relationship. When contract governance is implemented by the SL, they attempt to find divergent views when solving problems. As long as, organizations maintain SL, it would be able to maintain effective inter-firm relationships and to achieve firm social performance. Second, our study also gives a practical explanation that inter-firm relationships are contingent rather than pervasive; it depends on external to which TL behaviors are promoted in the level of organizations. Thus, managers are advised to continuously explore best approaches that improve managers' behavioral skills and adopt best practices to enhance sustainability performance. TL may inspire and supports actions that go beyond self-interest and enthusiastically support sustainability initiatives towards a great world for today and future generations. An organization needs a new style of leaders for the management of a complex web of the relationship on sustainability demands. Tripple bottom line practices become an urgent priority for manufacturers globally for the common good. In this context, the sustainable leader may serve as a change agent to take an exigent role in sustainable development.

The implication of the present study should be seen within the context of its limitations that provide directions for future research into the role of sustainable leadership and the success of corporate environmental management practices. There is a demand for successful inter-firm relationships not just to go beyond self-interest but to recognize best sustainability practices with the long-term goal to increase competitiveness. The present study took place in a South Asian developing country, and the sample was comprised of four manufacturing industries. The generalizability of this study may be of concern along with the fact that the research design of this study focuses on single informants so that common method bias may be a concern. Future research studies may consider what specific style of leadership is most critical for creating opportunities for the circular economy. Future studies could, therefore, examine how a leadership characteristic influences its efforts on agility, and lean production leads to achieving sustainable development performance outcomes. Future research may investigate which leadership style may influence on firm initiatives towards the generation of data-driven insights and initiate a circular economy in the industry 4.0 perspective. Furthermore, future researchers should explore whether there is a special leadership style that may influence on big data analytics with firm dynamic capabilities to enhance the firm's operational and economic performance. It is also vital to realize how different forms of institutional forces form ties with the supplier country's national government and how these affect a firm's corporate sustainability performance, particularly from the big data analytics capabilities. In recent years, an increased interest in social performance initiatives is warranted for global green growth. Within the manufacturing industry, the transformational leadership style as a sustainable leader is crucial for achieving gender equality, health, and safety issues and improving child labor issues.

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REFERENCES

Afsar B., Maqsoom A., Shahjehan A., Afridi S.A., Nawaz A., Fazliani H., 2020. Responsible leadership and employee's proenvironmental behavior: The role of organizational commitment, green shared vision, and internal environmental locus of control. Corp. Soc. Responsib. Environ. Manag. 27, 297–312. http://doi.org/10.1002/csr.1806

Aragón-Correa J.A., García-Morales V.J., Cordón-Pozo E., 2007. Leadership and organizational learning's role on innovation and performance: Lessons from Spain. Ind. Mark. Manag. 36, 349–359. http://doi.org/10.1016/j.indmarman.2005.09.006

Armstrong J.S., Overton T.S., 1977. Estimating nonresponse bias in mail surveys. J. Mark. Res. 14, 396–402.

Avery G.C., Bergsteiner, H., 2011. How BMW successfully practices sustainable leadership principles. Strateg. Leadersh.

Awan U., 2019. Effects of buyer-supplier relationship on social performance improvement and innovation performance improvement. Int. J. Appl. Manag. Sci. 11, 21–35.

Awan U., Kraslawski A., Huiskonen J., 2018. The Effects of an Ambidextrous Leadership on the Relationship between Governance Mechanism and Social Sustainability. Procedia - Soc. Behav. Sci. http://doi.org/10.1016/j.sbspro.2018.04.017

Awan U., Kraslawski A., Huiskonen J., 2017. Understanding the Relationship between Stakeholder Pressure and Sustainability Performance in Manufacturing Firms in Pakistan. Procedia Manuf. 11, 768–777.

Awaysheh A., Klassen R.D., 2010. The impact of supply chain structure on the use of supplier socially responsible practices. Int. J. Oper. Prod. Manag. 30, 1246–1268.

Bagozzi R.P., Yi Y., 1988. On the evaluation of structural equation models. J. Acad. Mark. Sci. 16, 74–94.

Barney J.B., Ketchen D.J., Wright M., 2011. The future of resource-based theory revitalization or decline? J. Manage. 37, 1299–1315.

Bass B.M., Riggio R.E., 2006. Transformational Leadership. Mahwah, NJ: L. I Lawrence Erlbaum.

Bendell J., Sutherland N., Little R., 2017. Beyond unsustainable leadership: critical social theory for sustainable leadership. Sustain. Accounting, Manag. Policy J. 8, 418–444.

Birasnav M., 2013. Implementation of Supply Chain Management Practices: The Role of Transformational Leadership. Glob. Bus. Rev. 14, 329–342. http://doi.org/10.1177/0972150913477525

Birasnav M., Mittal R., Loughlin S., 2015. Linking leadership behaviors and information exchange to improve supply chain performance: A conceptual model. Glob. J. Flex. Syst. Manag. 16, 205–217. http://doi.org/10.1007/s40171-015-0092-2

Blome C., Foerstl K., Schleper M.C., 2017. Antecedents of green supplier championing and greenwashing: An empirical study on leadership and ethical incentives. J. Clean. Prod. 152, 339–350. http://doi.org/10.1016/j.jclepro.2017.03.052

Carey S., Lawson B., Krause D.R., 2011. Social capital configuration, legal bonds and performance in buyer--supplier relationships. J. Oper. Manag. 29, 277–288.

Chin W.W., 1998. The partial least squares approach to structural equation modeling. Mod. methods Bus. Res. 295, 295–336.

Churchill Jr G.A., 1979. A paradigm for developing better measures of marketing constructs. J. Mark. Res. 16, 64–73.

Clifford Defee C., Esper T., Mollenkopf D., 2009. Leveraging closed-loop orientation and leadership for environmental sustainability. Supply Chain Manag. An Int. J. 14, 87–98. http://doi.org/10.1108/13598540910941957

Clifford Defee C., Stank T.P. (Ted), Esper, T., 2010. Performance implications of transformational supply chain leadership and followership. Int. J. Phys. Distrib. Logist. Manag. 40, 763–791. http://doi.org/10.1108/09600031011093205

Defee C.C., Stank T.P., Esper T.L., Mentzer J.T., 2009. The role of followers in supply chains. J. Bus. Logist. 30, 65–84.

Dubey R., Gunasekaran A., Samar Ali S., 2015. Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: A framework for green supply chain. Int. J. Prod. Econ. 160, 120–132. http://doi.org/10.1016/j.ijpe.2014.10.001

Efthimiou O., 2017. Heroic ecologies: embodied heroic leadership and sustainable futures. Sustain. Accounting, Manag. Policy J. 8, 489–511.

Engelen A., Gupta V., Strenger L., Brettel M., 2015. Entrepreneurial Orientation, Firm Performance, and the Moderating Role of Transformational Leadership Behaviors. J. Manage. 41, 1069–1097. http://doi.org/10.1177/0149206312455244

Ferguson R.J., 2005. Contractual Governance, Relational Governance, and the Performance of Interfirm Service Exchanges: The Influence of Boundary-Spanner Closeness. J. Acad. Mark. Sci. 33, 217–234. http://doi.org/10.1177/0092070304270729

Formentini M., Taticchi P., 2016. Corporate sustainability approaches and governance mechanisms in sustainable supply chain management. J. Clean. Prod. 112, 1920–1933. http://doi.org/10.1016/j.jclepro.2014.12.072

Fornell C., Larcker D.F., 1981. Structural equation models with unobservable variables and measurement error: Algebra and statistics. J. Mark. Res. 18, 382–388.

Fredendall L.D., Hopkins C.D., Bhonsle A., 2005. Purchasing 's Internal Service Performance: Critical External and Internal

Determinants. J. Supply Chain Manag. 41, 26–38. http://doi.org/10.1111/j.1055-6001.2005.04102003.x

Geisser S., 1974. A predictive approach to the random effect model. Biometrika 61, 101–107.

Gimenez C., Sierra V., Rodon J., 2012. Sustainable operations: Their impact on the triple bottom line. Int. J. Prod. Econ. 140, 149–159. http://doi.org/10.1016/j.ijpe.2012.01.035

Gosling J., Jia, F., Gong Y., Brown S., 2017. The role of supply chain leadership in the learning of sustainable practice: Toward an integrated framework. J. Clean. Prod. 140, 239–250. http://doi.org/10.1016/j.jclepro.2016.09.101

Gosling J., Jia F., Gong Y., Brown S., 2014. The role of supply chain leadership in the learning of sustainable practice: toward an integrated framework. J. Clean. Prod.

Hair J.F., Risher J.J., Sarstedt M., Ringle C.M., 2019. When to use and how to report the results of PLS-SEM. Eur. Bus. Rev. 31, 2–24. http://doi.org/10.1108/EBR-11-2018-0203

Hair Jr J.F., Hult G.T.M., 2016. A primer on partial least squares structural equation modeling (PLS-SEM). Sage Publications.

Hayes A.F., Krippendorff K., 2007. Answering the call for a standard reliability measure for coding data. Commun. Methods Meas. 1, 77–89.

Heide J.B., John G., 1992. Do Norms Matter in Marketing Relationships? J. Mark. 56, 32–44. http://doi.org/10.2307/1252040

Heide J.B., Stump R.L., 1995. Performance implications of buyer-supplier relationships in industrial markets: a transaction cost explanation. J. Bus. Res. 32, 57–66.

Henseler J., Dijkstra T.K., Sarstedt M., Ringle C.M., Diamantopoulos A., Straub D.W., Ketchen Jr D.J., Hair J.F., Hult G.T.M., Calantone R.J., 2014. Common beliefs and reality about PLS: Comments on R{ö}nkk{ö} and Evermann (2013). Organ. Res. Methods 17, 182–209.

Henseler J., Hubona G., Ray P.A., 2016. Using PLS path modeling in new technology research: updated guidelines. Ind. Manag. data Syst. 116, 2–20.

Hu L.-T., Bentler P.M., Hoyle R.H., 1995. Structural equation modeling: Concepts, issues, and applications, Evaluating model fit. Sage Publications, Inc.Thousand Oaks, CA, USA.

Hult G.T.M., Ferrell O.C., Hurley R.F., Giunipero L.C., 2000. Leadership and relationship commitment: a focus on the supplier-buyer-user linkage. Ind. Mark. Manag. 29, 111–119. http://doi.org/10.1016/S0019-8501(98)00039-X

Hult G.T.M., Ketchen D.J., Chabowski B.R., 2007. Leadership, the buying center, and supply chain performance: A study of linked users, buyers, and suppliers. Ind. Mark. Manag. 36, 393–403. http://doi.org/10.1016/j.indmarman.2005.12.002

Inkpen A.C., 2000. A note on the dynamics of learning alliances: Competition, cooperation, and relative scope. Strateg. Manag. J. 775–779.

Iqbal Q., Ahmad N.H., Nasim A., Khan S.A.R., 2020. A moderated-mediation analysis of psychological empowerment: Sustainable leadership and sustainable performance. J. Clean. Prod. 262, 121429.

Jang Y.J., Zheng T., Bosselman R., 2017. Top managers' environmental values, leadership, and stakeholder engagement in promoting environmental sustainability in the restaurant industry. Int. J. Hosp. Manag. 63, 101–111. http://doi.org/10.1016/j.ijhm.2017.03.005

Jones S.A., Michelfelder D., Nair I., 2017. Engineering managers and sustainable systems: the need for and challenges of using an ethical framework for transformative leadership. J. Clean. Prod. 140, 205–212. http://doi.org/10.1016/j.jclepro.2015.02.009

Kleindorfer P., Singhal K., Van Wassenhove L., 2005. Sustainable operations management. Prod. Oper. Manag. 14, 482–492.

http://doi.org/10.1111/j.1937-5956.2005.tb00235.x

Kurucz E.C., Colbert B.A., L., deke-Freund F., Upward A., Willard B., 2017. Relational leadership for strategic sustainability: practices and capabilities to advance the design and assessment of sustainable business models. J. Clean. Prod. 140, 189–204. http://doi.org/10.1016/j.jclepro.2016.03.087

Liao Z., Zhang M., 2020. The influence of responsible leadership on environmental innovation and environmental performance: The moderating role of managerial discretion. Corp. Soc. Responsib. Environ. Manag. 1–12. http://doi.org/10.1002/csr.1942

Liu Y., Luo Y., Liu T., 2009. Governing buyer--supplier relationships through transactional and relational mechanisms: Evidence from China. J. Oper. Manag. 27, 294–309.

Lumineau F., 2015. How contracts influence trust and distrust. J. Manage. 0149206314556656.

Luo Y., 2002. Contract, cooperation and performance in international joint ventures. Strateg. Manag. 23, 903–919. http://doi.org/10.1002/smj

Lusch R.F., Brown J.R., 1996. Interdependency, contracting, and relational behavior in marketing channels. J. Mark. 60, 19–38. http://doi.org/10.2307/1251899

Mohr A., Wang C., Goerzen A., 2016. The impact of partner diversity within multiparty international joint ventures. Int. Bus. Rev. 25, 883–894.

Muff K., Liechti A., Dyllick T., 2020. How to apply responsible leadership theory in practice: A competency tool to collaborate on the sustainable development goals. Corp. Soc. Responsib. Environ. Manag. 1–21. http://doi.org/10.1002/csr.1962

Orazalin N., Baydauletov M., 2020. Corporate social responsibility strategy and corporate environmental and social performance: The moderating role of board gender diversity. Corp. Soc. Responsib. Environ. Manag.

Pearce J. a., Doh J.P., 2005. The High Impact of The High Impact of Collabor. MIT Sloan Manag. Rev. 46, 29–39.

Pilbeam C., Alvarez G., Wilson H., 2012. The governance of supply networks: a systematic literature review. Supply Chain Manag. An Int. J. 17, 358–376. http://doi.org/10.1108/13598541211246512

Podsakoff P.M., MacKenzie S.B., Lee J.-Y., Podsakoff N.P., 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. J. Appl. Psychol. 88, 879–903.

Poppo L., Zenger T., 2002. Do formal contracts and relational governance function as substitutes or complements? Strateg. Manag. J. 23, 707–725. http://doi.org/10.1002/smj.249

Poppo L., Zhou K.Z., 2014. Managing contracts for fairness in buyer--supplier exchanges. Strateg. Manag. J. 35, 1508–1527.

Poppo L., Zhou K.Z., Zenger T.R., 2008. Examining the conditional limits of relational governance: Specialized assets, performance ambiguity, and long-standing ties. J. Manag. Stud. 45, 1195–1216. http://doi.org/10.1111/j.1467-6486.2008.00779.x

Preacher K.J., Hayes A.F., 2008. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behav. Res. Methods 40, 879–891.

Pureza A.P., Lee K.H., 2020. Corporate social responsibility leadership for sustainable development: An institutional logics perspective in Brazil. Corp. Soc. Responsib. Environ. Manag. 27, 1410–1424. http://doi.org/10.1002/csr.1894

Stouthuysen K., Slabbinck H., Roodhooft F., 2012. Controls, service type and perceived supplier performance in interfirm service exchanges. J. Oper. Manag. 30, 423–435.

Tideman S.G., Arts M.C., Zandee D.P., 2013. Sustainable Leadership 17–33.

Venus Lun Y.H., Lai K. hung, Wong C.W.Y., Cheng, T.C.E., 2015. Environmental governance mechanisms in shipping firms and their environmental performance. Transp. Res. Part E Logist. Transp. Rev. 78, 82–92. http://doi.org/10.1016/j.tre.2015.01.011

Vink P., Imada A.S., Zink K.J., 2008. Defining stakeholder involvement in participatory design processes. Appl. Ergon. 39, 519–526. http://doi.org/10.1016/j.apergo.2008.02.009

Voola R., Carlson J., West A., 2004. Emotional intelligence and competitive advantage : examining the relationship from a resource-based view 93, 83–93. http://doi.org/10.1002/jsc.667

Williamson O.E., 1985. Assessing contract. J. Law, Econ. Organ. 1, 177–208.

Wilson S., McCalman J., 2017. Re-imagining ethical leadership as leadership for the greater good. Eur. Manag. J. 35, 151–154. https://doi.org/10.1016/j.emj.2016.06.001

Zhou K.Z., Xu D., 2012. How foreign firms curtail local supplier opportunism in China: Detailed contracts, centralized control, and relational governance. J. Int. Bus. Stud. 43, 677–692. http://doi.org/10.1057/jibs.2012.7

MEDIACYJNA ROLA ZRÓWNOWAŻONEGO PRZYWÓDZTWA W RELACJI: KUPIEC-SPRZEDAWCA W ŁAŃCUCHU DOSTAW - BADANIE EMPIRYCZNE

STRESZCZENIE. **Wstęp:** Obszar łańcucha dostaw skupił się na rozwoju efektywnej relacji sprzedający-kupujący, co umożliwia lepsze rozwój zbalansowany w obszarze socjalnym. Poprzednie badania skupiały się na analizie zależności pomiędzy odpowiedzialnym przywództwem a wpływem na środowisko. Celem pracy jest przetestowanie wpływu zarządzania relacjami z dostawcami na rozwój zbalansowany w obszarze socjalnym przy umiarowym wpływie zrównoważonego przywództwa.

Metody: Celem pracy jest określenie roli moderatora zrównoważonego przywództwa pomiędzy relacjami sprzedający-kupujący oraz poprawą postępowania w obszarze socjalnym. Dane empiryczne zostały zebrane wśród 224 osób z różnych przedsiębiorstw. Do testowania hipotez zastosowania modelowanie równań strukturalnych PLS-SEM (partrial least squares).

Wyniki: Uzyskane wyniki wskazują, że cztery aspekty zrównoważonego przywództwa wspomagają postępowania w obszarze socjalnym, a mianowicie: wychodzenie poza dbałość tylko o własne interesy, entuzjazm w podejściu do innych, skupienie się na coachingu i instruktażu oraz zauważanie nowych idei w obszarze zrównoważonego rozwoju.

Wnioski: Praca dostarcza początkowych danych do zrozumienia roli przywództwa zrównoważonego i jego wpływ na socjalną strefę działalności. Zaprezentowano potencjalne implikacje wdrożenia w praktyce rozwoju zrównoważone, które jej wymagają dodatkowej analizy. Po pierwsze, praca zwiększa wiedzę jak zrównoważone przywództwa wpływa na relacje w obrębie firmy. Po drugie, daje praktyczne wyjaśnienie, że relacje w obrębie firmy są raczej zależne aniżeli o charakterze dominującym. Dlatego też zaleceniem dla kierownictwa jest ciągłe poznawanie i zwiększanie umiejętności miękkich oraz zaadaptowanie najlepszych praktyk dla dalszego rozwoju zrównoważonego.

Słowa kluczowe: relacja kupiec-sprzedawca, rozwój zrównoważony socjalnie, przywództwa w transformacji, zarządzanie łańcuchem dostaw

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ORIGINAL PAPER

A MODEL FOR CORPORATE SOCIAL RESPONSIBILITY RANKING ON IRON ORE MINE COMPANIES BY FUZZY COGNITIVE MAPPING METHOD

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ABSTRACT. **Background:** Due to the rising importance of our global interdependence, some concepts like corporate social responsibility (CSR) have a significant role in this dynamic and flourishing industry composed of lodging, transportation and so on. Accordingly; any small decisions or actions occurring in one of these centers, regardless of their direct effects on the desired sectors, can gradually have direct and indirect, hidden and obvious, as well as tangible and intangible impacts on all sectors in society and consequently lead to a series of actions and reactions in all levels and layers. Thus, the purpose of this study was to explain and rank factors affecting corporate social responsibility (CSR) of iron ore mining companies in Yazd Province, Iran. In addition, for the first time, the fuzzy FCM method has been used to rank corporate social responsibility

Methods: CSR indicators and dimensions were extracted using Content Analysis of interviews with expert groups from a total number of 9 iron ore mining companies in Yazd Province, Iran. Then, relations between the indicators were determined via Fuzzy Cognitive Map, and subsequently, they were ranked through FC Mapper. In the end, the intensity of the impact of the indicators on each other was calculated through Mic Mac.

Results: The obtained dimensions by Content Anaalysis, included safety and health as well as legal, ethical, environmental, philanthropic, and economical. Indicators of "striving to reduce harm to the environment", "striving to reduce toxic and greenhouse gases", "increasing employee satisfaction and motivation", "developing and promoting community knowledge and culture" and "providing real-time information about The work and the disadvantages resulting from it" were ranked the highest in the ranking model. In the end, the intensity of the impact of the indicators on each other was calculated through Mic Mac that influential indicators were included "voluntary support of employees in social activities", "efforts to reduce toxic and greenhouse gases" and "transparency in contracts with contractors".

Conclusions: This research can be beneficial to government, researchers and organizations in helping them to understand indicators based corporate social responsibility in order to persuade them to do their commitment about society.

Key words: Corporate Social Responsibility, Content Analysis, Fuzzy Cognitive Mapping, Mic Mac.

INTRODUCTION

Being socially responsible means that individuals and organizations need to treat social, cultural, and environmental issues by way of ethics and sensitivity. Efforts to establish social responsibility can thus help individuals, organizations, and governments have a positive impact on progress, working conditions, and society. Therefore, individual social responsibility extends beyond its scope by creating an active position to have a positive impact on others and the surrounding environment. Thus, individual social responsibility is considered as the basis of corporate social responsibility (CSR); since society is a community of individuals which

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can consequently shape the culture of social responsibility. The concept of CSR includes subjects related to an organization's behavior within a social environment, and it is also beyond merely traditional economic territories. Since the field of activity is not merely economic, businesses encounter a collection of rights and responsibilities within society that does not allow them only focus on economic management to achieve their goals. Organizations also deal with social, economic, legal, ethical, and environmental challenges in their everyday activities that can affect their behaviors. These organizations may aim at maximizing profitability or earning maximum shareholders' equity, while social obligations should be correspondingly taken into account. In fact, companies do not just meet the needs of their owners, but those of a set of social actors that are dependent on the company and its field of activity. Indeed, CSR is a greater responsibility assumed by the company considering its impacts on society and the natural environment.

STATMENT OF THE PROBLEM & SIGNIFICANCE OF THE STUDY

Growth and development of various industrial and commercial institutions and organizations as well as increased competitions among them has led these entities to think only of their organizational interests and accomplish their goals in any possible way. Currently, managers need to abandon particularism and mere preoccupation with organizational goals and set those of their community and country as a guide for their efforts [Seyyedjavadain et al., 2016]. Unquestionably, no sense of responsibility towards people is a barrier to the provision of effective services by managers and their success. Managers should not just think of concepts such as control, supervision, order, and guidance; but they are required to reflect on services to the public as a duty and a good thing to achieve organizational excellence [Norman, MacDonald, 2009].

CSR, as a guideline for businesses, has been growing over the recent years. The extent of this concept and its expansion can be thus realized through numerous publications, conferences, and active organizations working in this domain [Gao, 2011]. In other words, sustainable development can result when the role of CSR becomes bolder. Based on the concept of CSR, since organizations are members of a community like individuals and have responsibilities for their surrounding environment; they are required to improve their economic and social performance and also put the promotion of social life standards of individuals in the society into their agenda [Aluchna, 2010].

Studies have shown that social responsibility is one of the best tools for gaining public legitimacy and competitive advantage [Rhou et al., 2016]. According to Mattra et al. [2012], social responsibility means the responsibility or commitment of a person or organization to social concepts such as individuals or the physical environment around them.

The concept of CSR means how wealth is responsibly created through businesses. Thus, it includes the behavior of an organization in terms of employees, customers, contractors, the environment, and society. A win-win relationship and shared value creation for society and an organization is accordingly a conceptual infrastructure for CSR. This also emphasizes responsibility and responsiveness as the bases of behavior in an organization within a society and responsibly monitors businesses along with the production of wealth. While most companies currently believe that social and environmental responsibilities using a sustainable development approach needs to be stressed, the domains and boundaries of reporting and disclosure of CSR for Iranian companies are not clear enough, since there is no proper understanding of dimensions of CSR and no comprehensive studies explaining the operationalized concept of CSR and recognizing its nature, type, and content. Therefore, it is necessary to contribute to perception and development of disclosure of CSR in companies in Iran, as a developing country, based on an experimental study and its results in the light of a sustainable development approach, the Constitution of the Islamic Republic of Iran, the general policies of the perspective of the Islamic Republic of Iran on the horizon of 1404, the Fifth Development Plan, and privatization process [Asayesh, Feizpour, 2014]. Additionally, CSR has been defined within two intellectual schools. One group believes that businesses are only required to increase their profitability within legal boundaries and to observe ethical standards and limitations [Freeman 1998, Levitt 1958] and another group assumes that companies need to comply with a wide range of obligations in society [Carrol 1979]. Reviewing the related literature on CSR, the following models were identified as the main ones explaining this type of self-regulation (Table 1).

Table 1. CSR models

Model	Dimensions/Indicators	References
ISO260000 Model	Responsiveness	Castka & Balzarova
	Transparency	
	Ethical behavior	
	Respect for shareholders' equity	
	Respect for rule of law	
	Respect for international behavioral norms	
	Respect for human rights	
Stakeholder Theory	Society	Harrison & Freeman
	Environmental groups	
	Employees	
	Customers	
	Investors	
	Suppliers	
Global Reporting Initiative	Economy	Sustainable Reporting Guide
	Environment	
	Human rights	
	Working activities and proper working conditions	
	Product liability	
	Society	
Davis Model	Profitability	Davis (1975)
	Improved social welfare	
Lantos Model	Ethical	Lantos (2001)
	Philanthropic	
	Strategic	
Carrol Model	Philanthropic	Carrol (1979)
	Economic	
	Legal	
	Ethical	
Three-Level Model	Principles of CSR	Wood (1991)
	Policy-making and responsive processes	
	Tangible results relevant to organizational social issues	
CSR European Style	CSR in government	Albareda et al. (2007)
	CSR in government-business relationship	
	CSR in government-society relationship	
	CSR in government-business-society relationship	

RESEARCH LITERATURE

Zakaria SF., Ahmad AR. [2019] in a study entitled "AHP Ranking of CSR Human Resource Theme of Takaful Operators" by content analysis of the annual reports of 11 takaful operators in Malaysia for the year 2014 was undertaken to examine the CSR initiatives disclosed. The highest priority vector for each group—human-self, intellect, posterity and wealth—are provision of healthy & safe workplace (0.317), the existence of employee training and development programs (0.404), providing staff home ownership scheme (0.473) and policies on the company's remuneration schemes (0.493), respectively. Results of research of Erin H.Kao et al [2018] in title "The relationship between CSR and performance: Evidence in China" show variations in market response to CSR engagement by firm ownership type. That is, the market responds favorably to CSR by market-oriented non-SOEs but neutrally to CSR by SOEs with substantial agency costs. The Chinese firms are able to link their CSR activities to firm performance over time, likely recognizing the long-term benefits of CSR. Our study demonstrates the important role of ownership in the dynamic CSR-performance relationship. In a study entitled “Applications of analytical methods of gray relation entropy in ranking corporate social responsibility: Evidence of Iranian pharmaceutical companies,” Senowbar and Baz-Mohammadi (2017) introduced the analysis of gray relation entropy weighting to find solutions to analyze and rank companies in this perspective. Karabašević, D et al [2016] in a study entitled "Ranking of companies according to the indicators of corporate social responsibility based on SWARA and ARAS methods" proposed framework for evaluation and ranking is based on the SWARA and the ARAS methods. The usability and efficiency of the proposed framework is shown on an illustrative example. As well, Ghasemi-Hosseinabadi [2016] in a study entitled “Corporate social responsibility and how to measure it” examined motives and reasons for disclosure of CSR following a review of literature on this concept, and conclusively proposed a framework for a comprehensive report. According to this framework, the comprehensiveness rate of the CSR reports could be measured. Abd-RazakAhmad et al [2015] in title "i-CSR Ranking in the Workplace" showed that the activities that are highly ranked in each sub-areas are ‘fardhu ain tazkirah session’, ‘medical benefit for immediate family members’, ‘fringe benefit, like entitlement to comprehensive medical benefit or takaful protection’, ‘entitlement to special leave to visit the elderly, parents or attending own children's school activities’ and ‘free biannual medical check-ups’. The rankings of these activities will serve as a reference point for Islamic organizations to prioritize their CSR initiatives according to Islamic teachings. Ahmad et al. [2015] in an article entitled “Ranking Islamic corporate social responsibility” using analytical hierarchy process (AHP). Besides, Ardalan et al. [2015] fulfilled a project entitled “Investigation of the relationship between social capital, social responsibility, and organizational commitment: A case study on employees at Razi University of Kermanshah” using structural equation modeling (SEM) and found that only economic dimension, among the four CSR dimensions, had a positive and significant effect on it. Moreover, only ethical and philanthropic dimensions had positively and significantly influenced job satisfaction. Examining the impact of quality of relationships on consequences arising from it, the relationship between all variables (except for organizational trust on the intention to quit jobs) indicated a significant effect. Hirigoyen, and Poulain-Rehm [2014] measured the relationship between CSR and financial performance of 329 listed companies of three geographic regions, i.e., the United States, Europe, and Asia via SEM. The results of their study showed that not only CSR had failed to have a positive effect on corporate financial performance, but also corporate financial performance had no positive impact on CSR. Also, Nowrouzi et al. [2014] in an article entitled “Theoretical processing of corporate social responsibility based on the grounded theory” conducted an unstructured interview with CSR administrators and executives and collected a series of initial themes during the coding process and then extracted the desired categories. Valmohammadi [2014] also examined the relationship between CSR and organizational performance using SEM and reported that CSR had an impact on performance, and also participation and development could play an important role in increasing organizational performance. Hasas-Yeganeh and Arzegar [2013] in a study entitled “Developing components and indicators of corporate social responsibility and its current status in Iran” shed light on this issue. This study suggested and analyzed components and indicators of disclosing CSR via a sustainable development approach and using questionnaires and path analysis within a comprehensive framework. Also, the existing situation and the level of disclosure of the social dimension of the companies were determined through the content analysis of reports provided by the board of directors. Kitzmueller and Shimshack, [2012] in a project entitled “Investigating relationship between corporate social responsibility and limitations of supplying financial resources in companies listed in Tehran Stock Exchange" examined the relationship between CSR and financial performance using financial data of 100 companies through correlation and regression and showed a positive and significant relationship between CSR and financial performance; i.e. increase in one of the variables could be accompanied by a rise in another one. Moreover, Salehi-Omran et al. [2012] in a study entitled "Examining the importance of corporate social responsibility indicators in industrial centers and universities"; investigated the amount of attention to CSR indicators in industrial centers and universities. Given the importance of CSR in universities and higher education institutes; five indicators of proper working conditions, training programs, non-discrimination at work and attention to vulnerable groups, as well as concepts of environmental protection and society were highlighted.

RESEARCH METHOD

A combination of qualitative and quantitative methods was employed in this study. The research procedure started with studying theoretical foundations to identify factors affecting CSR ranking of iron ore mining companies in Yazd Province, Iran. Accordingly, there were attempts to review the most important factors and indicators affecting the explanation of SCR ranking for selected experts through studying and reviewing the resources available in this area, including existing models and theories in this field. About the review of the models and theories in the previous section and their explanation for the selected experts and given that the existing models had been generally prescribed for organizations, expert opinions about the CSR dimensions were also investigated via a series of interviews. In this study, content analysis was used to organize the collected data within a systematic framework. After extracting the dimensions and components of CSR for iron ore mining companies in Yazd Province, the indicators were rated via FCM.

At the first step of the study, a qualitative research methodology containing meetings and interviews with selected experts of iron ore mining companies of Yazd Province was used; the concepts associated with CSR were explained, key statements based on the identifiers (codes) were registered, and they were consequently introduced as open codes. Within the content analysis; after reviewing open codes, statements with overlapping concepts and meanings were merged, and then the dimensions were identified as axial codes. Afterward, FCM was used to better understand the relations between the indicators and their significance of coefficients.

A total number of 21 iron ore mining companies (with active status) licensed by the end of November 2013 had been listed in the system of the Ministry of Industry, Mine, and Trade in Yazd Province at the time of the study. Of these companies, only nine cases had a well-defined organizational chart. Therefore, following talks with relevant authorities in these nine companies, each one accepted to create and introduce a group consisting of experts in the field of human resources, industrial psychology, or safety and health in order to collaborate in this study. Accordingly, 9 groups were selected to advance the research objectives.

Content Analysis

Content analysis is known as an appropriate research technique to respond to questions about the content of a message. Although there were claims in preliminary approaches that content analysis can also encompass characteristics of authors along with effects on the audience; today, these two functions are only possible in field methods and documentary integration ones [Bakhshi, Jalaeian, 2016]. In qualitative content analysis, there are also attempts to identify and extract categories in communicative massages through selective, open, and axial coding. Considering the use of qualitative content analysis in this study, the following steps were followed:

Step 1: Explain the concepts and foundations of CSR for selected experts

Step 2: Implement open coding via identifying statements from interviews and assigning them with identifiers (codes)

Step 3: Divide up codes by examining statements and paying attention to their overlapping and then their aggregation and integration

Step 4: Perform axial coding for identifying groups in which the concepts are located on the axis of the main category.

FUZZY COGNITIVE MAPPING

Building an FCM model requires inputs resulting from experiences and knowledge of experts in a subject matter. Accordingly, in such models, accumulated experiences of individuals and existing knowledge of the domain in which the model is drafted are integrated, and then causal relations are created between the constituent elements of the system (Kosko, 1988). The methodology developed by Rodriguez-Repiso [2005] also used the initial matrix of success (IMS), the fuzzified matrix of success (FZMS), the strength of relationships matrix of success (SRMS), and final matrix of success (FMS) for FCM. So, calculating the four matrices for FCM was as follows:

IMS

IMS is a $[m \times n]$ matrix in which *n* refers to the number of key success factors and *m* is the number of people interviewed for data collection. Each O_{ij} element in the matrix indicates the importance given by person *j* to specific concept *i*; which can be different in various projects and even for various success factors.

FZMS

Numeric vector V_i can be moved to fuzzy sets in which each element of fuzzy set means the element O_{ij} of vector V_i with vector V_i. Numeric vectors with 0 and 1 values can be thus converted into fuzzy sets as follows:

Find the maximum value in V_i and consider $X_i = 1$ for it:

$$Max\ (O_{iq}) \to X_i(O_{iq}) = 1 \qquad (1)$$

Find the minimum value in V_i and consider $X_i = 0$ for it:

$$Max\ (O_{iq}) \to X_i(O_{iq}) = 0 \qquad (2)$$

Specify the ratio of all the other elements of vector V_i within [0,1]; i.e.

$$X_i(O_{ij}) = \frac{O_{ij} - Min\ (O_{ip})}{Max\ (O_{iq}) - Min\ (O_{ip})} \qquad (3)$$

In which, $X_i(O_{ij})$ is the degree of membership for the element O_{iq} in vector V_i.

SRMS

SRMS is a $[n, n]$ matrix. In this respect, rows and columns are associated with the matrix of the key success factors and each element in the matrix indicates the relation between factor *i* and factor j. As well, S_{ij} can accept values within [0,1] .

Proximity of the relation between V_1 and V_2 with regard to computing similarity between the two vectors confirms the strength of the relation between concepts *1* and *2* which is associated with these two vectors represented by the element S_{12} in SRMS. Proximity of relation between these two vectors is based on the distance between both vectors according to the concept of distance between vectors [Kosko, 1985].

If d_j is the distance between element *j* of vectors V_1 and V_2,

$$d_j = |X_1(V_j) - X_2(V_j)| \qquad (4)$$

And *AD* is the average distance between vectors V_1 and V_2,

$$AD = \frac{\sum_{j=1}^{m} |d_j|}{m} \qquad (5)$$

Proximity or similarity of *S* between two vectors is presented based on the following equation:

$$S=1-AD \quad (6)$$

S=1 verifies the similarity of the whole and *S=0* is a marker of the maximum degree of non-similarity.

If vectors V_1 and V_2 have an inverse relation, the method to compute the similarity between them is like the former one with the exception that the equation of the distance between the given elements is inversely related with vectors V_1 and V_2.

$$d_j = |X_1(V_j) - (1 - X_2(V_j)| \quad (7)$$

FMS

Once SRMS is completed, some data inserted in this matrix can be misleading. All the key success factors are not related, and there is not always a causal relation between them. To analyze the data and to convert SRMS into FMS, there is a need to use expertise, which includes only the set of fuzzy numeric elements that represent causal relations between key success factors. During data analysis in SRMS matrix, both vectors can be assumed relatedly adjoining. Vectors can also indicate close mathematical relations, while two indicators or concepts can be logically and completely non-related. These unconventional relations can be easily analyzed through expertise [Rodriguez-Repiso, 2005].

MIC MAC

MicMac forms up based on driving power (effect) and dependence power (being influenced) of each variable and makes it possible to further study the range of each variable. In this analysis, the variables are divided into four groups: autonomous, dependent, linkage (interface), and independent (Figure 1).

The manner of distribution of the variables on the dispersion indicates sustainability or non-sustainability of a system. In the domain of mutual effects analysis method using Mic Mac, two types of dispersion were defined; known as sustainable and non-sustainable systems. In the sustainable system, distribution of the variables is L-shaped; that is, some variables have high driving, and some have high dependence powers. In the sustainable system, three variables can be observed:

- Variables with significant effects on the system (key factors)
- Independent variables
- Output system variables (outcome variables).

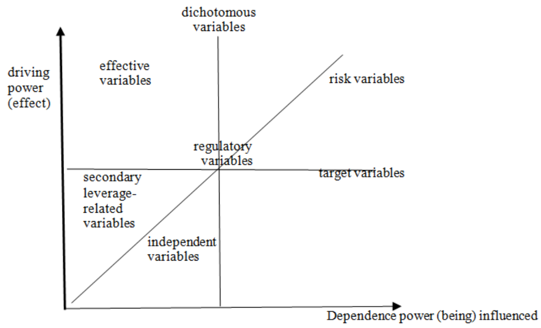

Fig. 1. Dispersion of variables in Mic Mac

In Figure 1; effective variables, dichotomous variables (risk variables and target variables), regulatory variables, variables being influenced (outcome variables), and independent variables can be observed

In this study; Microsoft Excel, MicMac, Pajek, FCMapper software programs were used in different sections.

RESEARCH FINDING

Content Analysis

In content analysis, messages generated are analyzed, and there are attempts to seek answers to research questions. Accordingly, content analysis can provide diverse opportunities for scholars in the fields of social sciences and humanities to make regular use of documents relating to human affairs; i.e., the content of communications.

Open Coding

To implement this step, an introductory meeting was held for each selected expert to explain research subject, definitions, and objectives; and they were then asked to consider important dimensions in CSR ranking on iron ore mining companies according to the status of their company. Their verbal and sometimes written statements were subsequently summarized and aggregated in the form of initial open codes in Table 2. In this step, each item was assigned with a title and a label according to conventional methods. The title, so-called the code needed to reveal data content, so that researchers and readers could realize the concepts of statements after observing the given titles and labels [Mills, Huberman, 1994].

Table 2. Initial open codes

Identifiers	Verbal statements	Concepts (Codes)
R1	Efforts to comply more with occupational health	Attention to occupational health
R2	Similar rules for everyone	Equal rules
R3	Utilization of safe machinery and equipment	Safety
R4	Encouragement of employees to use safety equipment	Guarantee of employee health
R5	Job identity for employees	Ethics
R3	Adherence to safety standards at work	Safety
R6	Observance of employee rights	Legality
R7	Use of environmentally reusable tools and implements	Environmental protection
R6	Respect for contractual obligations	Legality
R8	Transparency in employee promotion	Fair promotion
R9	Transparency in signing contracts with contractors	Transparency in contracts
R5	Attention to employees' working conditions	Ethics
R7	Research for optimal water use	Environmental protection
R5	Provision of factual information about work and its resulting damage	Ethics
R10	Equal opportunities and non-discrimination	Justice
R7	Efforts to reduce damage to the environment	Environmental protection
R5	Planning for employee unions at different occasions	Ethics
R7	Recycling and reducing waste	Environmental protection
R7	Increased use of clean energy	Environmental protection
R11	Maintaining and enhancing green space in alternative locations	Green space development
R12	Maintaining quality of product grade	Maintaining quality
R13	Energy saving	Energy efficiency
R7	Restoration of mines to their original states after complete extraction according to existing instructions	Environmental protection
R7	Efforts to reduce toxic and greenhouse gases	Environmental protection
R14	Public works	Philanthropic
R15	Higher priority for recruitment of native individuals in equal conditions	Native individuals' consent
R14	Support for voluntary involvement of employees in social activities	Philanthropic
R14	Development and promotion of community knowledge and culture	Philanthropic
R14	Increase in employee satisfaction and motivation	Philanthropic
R17	Consideration of shareholders' and investors' equity in decisions	Profitability
R5	Fair payment method	Ethics
R16	Improved productivity	Reduced final cost
R18	Attention to customer satisfaction	Long-term profitability
R19	Conducting transparent bids and tenders in the presence of supervisory representatives	Transparency in transactions

Axial Coding

In this step, titles extracted from the data are categorized and compared which can take a lot of time and patience, since the relationship between them is not so obvious at first; in fact, researchers encounter a huge amount of raw data that is not very interrelated, but invisible links will almost immediately appear. Comparing different concepts, it is possible to discover more common grounds among them, which allows for categorization of similar concepts within the same groups. This theory, as the process of continuous comparison of concepts with each other has been called a comparison method for sustainability analysis [Selden, 2005]. Using the given technique, the grounds for the emergence of common dimensions of concepts, i.e., an axial coding, become possible. As can be seen, identical concepts had the same identifiers. But, some concepts had meanings that were equal or close together, as aggregated in the next table.

Given the proximity and overlapping of the meanings; identifiers R1, R3, and R4 were placed in safety and health dimension and identifiers R2, R6, R8, and R9 were enlisted in the legal dimension. As well; identifiers R7, R11, and R13 were assigned to environmental dimension, and identifiers R5 and R15 were categorized into an ethical dimension. Furthermore; identifiers R14 and R15 were set in philanthropic dimension, and identifiers R12, R16, R17, R18, and R19 were registered in the economic dimension. So, open and axial codes were extracted according to the above-mentioned analysis, as shown in Table 3.

Table 3. Open and axial codes

No.	Open codes	Axial codes
1	Use of environmentally reusable tools and implements	Safety and health
2	Encouragement of employees to use safety equipment	
3	Adherence to safety standards at work	
4	Observance of employee rights	Legal
5	Respect for contractual obligations	
6	Transparency in employee promotion	
7	Transparency in signing contracts with contractors	
8	Attention to employees' working conditions	Ethical
9	Provision of factual information about work and its resulting damage	
10	Creation of equal opportunities and non-discrimination	
11	Efforts to reduce damage to the environment	Environmental
12	Recycling and reducing waste	
13	Increased use of clean energy	
14	Maintaining and enhancing green space in alternative locations	
15	Energy saving	
16	Restoration of mines to their original states after complete extraction according to existing instructions	
17	Efforts to reduce toxic and greenhouse gases	
18	Public works	Philanthropic
19	Higher priority for recruitment of native individuals in equal conditions	
20	Support for voluntary involvement of employees in social activities	
21	Development and promotion of community knowledge and culture	
22	Increase in employee satisfaction and motivation	
23	Consideration of shareholders' and investors' equity in decisions	Economic
24	Improved productivity	
25	Attention to customer satisfaction	
26	Conducting transparent tenders and bids in the presence of supervisory representatives	

Considering the discussed issues and taking the axial codes derived from the qualitative content analysis into account, the dimensions of CSR ranking on iron ore mining companies (safety and health, legal, ethical, environmental, philanthropic, economic) along with 26 indicators were extracted. In the next step, the relevance of these dimensions in determining the ranking of iron ore mining companies was specified. Therefore, structural relations of the given dimensions were analyzed through interpretive structural modeling (ISM).

Analysis of Relations between Indicators using FCM

According to FCM, the analysis initially progressed step by step, and FMS eventually emerged.

Forming IMS

In this step, the initial matrix was formed based on the scores given by the nine selected experts to 26 factors, illustrated in the following table. It is worth noting that to avoid the bias of responses, the lower limit of 20 and the upper limit of 80 were considered for them. However, all the responses involving a score equal to or less than 20, were considered zero; and all the responses equal to or greater than 80 were set to 100 in the initial matrix. Table 4 showed part of the initial matrix.

Table 4. Part of the initial matrix

9	8	7	6	5	4	3	2	1	
35	60	25	30	55	45	30	0	45	1
60	65	40	65	60	55	55	35	60	2
35	30	35	70	55	60	60	60	45	3
65	35	45	55	30	60	0	40	60	
100	30	70	25	0	65	0	45	30	5
55	55	35	45	30	0	40	40	25	6
45	50	50	55	25	0	30	50	70	7
0	0	55	40	70	55	25	60	55	8
				...					...
65	40	25	40	55	25	70	35	60	26

Fuzzified Data

Table 5. Part of fuzzified matrix of factors

9	8	7	6	5	4	3	2	1	
0.25	0.67	0.08	0.17	0.58	0.42	0.17	0.00	0.42	1
0.67	0.75	0.33	0.75	0.67	0.58	0.58	0.25	0.67	2
0.25	0.17	0.25	0.83	0.58	0.67	0.67	0.67	0.42	3
0.75	0.25	0.42	0.58	0.17	0.67	0.00	0.33	0.67	4
1.00	0.17	0.83	0.08	0.00	0.08	0.00	0.42	0.17	5
0.58	0.58	0.25	0.42	0.17	0.00	0.33	0.33	0.08	6
0.42	0.50	0.50	0.58	0.08	0.00	0.17	0.50	0.83	7
0.00	0.00	0.58	0.33	0.83	0.58	0.08	0.67	0.58	8
				...					...
0.75	0.33	0.08	0.33	0.58	0.08	0.83	0.25	0.67	26

In this step, using formulas (1), (2), and (3); the initial matrix was fuzzified. The results were presented in Table 5.

SRMS

According to formulas (4), (5) and (6) in the third section, the 26*26 matrix was established in this step. Then, a meeting was held with expert groups to form up the final matrix. Considering their opinions, meaningless relations between the factors affecting CSR ranking on iron ore mining companies in Yazd Province were deleted, and the direction of the causal relations was determined. In this step, the raw matrix table was given to each group, and they were asked to specify the potential relations between the variables with number 1. The forms were then collected, and the incomplete cells were assigned with zero. So, nine matrices were calculated using arithmetic mean, and the results were rounded up. Zero values meant no diagnostic relations based on expert groups' opinions. Results were shown in Table 6.

Table 6. FMS

C26	C25	...	C8	C7	C6	C5	C4	C3	C2	C1	
0.00	0.00	...	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	C1
0.00	0.00	...	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.44	C2
0.00	0.00	...	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.38	C3
0.00	0.00	...	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	C4
0.00	0.00	...	0.00	0.37	0.00	0.00	0.43	0.00	0.00	0.00	C5
0.00	0.00	...	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	C6
0.37	0.00	...	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	C7
0.00	0.00	...	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	C8
...	...	0.00	...	...	...	...	...	...	...	…	…
0.00	0.00	...	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	C25
0.00	0.00	...	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	C26

FMS

In this section, based on a matrix designed to illustrate the impact of each indicator on each other, a survey was conducted on the selected experts. Then, the mean score was calculated based on the completed matrices to summarize the expert groups' opinions. The completed matrix data were also normalized for cognitive mapping based on FCM, so the data were normalized in the -1 to +1 interval.

Normalized matrix data were then imported into FCMapper as input matrix, and then net output file was obtained. This file was subsequently used as the input into Pajek to draw the FCM. With attention to 26 main factors involved in drawing the cognitive map, 59 relations were extracted between the factors. Of the 26 factors, 12 factors had higher out-degree (Od) than in-degree (Id) and 14 factors had higher Id than Od. 20 variables were normal and six variables were of transferred type. Id could also indicate the degree of being influenced by the factors; so that, the highest Id in this study was associated with factor 11 (Efforts to reduce damage to the environment). Besides, the Od showed the effects of a concept; in other words, it included the effect rate of the factors. Variable 20 (Support for voluntary involvement of employees in social activities) also had the highest Od. Accordingly, the degree of centrality was the sum of the two previous factors. In this study, factors 11 (Efforts to reduce damage to the environment), 17 (Efforts to reduce toxic and greenhouse gases), 22 (Increase in employee satisfaction and motivation), 21 (Development and promotion of community knowledge and culture), and 9 (Provision of factual information about work and its resulting damage) had the highest degree of centrality; respectively. Values associated with each variable were illustrated in Table 7.

To draw the FCM, the output from FCMapper was used as input for Pajek. In Figure 2, FCM indicating the causal relations between the indicators affecting the CSR ranking on iron ore mining companies of Yazd Province was presented.

Table 7. General information about FCM model

indicators	out-degree (Od)	in-degree (Id)	degree of centrality
C11	0.91	2.12	3.02
C17	1.10	1.59	2.69
C22	0.96	1.61	2.57
C21	0.57	1.89	2.46
C9	0.87	1.57	2.44
C5	1.15	1.28	2.42
C8	0.98	1.21	2.19
C23	0.76	1.29	2.05
C25	0.52	1.43	1.94
C7	0.94	0.96	1.91
C24	1.10	0.72	1.82
C1	0.89	0.82	1.71
C20	1.37	0.33	1.71
C4	0.63	0.79	1.42
C3	0.86	0.54	1.40
C10	0.65	0.50	1.15
C16	0.99	0.00	0.99
C2	0.98	0.00	0.98
C19	0.88	0.00	0.88
C15	0.67	0.17	0.83
C26	0.37	0.37	0.74
C13	0.20	0.37	0.57
C14	0.48	0.00	0.48
C6	0.44	0.00	0.44
C12	0.19	0.19	0.37
C18	0.28	0.00	0.28

In Figure 2, the direction of the lines displayed driving and dependence powers. The data inserted in Table 7 as the output of the FCM of FCMapper denoted the importance of each indicator concerning its centrality. The main objective of this study was to present an SCR ranking model of iron ore mining companies of Yazd Province.

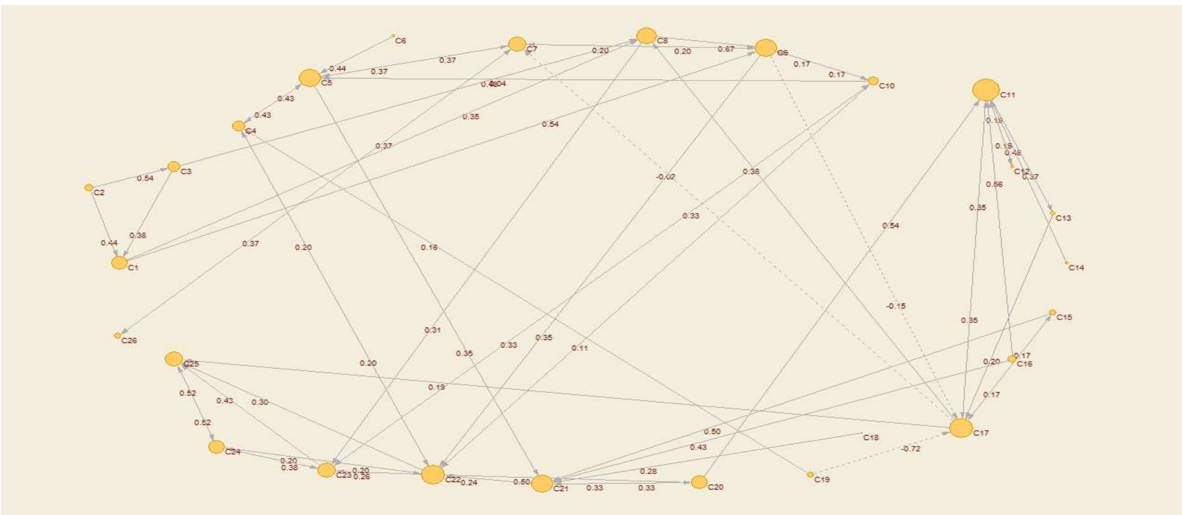

Fig. 1. FCM of indicators affecting CSR ranking

Table 8. Weight of each indicator of CSR ranking model

weight	symbol	indicator	dimensions
0/0433	C1	Use of environmentally reusable tools and implements	Safety and health (0/1036)
0/0248	C2	Encouragement of employees to use safety equipment	
0/0355	C3	Adherence to safety standards at work	
0/0355	C4	Observance of employee rights	Legal (0/1569)
0/0613	C5	Respect for contractual obligations	
0/0112	C6	Transparency in employee promotion	
0/0488	C7	Transparency in signing contracts with contractors	
0/0555	C8	Attention to employees' working conditions	Ethical (0/1465)
0/0618	C9	Provision of factual information about work and its resulting damage	
0/0291	C10	Creation of equal opportunities and non-discrimination	
0/0765	C11	Efforts to reduce damage to the environment	Environmental (0/2268)
0/0094	C12	Recycling and reducing waste	
0/0144	C13	Increased use of clean energy	
0/0122	C14	Maintaining and enhancing green space in alternative locations	
0/0210	C15	Energy saving	
0/0251	C16	Restoration of mines to their original states after complete extraction according to existing instructions	
0/0682	C17	Efforts to reduce toxic and greenhouse gases	
0/0071	C18	Public works	Philanthropic (0/2002)
0/0223	C19	Higher priority for recruitment of native individuals in equal conditions	
0/0433	C20	Support for voluntary involvement of employees in social activities	
0/0623	C21	Development and promotion of community knowledge and culture	
0/0651	C22	Increase in employee satisfaction and motivation	
0/0520	C23	Consideration of shareholders' and investors' equity in decisions	Economic (0/1660)
0/0461	C24	Improved productivity	
0/0492	C25	Attention to customer satisfaction	
0/0188	C26	Conducting transparent tenders and bids in presence of supervisory representatives	

Hence, the centrality of each of the indicators in the FCM model could be the basis for determining the weight of each indicator shown in Table 8.

Accordingly, the weight of each dimension was obtained from the sum of the weights of the indicators in the presented model.

Determining Types of Indicators using Mutual Effects Analysis

After identifying the indicators related to SCR ranking on iron ore mining companies in Yazd Province as well as FCM analysis, it was necessary to measure the effect of related indicators dichotomously to identify the most effective indicators in SCR ranking. To this end, a 26*26 square matrix was provided to expert groups. The process of completing the cells was based on the rounded-up mean of opinions derived from expert groups on mutual effects of the indicators. In this step of the study, MicMac was used. It should be noted that the interpretation of numbers 0, 1, 2, and 3 were as follows; number zero=no effect, number 1=poor effect, number 2=moderate effect, and number 3=strong effect.

After collecting nine matrices and rounding up the mean opinions of expert groups, a single matrix was created and imported into MicMac. Considering the FCM output, a total of 58 cells had non-zero numbers, which meant that there was a relationship. Therefore, the expert groups were asked to assign 1 to 3 to the same fields based on driving power. The results were summarized in Table 9.

Table 9. Map of characteristics

Indicator	Value
Matrix size	26
Number of iterations	2
Number of zeros	618
Number of ones	27
Number of twos	18
Number of threes	13
Number of P	0
Total	58
Fill rate	8.579882%

The single matrix formed up was derived from the rounded-up mean opinions of the expert groups, which was used as an input in MicMac, outlined in Table 10.

Table 10. Input matrix of MicMac

	1 : Var01	2 : Var02	3 : Var03	4 : Var04	5 : Var05	6 : Var06	7 : Var07	8 : Var08	9 : Var09	10 : Var10	11 : Var11	12 : Var12	13 : Var13	14 : Var14	15 : Var15	16 : Var16	17 : Var17	18 : Var18	19 : Var19	20 : Var20	21 : Var21	22 : Var22	23 : Var23	24 : Var24	25 : Var25	26 : Var26
1 : Var01	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 : Var02	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 : Var03	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 : Var04	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
5 : Var05	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
6 : Var06	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 : Var07	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3
8 : Var08	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
9 : Var09	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
10 : Var10	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
11 : Var11	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0
12 : Var12	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 : Var13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
14 : Var14	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 : Var15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0
16 : Var16	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
17 : Var17	0	0	0	0	0	0	0	2	1	0	1	0	0	0	2	0	0	0	2	0	0	0	0	0	2	0
18 : Var18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
19 : Var19	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 : Var20	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0
21 : Var21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
22 : Var22	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	0
23 : Var23	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
24 : Var24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3	0
25 : Var25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
26 : Var26	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

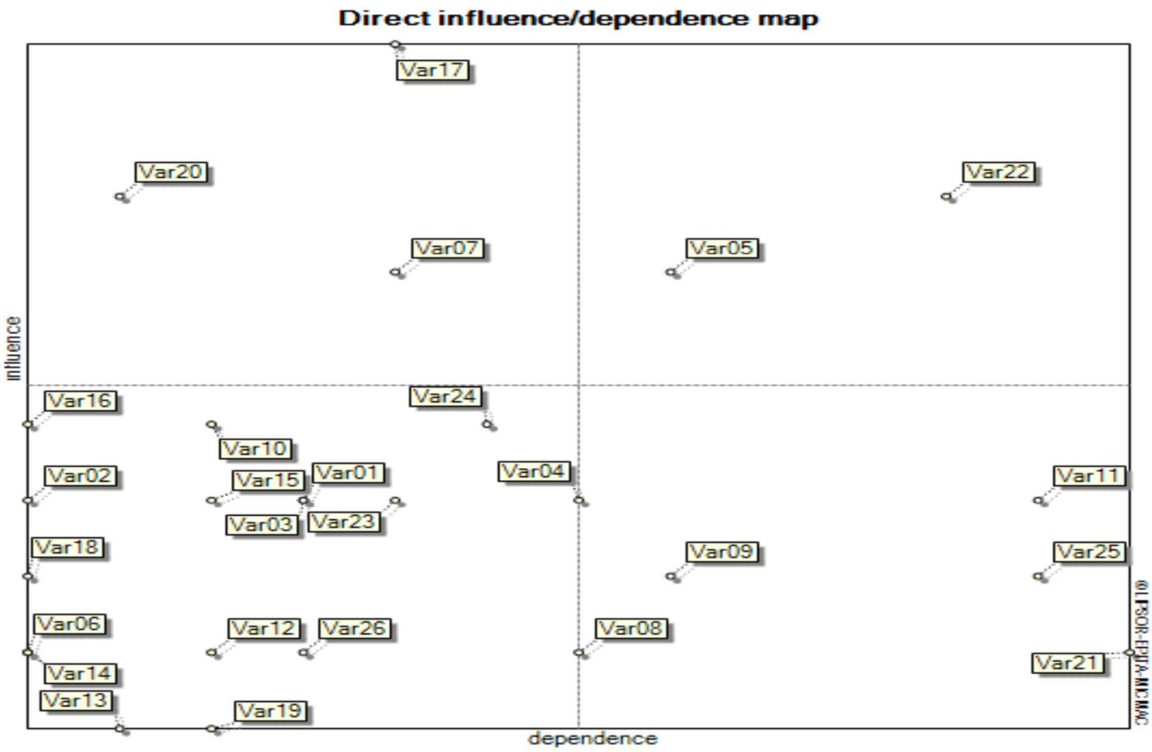

Fig. 3. Mutual effects of indicators

MicMac output was illustrated in Figure 3. As can be seen, the shape of the dispersion of the variables was continuous along the axis and represented a sustainable system. Based on the distribution of the indicators in the four areas above, the indicators in each area had their interpretations, which were discussed below.

Driving (Effective) Indicators

According to the definitions as well as placement of variables in Figure 3, indicators located on the northwestern area of the figure above were called driving (effective) variables; in other words, they were the most critical indicators including "Support for voluntary involvement of employees in social activities", "Efforts to reduce toxic and greenhouse gases", and "Transparency in signing contracts with contractors".

Dichotomous Indicators

Indicators located in the northeastern area of the figure were dichotomous ones which could be influenced or affect other ones. These variables were divided into two categories of risk and target ones. The risk variables were located near the diagonal line of the northeastern area of the figure. Indicators 5 and 22 were located in the northwest corner and near the diagonal line. These variables were endowed with a very high capacity to become key actors in the system. These indicators included "Respect for contractual obligations" and "Increase in employee satisfaction and motivation."

Dependence (Influenced) Indicators

Indicators located in the southeastern area of Figure 3 had a very low effect, but they could be significantly influenced. These indicators had been called outcome indicators including "Attention to employees' working conditions," "Provision of factual information about work and its resulting damage," "Efforts to reduce damage to the environment", "Development and promotion of community knowledge and culture," and "Attention to customer satisfaction".

Independent Indicators

Indicators in the southwestern area of the figure had a low effect and they could not be influenced also significantly. In other words, these indicators did not play a role in the development or evolution of the system and even in discontinuing it. Other indicators in this area were referred to as independent indicators.

CONCLUSIONS

The concept of CSR means how to responsibly create wealth through businesses. Therefore, the behavior of an organization encompasses employees, customers, contractors, the environment, and society. Given that iron ore mining companies in Yazd Province were included in this study, a total number of 26 indicators (open codes) in 6 dimensions (safety and health, legal, ethical, environmental, philanthropic, and economic) were extracted after analyzing the content of 34 verbal statements. The relations between the indicators were also determined via FCM. Using FCMapper, the weight of the indicators was also measured. Indicators of "Efforts to reduce damage to the environment," "Efforts to reduce toxic and greenhouse gases," "Increase in employee satisfaction and motivation," "Development and promotion of community knowledge and culture," and "Provision of factual information about work and its resulting damage" had the highest weight from the perspective of the expert groups. The severity of the effects of variables on each other was also calculated through MicMac. Accordingly, indicators of "Supporting voluntary involvement of employees in social activities", "Efforts to reduce toxic and greenhouse gases", and "Transparency in signing contracts with contractors" were considered as effective ones. As well, dichotomous indicators with very high capacity in becoming a key actor within the system included "Respect for contractual obligations" and "Increase in employee satisfaction and motivation". The indicators influenced were "Attention to employees' working conditions", "Provision of factual information about work and its resulting damage," "Efforts to reduce damage to the environment," "Development and promotion of community knowledge and culture," as well as "Attention to customer satisfaction". The remaining indicators were placed in the independent group.

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REFERENCES

Abd-RazakAhmad, Ida-Normaya M.Nasir, Wan-Asma'Wan-Abu-Bakar, FaizahDarus, Noor Zahirah MohdSidek, 2015. i-CSR Ranking in the Workplace, Procedia Economics and Finance, 31, 2015, 520-524. https://doi.org/10.1016/S2212-5671(15)01196-X

Aluchna M., 2010. Corporate social responsibility of the top ten; examples taken from the Warsaw Stock Exchange. Social Responsibility Journal, 6(4), 611-626. http://doi.org/10.1108/17471111011083473

Ardalan M.R., Ghanbari S., Beheshti-Rad R., Navidi P., 2015. Investigation of the relationship between social capital, social responsibility, and organizational commitment (A case study on employees at Razi University of Kermanshah). Educational Measurement and Evaluation Studies, 109-132.

Asayesh F., Feizpour M.A., 2014. Development in Iran and its comparison with countries in the region: Vision Document. Journal of Parliament and Strategy, 21(78), 85-119.

Bakhshi H., Jalaeian V., 2016. Content Analysis Guide, Academic Center for Education, Culture, and Reserach, First Ed.

Castka P. Balzarova A.M., 2007. "ISO 26000 and Supply Chains – on the Diffusion of the Social Responsibility Standards". International Journal of Production Economics. 111, 274-286. http://doi.org/10.1016/j.ijpe.2006.10.017

Davis K., 1975. Five Propositions for Social Responsibility, Business Horizons. https://doi.org/10.1016/0007-6813(75)90048-8

Erin H., Kao Chih-ChuanYeh, Li-HsunWang, Hung-GayFung, 2018. The relationship between CSR and performance: Evidence in China, Pacific-Basin Finance Journal, 51, October 2018, 155-170. http://doi.org/10.1016/j.pacfin.2018.04.006

Freeman R.E., 1998. A stakeholder theory of the modern corporation, in Pincus, L. B. (Ed.), Perspectives in business ethics, McGraw-Hill, Singapore. http://doi.org/10.4236/jss.2015.37019

Gao Y., 2011. CSR in emerging country: a content analysis of CSR reports of listed companies, Baltic Journal of Management, 6, 2011, 263-291. http://doi.org/10.1108/17465261111131848

Ghasemi-Hosseinabadi F., 2016. Corporate social responsibility and how to measure it. Bi-Monthly of Applied Studies in Science Management and Development, 1 (2).

Harrison J., Freeman R., 1999. Stakeholders, social responsibility, and performance: Empirical evidence and theoretical perspectives. The Academy of Management Journal. 42. 479-487. 10.2307/256971. http://doi.org/10.2307/256971

Hasas-Yeganeh Y., Barzegar G., 2013. Developing components and indicators of corporate social responsibility and its current status in Iran. Quarterly Journal of Social-Cultural Development Studies, 2 (1), 209-234.

Hirigoyen G., Poulain-Rehm T., 2014. The corporate social responsibility of family businesses: An international approach. International Journal of Financial Studies, 2,240-265. http://doi.org/10.3390/ijfs2030240

John M., et al. 2006. Corporate Social Responsibility: The 3C-SR Model. International Journal of Social Economics.33:5-6. http://doi.org/10.1108/03068290610660661

Karabašević D., Paunkovic J., Stanujkić D., 2016. Ranking of companies according to the indicators of corporate social responsibility based on SWARA and ARAS methods. Serbian Journal of Management, 11(1), 43-53. http://doi.org/10.5937/sjm11-7877

Kitzmueller M., Shimshack J., 2012. Economic perspectives on corporate social responsibility. Journal of Economic Literature, 50 (1), 51-84. http://doi.org/10.1257/jel.50.1.51

Kosko B., 1988. Hidden patterns in combined and adaptive knowledge networks, International Journal of Approximate Reasoning, 2, 4, 377. http://doi.org/10.1016/0888-613X(88)90111

Lantos G.P., 2001. The boundaries of strategic corporate social responsibility, Journal of Consumer Marketing, 18, 7, 595-630. http://doi.org/10.1108/07363760110410281

Albareda L., Lozano J.M., Ysa T., 2007, Public Policies on Corporate Social Responsibility: The Role of Governments in Europe, Journal of Business Ethics, 74, 391-407. http://doi.org/10.1007/sl0551-007-9514

Levitt T., 1958. The Dangers of Social Responsibility, Harvard Business Review, 33 5, 41-50. https://doi.org/10.4236/tel.2018.83031

Mattera M., Baena V., Cerviño J., 2012. Analyzing Social Responsibility as a Driver of Firm's Brand Awareness. Procedia-Social and Behavioral Sciences, 58, 1121-1130. http://doi.org/10.1016/j.sbspro.2012.09.1093

Mills M.B., Huberman M. 1994. Qualitative Data Analysis: Sourcebook of New Methods, London: Sage Publications Ltd. http://doi.org/10.3102/01623737008003329

Norman W., MacDonald C., 2009. Getting to the bottom of triple bottom- line. Business Ethics Quarterly March, 1(1): 1-19. https://doi.org/10.5840/beq200414211

Nowrouzi M.R., Danaeefard H., Asghar-Fani A., Hasanzadeh A., 2014. Theoretical processing of corporate social responsibility based on grounded theory. Improved Management, 8 (26).

Rhou Y., Singal M., Koh Y., 2016. CSR and financial performance: The role of CSR awareness in the restaurant industry. International Journal of Hospitality Management, 57, 30-39. http://doi.org/j.ijhm.2016.05.007

Rodriguez-Repiso L., 2005. Indicators of Success for IT Projects .Case Study. MSc Systems Engineering with IT Applications .Cardiff University.

Salehi-Omran I., Fatemi A., Hassanzadeh Barani Kord S., 2012. Examining the importance of corporate social responsibility indicators in industrial centers and universities. Higher Education in Iran, 1-35.

Selden L., 2005. On grounded theory - with some malice. Journal of Documentation, 61(1), 114-129. https://doi.org/10.1108/00220410510578041.

Senowbar N., Baz-Mohammadi S., 2017. Applications of analytical methods of gray relation entropy in corporate social responsibility ranking: Evidence of Iranian pharmaceutical companies. Industrial Management Studies, 15 (44), 51-74.

Seyyedjavadain R., Hashemi M., Mahmoudain O., 2016. Providing a model to explain corporate social responsibility of oil and gas companies using interpretive structural modeling. Governmental Management, 75-92. http://doi.org/10.22059/JIPA.2016.57505

Valmohammadi C., 2014. Impact of corporate social responsibility practices on organizational performance: an ISO 26000 perspective. Social Responsibility Journal, 10(3), 455-479. http://doi.org/10.1080/10508422.2018.1501566

Wood D.J., 1991. Corporate social performance revisited- Academy of Management Review 16, 691–718. http://doi.org/10.5465/amr.1991.4279616.

Zakaria SF., Ahmad AR., 2019. AHP Ranking of CSR Human Resource Theme of Takaful Operators. In: Kor LK., Ahmad AR., Idrus Z., Mansor K. (eds) Proceedings of the Third International Conference on Computing, Mathematics and Statistics (iCMS2017). Springer, Singapore. http://doi.org/10.1007/978-981-13-7279-7_63

MODEL RANKING ODPOWIEDZIALNOŚCI SPOŁECZNEJ KOPALNI RUD ŻELAZA METODĄ KOGNITYWNEGO ROZMYTEGO MAPOWANIA

STRESZCZENIE. **Wstęp:** Ze względu na rosnące znaczenie globalnych współzależności, niektóre koncepcje typu odpowiedzialność społeczna firmy (CSR) ma istotne znaczenie w dynamicznym i rozwijających się sektorze składającym się z zakwaterowania, transportu, itp. Nawet małe decyzje czy działania pojawiające się w tych centrach, niezależnie od bezpośrednich efektów na określony obszar, mogą mieć też bezpośredni lub pośredni, jasny lub ukryty, materialny lub niematerialny wpływ na wszystkie obszary społeczności i w konsekwencji prowadzić do serii akcji i reakcji zwrotnych na nie we wszystkich obszarach i poziomach.

Celem tej pracy jest wyjaśnienie oraz uszeregowanie czynników wpływających na odpowiedzialność społeczną firm (CSR) kopalni rud żelaza w prowincji Yazd, w Iranie. Dodatkowo, po raz pierwszy, metoda rozmyta FCM została użyta do stworzenia rankingu odpowiedzialności społecznej firm.

Metody: Wskaźniki I wymiary CSR zostały wydzielone przy użyciu analizy treści wywiadów z grupami ekspertów z 9 kopalni rud żelaza, zlokalizowanych w prowincji Yazd, w Iranie. Następnie określono relacje pomiędzy tymi wskaźnikami przy użyciu rozmytej kognitywnej mapy. Kolejnym etapem było ich uszeregowanie przy pomocy narzędzia FC Mapper. W ostatnim etapie wyliczono intensywność wpływu wskaźników na pozostałe przy pomocy Mic Mac.

Wyniki: Wymiary, uzyskane poprzez analizę treści, obejmowały bezpieczeństwo i ochronę zdrowia, jak również były to wymiary prawne, etyczne, środowiskowe, charytatywne oraz ekonomiczne. Najwyżej w modelu znalazły się wskaźniki: „starający się zredukować szkodliwy wpływ na środowisko", „rozwijający i stymulujący kulturę i wiedzę społeczności", „dostarczający aktualnej informacji o pracy i jej wadach". Przez zastosowanie metody Mic Mac, określono intensywność wpływu poszczególnych wskaźników na siebie. Najbardziej wpływającymi na inne były: „dobrowolne wsparcie pracowników w działalności społecznej", „działania mające na celu redukcję gazów toksycznych i cieplarnianych" oraz „transparentność w kontaktach z partnerami".

Wnioski: Wyniki uzyskane w tej pracy mogą wspomóc organy rządzące, naukowców oraz organizacje w zrozumieniu przez nich wskaźników odpowiedzialności społecznej firm w celu zintensyfikowania ich działań na rzecz społeczeństwa.

Słowa kluczowe: odpowiedzialność społeczna firm, analiza treści, rozmyte kognitywne mapowanie, Mic Mac

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ORIGINAL PAPER

A SOFTWARE DEVELOPMENT APPLICATION FOR SUSTAINABLE AIRPORT PERFORMANCE ANALYSIS

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ABSTRACT. **Background**: In today's rapidly changing global economy, airports have an important role in the social, cultural, and economic development of societies and in building bridges between interconnected markets. Sustainability requires a balance between economic, social, and environmental processes and performance-based progress in efforts on all three dimensions at an optimum level. Therefore, sustainable performance measurement and management is an important function for the control of airports. The suitability of investments in airports to respond to the increasing needs and expectations of the future can be realized through a rational structure that operates technologically, effectively, and efficiently. The need for this structure to be sustainable with above-average performance further increases the importance of the issue. This study aims to develop a sustainable performance software for airports by conducting a sustainable performance analysis based on multiple variables.
Methods: For sustainable performance analysis at airports, it is important to include economic, social, and environmental parameters, which are the three sub-dimensions of sustainability, in all strategic, tactical, and operational processes and decision-making mechanisms. For the performance analysis of airports, the DEMATEL Method, and the Objectives Matrix (OMAX) Method, which evaluates all the criteria together, were used to weight various performance indicators.
Results: The most important criterion at Antalya Airport, which is also the most affected by other criteria, is "economic". Sustainable performance scores of Antalya Airport for 2018 and 2019 were calculated. The airport's performance in 2019 is higher compared to 2018.
Conclusions: The biggest achievement of this research is thought to be developing a "Sustainable Performance Software" for national and international airports. This study will also contribute to the emergence of studies that will reveal the performances of other airports and compare their past performances with their current and national performances.

Key words: airport, airport performance, sustainability, performance analysis, sustainable performance software.

INTRODUCTION

"Air Transportation" and "Airport Management" constitute one of the most functional aspects of logistics and supply chain management today [Yuan et al. 2010]. Aviation, which has undergone a tremendous change in the recent past, has experienced a continuous development trend for the last 20 years and has become one of the fastest-growing sectors of the global economy with an average of 5% growth each year [Kumar et al. 2020]. In this respect, the aviation industry contributes significantly to local economies and facilitates the integration of a country into the global economy, providing socio-economic benefits [Chourasia et al. 2020]. Expectations of an increase in demand for airline freight and passenger transport show that the aviation industry will continue to grow, which means building new airports or expanding existing airports. All these developments in the aviation sector cause an increase in concerns about sustainable development, which includes environmental complexity [Sameh, Scavuzzi 2016] and details of all operational processes

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and costs for all medium-long-term activities [Janic 2010].

Air transportation is positively and negatively associated with society and the environment and has a dynamic interaction with persistence [Janic 2010]. Airports are the places where all logistics activities between land and air modes of transportation are carried out and play a vital role in the value chain [Baxter 2018]. Over the years, the evaluation of airports has focused on the quality of service, which led to pushing significant environmental and social impacts into the background. For instance, the Airport Service Quality (ASQ) Program, an initiative of the International Airports Council (ACI), evaluates and ranks various operations and services at world airports to help improve airport service quality [Chao, et al. 2017]. However, environmental concerns that have increased in recent years have made it necessary for a program that evaluates the environmental pollution of airports. In response to communities' concerns, airport officials try to instill public awareness of the environmental problems of aviation activities and the regulatory measures of local governments and governments; however, they present several factors to reduce the negative impact of their activities on the environment and try to implement the strategies developed accordingly [Sameh, Scavuzzi dos Santos 2018]. In this context, Airports Council International (ACI) has launched the "Airport Carbon Accreditation (ACA)" programme to measure carbon emissions and make it a global standard, which is one of the most important parameters in determining the pollution level of airports. The purpose of this programme is to encourage practices that will benefit most in carbon management with the goal of ultimately minimizing carbon emissions in airports and to validate them with sustainable policies. The programme was developed in accordance with international standards, including the Greenhouse Gas Protocol and ISO 14064. As the related standards develop, the programme is updated accordingly [ACI 2018].

Although the socio-economic benefits created by the aviation sector are frequently emphasized, the limited importance given to environmental sustainability at airports negatively affects the ecology and society around it [Chourasia et al. 2020]. However, it should be noted that the problems posed by airports should not be assessed solely on environmental aspects. In addition to the development of activities aimed at achieving environmental sustainability, it is necessary to focus on the areas of economic and social sustainability [Boons, et al. 2010]. On the other hand, since the Industry 4.0 phenomenon has a content that affects aviation organizations [Rodoplu Şahin, et al. 2019], technical and process dimensions also need to be integrated into the developmental process of sustainability practices.

Increasing the pressure of national and international authorities on airports on sustainability caused airport managers to need new solutions for performance optimization [Kucuyak 2001]. Nevertheless, it is a practical challenge under which criteria the performance is to be examined in a complex and dynamic service environment such as airports [Bezerra, Gomes 2018]. Although the sustainable performance of airports is generally researched under social, environmental, and economic criteria [Koç, Durmaz 2015, Upham 2001], there are also studies in which criteria dimensions such as physical [Chourasia et al. 2020] and operational [Brisbane Airport Corporation 2020, Güngören 2016] are added.

In the analyses carried out in this study, the sustainable performance of the airport was assessed under economic, social, environmental, process, and technical dimensions. The main source of motivation in the creation of the study addresses the idea of approaching sustainability and performance issues at airports with a business perspective and developing software and scale as an original and innovative idea that will serve logistics management practices in total on an interdisciplinary ground. In line with these objectives and purposes, the relevant literature on sustainable airport performance indicators was reviewed, and in light of the information obtained, sustainable performance criteria were determined to be used in the research method. The DEMATEL method was used to determine the weights of the criteria, and the OMAX method was used to achieve the annual performance score. Total Productivity Index software was developed to ensure easy access to airport sustainable performance scores by airport managers. Within the scope of this study, objective performance data will be presented in all dimensions of sustainability, and it is aimed to make a scientific contribution in reducing the effects of "operational blindness" in airports.

SUSTAINABLE PERFORMANCE INDICATORS AT AIRPORTS

Historically, since the airports are often operated by governments, performance comparisons have been focusing on financial and output metrics. The measurements developed are the workload unit (WLU) defined for a passenger or load handling for 100 kg. The output criteria obtained from these measurements are total cost, labor cost, and total income per WLU. Other measurements were carried out on airport design and operational standards [Frankis, et al. 2002]. The International Civil Aviation Organization (ICAO) provides performance comparisons of airports based on size, organization, planning, terminal passenger flows, waiting times, etc. [Vreedenburg 1999]. ACI has released a guide to help improve the performance of airports worldwide. This guide consists of 6 key performance criteria and 42 sub-indicators. The main criteria are core, safety and security, service quality, productivity/efficiency, financial/commercial, and environmental [Eshtaiwi, et al. 2018]. In the academic literature, it is observed that studies over the last decade have been conducted on the measurement of quality of service relative to passenger perception. As the airport business became commercial, the need for performance measurements increased. Andersson Granberg and Munoz [2013] listed the airport performance indicators they selected from various studies as operational, economic, environmental, safety/security, and customer service. In addition to these criteria, Baltazar et al. [2018] added efficiency/cost-effectiveness.

Bezerra et al. [2016] examined the performance dimensions in airports extensively for the past 45 years in the literature. They emphasized the need to develop reliable performance management issues that will make performance definition, measurement, and analysis important. They listed the percentage of handling performance dimensions at airports, including 38.3% Efficiency/Effectiveness, 21.2% Service Quality, 16% Economic/Financial, 7.9% Environmental, 5% Commercial, 3.6% Security, 3.4% Competitiveness, 2.6% Social, and 1.9% Safety.

There are many studies in the literature, where measurement criteria for determining airport sustainability performance are set. Koç and Durmaz [2015] use the social, economic, and environmental criteria set by the Global Reporting Initiative (GRI) to measure sustainable performance, under the criteria of the sustainable performances of the best airports published in Skytrax's World Airport Awards and ACI's Airport Service Quality (ASQ). Olfat et al. [2016] analyzed sustainable airport performance under policies, commercial, social responsibility, environmental pollution level, and service quality components. Lu et al. [2018] identified forecast indicators to improve sustainable performance at international airports. These indicators are financial, internal business processes, learning, and growth, environmental and social perspective. Wan et al. [2020] evaluated the sustainable development performance of Guangzhou Baiyun International Airport between 2008-2017 by creating a synthetic assessment index model under the dimensions of economy, environment, society, and operation.

In airport management, safety, security operation, customer, human resources, and environmental impact-oriented indicators are also very important besides indicators such as efficiency, profitability, financial situation. In addition, considering the requirements of the International Air Transport Association (IATA) standards, ICAO and the European Civil Aviation Conference (ECAC), which are the organizations where the airport management interacts, are important for performance management effectiveness. In order to evaluate the quality of the service provided at the airports, it is necessary to categorize them into main groups as arriving, departing, transfer and transit passengers, considering that the airport is the main customer base. The reason is that the basic needs and expectations of the passengers in each group will be different. On the other hand, airport enterprises implement some effective environmental management plans to minimize the negative effects on noise, carbon emission, water pollution, birds, and other wild animals due to their activities [Güngören 2016].

METHODOLOGY

The performance measurement system generally includes the system, objectives, measurements, and steps for improvement. Objectives are definitions that must be achieved in order for the business to implement its strategy. Measuring performance does not change alone, but steps to achieve performance improvement are required [Bourne, Bourne 2011]. In this respect, the main objective of the management is to create team spirit and increase performance by directing all contributions and efforts in the same direction, without unnecessary operations, gaps and obstacles around the objectives set by the employees. The company strategy, which is formed with clear and consistent goals, increases the competitive position in the long run and helps to become the leader in the sector if it is well planned and implemented. Since turning to opportunities that can be achieved in the short term without setting long-term goals will fail the business, it is beneficial for the company to pursue a strategy based on strategy and vision that will provide a competitive advantage in the long run [Zaim 2002].

In this study, it is aimed to demonstrate the sustainable performance of Antalya Airport in terms of years and to develop a sustainable airport performance software. For this purpose, firstly, Antalya Airport officials were contacted, and the data to be used in the analysis were provided. In the second step, the weights of the sustainable performance criteria determined were determined by using the DEMATEL Method. In the third step, the OMAX Method was used to reach the sustainable performance scores of Antalya Airport in 2018 and 2019, and the related scores were compared with one another. In the last step, the software called Total Productivity Index, which will directly calculate the annual sustainable performance of airports, was developed, and the findings obtained in this study were tested with the developed software. Except for the software development step, the flow diagram applied in this study is shown in Figure 1.

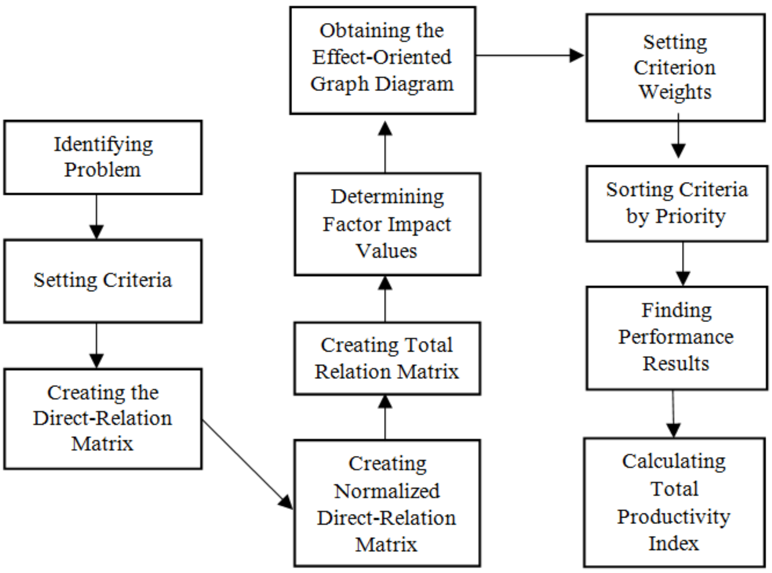


Fig. 1. Flow diagram

DEMATEL METHOD (WEIGHTING METHOD)

The DEMATEL Method (The Decision-Making Trial and Evaluation Laboratory Method) was used as a multi-criteria decision-making method to determine the weights of the criteria for sustainable airport performance. The method was developed in 1972 and 1976 by the Battelle Memorial Institute in Geneva [Wu 2008]. The DEMATEL method can improve the understanding of specific problems and a set of nested problems. It can contribute to the definition of applicable solutions with a hierarchical structure. It differs from the assumption that the criteria discussed in traditional multi-criteria decision-making methods, such as the analytical hierarchy process, are independent. One of the structural modeling techniques, this method can causally determine dependence among the components of a system. The DEMATEL method procedure is summarized with the following steps [Tzeng et al. 2007, Wu 2008]:

Step One: Creating the Direct-Relation Matrix

In this first step, expert opinions are correlated based on the 5-point scale to create a direct-relation matrix. These are as follows:

- 0 indicates that there is no interaction between criteria,
- 1 indicates that the interaction between criteria is low,
- 2 indicates that the interaction between criteria is moderate,
- 3 indicates that the interaction between criteria is high, and
- 4 indicates that the interaction between criteria is very high.

Step Two: Creating a Normalized Direct-Relation Matrix

By adhering to the direct-relation matrix, the normalized direct-relation matrix (M) is obtained by the following equations. It is obtained by using the smallest value (k) in rows and columns by means of equations 2.1 and 2.2.

$$M = kxA \qquad 2.1$$

$$k = Min\left(1/\max\sum_1^a |a_{ij}|, 1/\max\sum_1^a |a_{ij}|\right) \qquad 2.2$$

$$1 \le i \le 0 \qquad 1 \le j \le 0$$

$$i,j \in \{1,2,3,4 \ldots .. n\}$$

Step Three: Creating a Total Relation Matrix

After the normalized direct-relation matrix is obtained, the total relation matrix is created with the equation (S). The value (I) in this equation is the unit matrix.

$$S = M^1 + M^2 \ldots .. = \sum_{i=1}^{\infty} M^i \qquad 2.3$$

$$= M\,(I - M)^{-1} \qquad 2.4$$

Step Four: Creating the Sender and Receiver Group

While the value obtained from the sum of the columns in the S matrix is encoded as R, the sum of the rows in the same matrix is encoded as D. D-R and D+R values are obtained after the calculations made using the equation 2.5 and 2.6 given below. These values are expressions that reveal the effect of the criteria on others or the relationship between the criteria. Some of the D-R values may be positive. Although the positive values show that the criteria have a high impact on other criteria, it is concluded that they have high priority over other criteria. D-R values being negative suggest that the criteria are affected more than other criteria. D+R values express the relationship between each criterion and the other. Criteria with high D+R value are more related to other criteria. If the D+R value is low, we can say that the resulting values are less related to other criteria.

$$S = [S_{i,j}]_{nxn}, \; i,j \,\epsilon \{1,2,3,4 \ldots \ldots .. n\} \qquad 2.4$$

$$D = \sum_1^n S_{i,j} \qquad 2.5$$

$$R = \sum_1^n S_{i,j} \qquad 2.6$$

Step Five: Obtaining the Effect-Oriented Graph Diagram

Decision-makers need to set a threshold for the effect level in order to obtain an impact-oriented graph. In the S matrix, a number of values with impact values greater than the threshold value are selected, and an effect-oriented graph diagram is created. The threshold value is determined by the decision-maker or expert group. The effect-oriented graph diagram is obtained by showing the points in a coordinate plane (D+R, D-R) with the horizontal axis D+R and the vertical axis D-R [Tsai and Chou 2009]. The threshold value determined by the expert group is significant to prevent the complexity of the effect-oriented diagram obtained. The high or low threshold value to be used affects the impact of the relationship between the criteria and can make the solution more complex or simpler [Aksakal and Dağdeviren 2010].

Step Six: Setting Criterion Weights

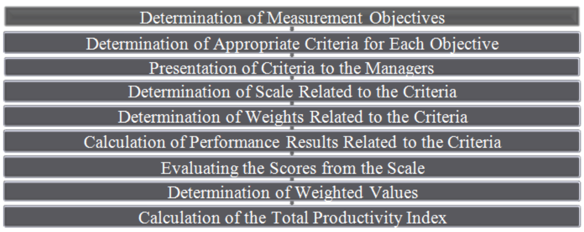
Weights (w) are calculated by taking the squared average of the total effects $(D + R)$ and the net effects $(D - R)$ of the D and R vectors.

$$w = [(D + R)^2 + (D - R)^2]^{1/2}$$

OMAX METHOD (OBJECTIVES MATRIX METHOD)

The original implementation of OMAX is linked to the study of James L. Riggs, the founder and first director of the Oregon Productivity Center in the early 1980s. Other applications were carried out by Carl Thor at the American Center for Productivity and Quality and John Parsons at the National Institute of Productivity in South Africa [Dervitsiotis 1995]. To date, the OMAX efficiency matrix has been used under different names such as multi-criteria performance measurement technique (MCP/PMT), importance-performance matrix, and interpretations of the matrix method. The first application of the matrix method was made by Riggs [1986]. The measurement framework was applied in manufacturing industries, services, and public institutions. Rantanen and Holtari [1999] emphasized that the performance measurement matrix method is one of the most used systems, such as the balanced performance measurement method Balanced Scorecard [Jääskeläinen 2009].

OMAX is a performance measurement method that evaluates various performance indicators together with the method of weighting to obtain a total performance indicator [Balkan 2011]. In this method, it is encouraged to use other indicators instead of real output. The main feature of the method is the approach followed in determining the indicators that determine performance. The basis of this approach is based on the argument that the performance criteria can be determined by those who know the factors that affect the performance in the organization, group, or individual studies in the best way. Employees can more easily evaluate which activities and efforts will positively support organizational performance and which can be ineffective or insignificant. There are different job characteristics unique to each group. Based on these characteristics, it is possible to differentiate the factors that affect organizational performance (group performance). The important thing is to choose the ratios that have known effects on the common result (output) and which can reveal measurable behavior types [Akal 2005]. The workflow of the method is as follows [Balkan 2011].



Source: Balkan 2011

Fig. 2. Objectives Matrix Method Workflow Chart

In the implementation phase of the specified workflow process, the lowest and highest measurement values targeted for each criterion are determined after the objectives and criteria for the targets are determined, and the approval of the managers is obtained. Since each criterion has different weights in terms of organization, weights are given to each to complete one hundred percent. As a result of calculating the scores and multiplying them by their weight, an efficiency score is generated for each criterion. With the sum of all these weighted scores on the scales, the Total Performance Index is calculated by taking into account the objectives of the enterprise and showing how close it is to its objectives [Akal 2005].

SOFTWARE DEVELOPMENT

The C# programming language was used for the software developed as part of this study. C# is an object-oriented programming language developed by Anders Heljsberg and his team for Microsoft's .NET platform [ECMA 2001]. The interface of the software is shown in Figure 3.

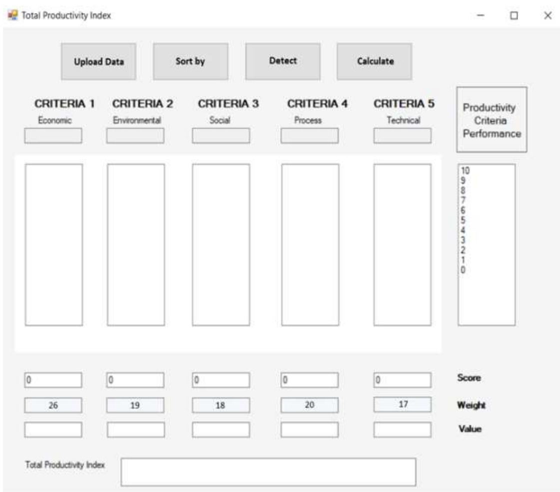


Fig. 3. The Interface of the Software

OPERATING PRINCIPLE OF SOFTWARE

The software consists of 5 key stages for calculating the Total Productivity Index. The flow diagram of the software is seen in Figure 4.

The data used in the software is kept annually in the Excel file (.xls) file. The user selects the file containing the data using the "Upload Data" button. Target values are uploaded to Textbox, and monthly data to Listbox controls.

The user sorts the data using the "Sort by" button. Economic, Social, Process and Technical data are sorted descending, while Environmental data are listed as ascending.

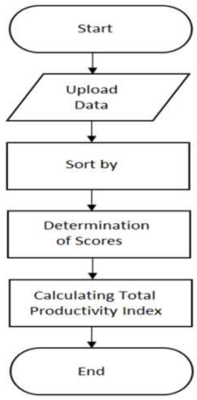


Fig. 4. Flow Diagram of Software

Scores are calculated for each criterion using the "Detect" button. For this, the maximizing method is used for Economic, Social, Process and Technical criteria and minimizing method for the Environmental criterion.

Total Productivity Index calculation is made using the "Calculate" button. For this, the determined score value and the weight value are multiplied, and the value obtained is the value of that criterion. The Total Productivity Index value of that year is obtained by summing the values determined for each criterion.

RESULTS

At the application stage of the method, the sustainable airport performance criteria and sub-criteria obtained from the literature are listed under 5 main headings. These are as follows:

1. Process (C1): Air traffic control performance, Hourly aircraft landing-take-off number, Taking slots at any time, Waiting times in taxi and apron, Delay performance due to airport service, Bridge usage rate.
2. Technical (C2): Technical systems operating performance, IT systems operating performance, Failure response times.

3. Social (C3): turnover rate, absenteeism rate, average training hours per person, employee satisfaction rate, social activities.
4. Environmental (C4): Emission, noise.
5. Economic (C5): Profitability (net income/net expense), Air traffic revenues, Landing-accommodation revenues, Commercial Efficiency (Non-Aviation revenues/Total revenues), Non-aviation passenger income, Advertising space occupancy rate, Commercial space occupancy rate.

The analysis of whether the relationship between the data obtained based on expert opinions and the criteria is causal is presented in the following steps.

Step One: Creating the Direct-Relation Matrix

Criteria for determining airport performance the direct-relation matrix created according to the scores given to measure the effect of each of the 5 criteria on the other is presented in Table 1 in accordance with the information obtained from the experts.

Table 1. Direct-Relation Matrix

	C1	C2	C3	C4	C5
C1	0	2	3	2	4
C2	1	0	3	1	4
C3	1	1	0	1	3
C4	1	3	3	0	3
C5	4	1	1	3	0

Then the rows and columns of each criterion of the direct-relation matrix obtained in Table 1 are summed. The C5 criterion (s value: 14), where the sum of the criteria in the rows and columns is the highest, is determined as the s value for use in the method.

Step Two: Normalized Direct-Relation Matrix (M)

Table 2. Normalized Direct-Relation Matrix

	C1	C2	C3	C4	C5
C1	0	0.142857	0.214286	0.142857	0.285714
C2	0.071429	0	0.214286	0.071429	0.285714
C3	0.071429	0.071429	0	0.071429	0.214286
C4	0.071429	0.214286	0.214286	0	0.214286
C5	0.285714	0.071429	0.071429	0.214286	0

The normalized direct-relation matrix is obtained by dividing the intersection of each row and column in the direct-relation matrix to the “s value” to clear the numbers in Table 2 from residual values and to perform calculations on a unit basis.

Step Three: Creating the Total Relation Matrix (S)

Table 3. Creating the Total Relation Matrix

	C1	C2	C3	C4	C5
C1	0.268327	0.341442	0.471523	0.376768	0.641711
C2	0.295092	0.171596	0.414148	0.276955	0.567147
C3	0.233015	0.194015	0.168751	0.220568	0.41972
C4	0.30343	0.376096	0.446471	0.220238	0.551302
C5	0.465122	0.275691	0.343457	0.404665	0.371973

The normalized-relation matrix (M) in Table 2 is subtracted from the unit (I) matrix to obtain the total relation matrix. Then the reciprocal of the resulting matrix is taken. The resulting new matrix is multiplied by the normalized-relation matrix to obtain the total relation matrix.

Step Four: Determining the Sender and Receiver Group

Table 4. Determining the Sender and Receiver Groups

	D+R	D-R
C1	3.664756	0.534785
C2	3.083779	0.366099
C3	3.08042	-0.60828
C4	3.396731	0.398343
C5	4.41276	-0.69095

As a result of taking the sum and difference of the D and R lines in Table 3, the values of (D+R) and (D-R) in Table 4 above are obtained. These values reveal the effect of the criteria on other criteria or the existence of a relationship between the criteria.

Step Five: Obtaining the Effect-Oriented Graph Diagram

From the D+R values showing the relationship between the criteria, it is seen that the Economic (C5), Process (C1), and Environment (C4) criteria are in more relation with the other criteria, respectively. It was found out that the Social (C3) and Economic (C5) criteria, which are called as receiving or affected, have lower priority and are more affected by other criteria in comparison with the other criteria. The D-R (positive) values, which are referred to as sender or effectual, have higher effects and a higher priority, were found to affect Process (C1), Environment (C4), and Technical (C2) criteria, respectively, more than other criteria. In Figure 5, an effect-oriented graph diagram showing the interaction between D+R and D-R values in Table 4 was created.

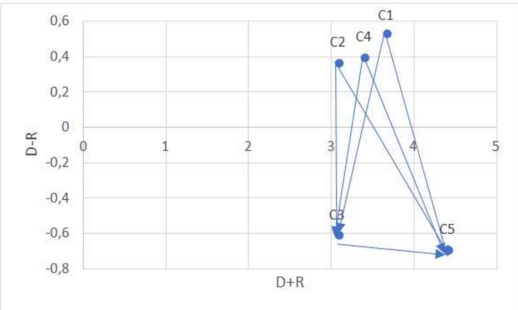


Fig. 5. Effect-Oriented Graph Diagram

Step Six: Determining the Priorities of the Criteria

In this step, the importance weights of the criteria in Table 4 are shown respectively. According to Table 5 below, priority criteria can be given as Economic, Process, Environment, Social, and Technical.

Table 5. Determining the Priorities of the Criteria

Criteria	*w*	Sorting
C1	0.207652	2
C2	0.174116	5
C3	0.176049	4
C4	0.191754	3
C5	0.25043	1

The criteria used in the method were obtained from Güngören's study [2016]. In the implementation of the method, performance scales were created with the lowest and highest levels of performance that can be reached according to performance criteria. The upper and lower scale values that constitute the objectives of the airport enterprise were determined by the business management, and the intermediate values were distributed equally on the scale of 1 - 10 intervals. In this context, performance calculation results for 2018 and 2019 of the subject airport business by objectives are shown in Table 6 and Table 7.

Table 6. Antalya Airport 2018 Sustainable Performance Evaluation

2018	**Economic**	**Environmental**	**Social**	**Process**	**Technical**	**Performance Criteria**
	58,2	20,72	83,81	76,10	99,9925	**Target Performance Figures**
						Performance Scale
Actual Performance Figures	59,14	18,41	99,50	83,62	99,9924	**10**
	57,95	19,13	98,40	82,93	99,9923	**9**
	56,75	19,98	92,80	80,21	99,9922	**8**
	56,48	21,47	89,20	78,57	99,9922	**7**
	56,01	22,18	86,40	76,56	99,9921	**6**
	53,57	23,00	83,50	74,97	99,9921	**5**
	52,94	25,82	79,60	70,34	99,9921	**4**
	50,55	26,63	74,90	67,22	99,9921	**3**
	48,77	26,81	72,10	64,98	99,9920	**2**
	48,52	27,13	71,60	61,24	99,9920	**1**
	47,72	28,08	68,50	54,97	99,9919	**0**
	9	7	5	5	10	**Scores**
	26	19	18	20	17	**Weights**
	234	133	90	100	170	**Value**
					727	**Total Productivity Index**

Table 7. Antalya Airport 2019 Sustainable Performance Evaluation

2019	**Economic**	**Environmental**	**Social**	**Process**	**Technical**	**Performance Criteria**
	60,00	20,00	85	77,50	99,9985	**Target Performance Figures**
						Performance Scale
Actual Performance Figures	59,14	16,90	99,99	86,30	99,9949	**10**
	59,07	17,72	99,10	84,50	99,9949	**9**
	56,75	18,54	97,40	84,40	99,9948	**8**
	56,48	19,36	94,90	82,55	99,9948	**7**
	56,01	20,18	88,20	79,80	99,9948	**6**
	53,57	21,00	83,00	76,77	99,9948	**5**
	52,94	21,82	81,00	76,65	99,9947	**4**
	50,55	22,64	75,60	74,18	99,9947	**3**
	48,77	23,46	74,40	73,75	99,9947	**2**
	48,52	24,28	73,10	72,62	99,9947	**1**
	47,72	25,1	70,20	56,25	99,9943	**0**
	10	6	5	5	10	**Scores**
	26	19	18	20	17	**Weights**
	260	114	90	100	170	**Value**
					734	**Total Productivity Index**

In the method, while finding the equivalent of the actual performance values in the scale, the highest scale level that the actual value can reach is also taken into consideration. For example, the economic criterion for 2018 is 58.2 on average. The objectives set in these criteria were determined in a way to maximize the value (minimize the environmental criterion) at high performance.

In this method, scores were formed according to the levels at which the realized performance values can reach in the performance scale. The scores of the performance criteria formed a performance value in proportion to their weight calculated according to the DEMATEL method, and the total performance index of the airport was obtained with the sum of all these values. As a result of the performance measurement, the 2019 performance index of the airport was calculated as "734" and the 2018 performance index as "727".

CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

Based on the literature and the mass data obtained from the interviews at the Antalya Airport, evaluation criteria for sustainable airport performance were firstly determined in this study. Then, by using the DEMATEL method, an effect-oriented graph diagram was obtained, and the effect levels of the criteria against one another were obtained, and the weights of the relevant criteria were determined and ranked according to their importance levels. The criteria weights determined by the DEMATEL method were used in the OMAX Method to reach the annual performance index of Antalya Airport. In addition to reaching comparable performance values of Antalya Airport on a yearly basis, the software called "Total Productivity Index," which has a user-friendly interface that can be used by all airport authorities in the world, was developed in the evaluation of sustainable performance in this study.

According to the research findings, the "economic" criterion with a weight of 0.250 was the most important criterion, as well as the one most affected by other criteria. Process and environment criteria followed the economic criteria with weights of 0.207 and 0.191, respectively, with regards to the significance but appeared as the two criteria with the power to affect the other criteria the most. Social and technical criteria were relatively low in terms of significance. Considering the difference between them, it is seen that the social criterion is influenced by other criteria, and the technical criterion affects the other criteria. Although the criteria weights determined in practice vary from airport to airport, the sustainable performance criteria obtained from the study and the hierarchical model established were determined to provide an effective, sustainable performance assessment that the aviation sector can utilize.

This study contributes to the literature by showing that the "DEMATEL" method, which is one of the structural modeling techniques, and "OMAX," which is one of the performance evaluation methods, can be integrated into each other and used in the physical performance evaluation of an airport enterprise. On the other hand, the research also provides significant benefits to many practitioners, especially airport businesses. Thanks to this study, airports can make their own self-assessments on sustainable performance, and a "benchmarking tool" can be established between airports and innovation-based practices. The index obtained as a result of the sustainable performance evaluation study can be compared with the index values in the previous period, and the change occurring can be observed by the airport operators. Public organizations and private sector business executives who are stakeholders of airports will look at airport performance management practices through a sustainability window, and this will help them develop a prospective strategy by providing a self-assessment opportunity on which steps and which priorities can be implemented to achieve desired results in the sector. Another sectoral contribution of the research is the development of "Total Productivity Index" software, which has a simple interface in which the analyzes used in this study can be performed quickly. The developed software can be used not only for aviation organizations but also for the purpose of evaluating sustainable performance in operational units of other organizations.

The resulting performance index is a subjective value, as airport performance is evaluated within the framework of the objectives and weights set by the enterprise in the method. If the objectives, criteria, and weights determined in different airport businesses differ, it would be more appropriate to use performance index values in internal evaluations. However, as the current physical structure, financial structure, and/or management of the airport business change or develop, the criteria used in the performance assessment, their weight, or the objectives may change. Despite various subjective effects, index values, in general, are comparable values.

The integrated use of the data obtained in this study with different performance evaluation methods will also be useful for future studies. In addition, it is thought that the evaluation method by objectives will make significant contributions to airport businesses by giving an index value for a given period and ensuring that management sets out its performance objectives clearly.

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REFERENCES

ACI 2018. Airport Carbon Accreditation Annual Report 2017-2018, Airports Council International. Available from Internet: https://www.airportcarbonaccreditation.org/library/annual-reports.html

Akal Z., 2005. İşletmelerde Performans Ölçüm ve Denetimi [Performance Measurement and Control in Enterprises]. Milli Prodüktivite Merkezi Yayınları 473: Ankara.

Aksakal E., Dağdeviren, M., 2010. "ANP ve DEMATEL Yöntemleri ile Personel Seçimi Problemine Bütünleşik Bir Yaklaşım [An integrated approach for personnel selection with DEMATEL and ANP methods]", Gazi Üniv. Müh. Mim. Fak. Dergisi, 25(4), 905-913. Available from Internet: https://dergipark.org.tr/en/pub/gazimmfd/issue/6686/88614

Andersson Granberg T., Munoz A.O., 2013. Developing key performance indicators for airports. In 3rd ENRI International Workshop on ATM/CNS, February 19, Singapore. Available from Internet: http://liu.diva-portal.org/smash/get/diva2:618079/FULLTEXT01.pdf

Balkan D., 2011. Enterprise productivity measurement in services by OMAX (Objective Matrix) method and an application with Turkish emergency service. In Reser Conference, Productivity of Services Next Gen–Beyond Output/Input. Hamburg, 1-13.

Baltazar M.E., Rosa T., Silva J., 2018. Global decision support for airport performance and efficiency assessment. Journal of Air Transport Management, 71, 220-242. http://doi.org/10.1016/j.jairtraman.2018.04.009

Baxter G., Srisaeng P., Wild G., 2018. An Assessment of Airport Sustainability, Part 1—Waste Management at Copenhagen Airport. Resources, 7(1), 21. http://doi.org/10.3390/resources7020032

Bezerra G.C., Gomes C.F., 2018. Performance measurement practices in airports: Multidimensionality and utilization patterns. Journal of Air Transport Management, 70(C), 113-125. http://doi.org/10.1016/j.jairtraman.2018.05.006

Bezerra G.C.L., Gomes C.F., 2016. "Performance measurement in airport settings: a systematic literature review", Benchmarking: An International Journal, 23(4), 1027-50. http://doi.org/10.1108/BIJ-10-2015-0099

Boons F., Van Buuren A., Teisman G., 2010, November. Governance of sustainability at airports: Moving beyond the debate between growth and noise. In Natural resources forum, 34, 4, 303-313. Oxford, UK: Blackwell Publishing Ltd. http://doi.org/10.1111/j.1477-8947.2010.01314.x.

Bourne M., Bourne P., 2011. Handbook of Corporate Performance Management. Chichester, UK: Wiley.

Brisbane Airport Corporation, 2020. Brisbane Airport 2020 Master Plan, Available from Internet: https://www.bne.com.au/corporate/projects/airport-master-plan

Chao C.C., Lirn T.C., Lin H.C., 2017. Indicators and evaluation model for analyzing environmental protection performance of airports. Journal of Air Transport Management, 63, 61-70. http://doi.org/10.1016/j.jairtraman.2017.05.007

Chourasia A.S., Jha K., Dalei N.N., 2020. Development and planning of sustainable airports. Journal of Public Affairs, e2145. http://doi.org/10.1002/pa.2145

Dervitsiotis K., 1995. The objectives matrix as a facilitating framework for quality assessment and improvement in education. Total Quality Management & Business Excellence, 6: 5, 563-570. http://doi.org/10.1080/09544129550035215

ECMA., 2001. C# language specification. Standard-ecma334

Eshtaiwi M., Badi I., Abdulshahed A., Erkan T.E., 2018. Determination of key performance indicators for measuring airport success: A case study in Libya. Journal of Air Transport Management, 68, 28-34. http://doi.org/10.1016/j.jairtraman.2017.12.004

Frankis G., Humphreys I., Fry J., 2002. The benchmarking of airport performance. Journal of Air Transport Management, 8, 239-247. http://doi.org/10.1016/S0969-6997(02)00003-0

Güngören M., 2016. Havaalanlarında Performans ve Kalite Yönetimi [Performance in Airports and Quality Management], in F. Kuyucak Şengür (Ed.), Havaalanı Yönetimi, Anadolu Üniversitesi Yayınları, Eskişehir, Türkiye, 142-167.

Jääskeläinen A., 2009. Identifying a Suitable Approach for Measuring and Managing Public Service Productivity. Electronic Journal of Knowledge Management, 7(4): 447-458. Available from Internet: http://www.ejkm.com/issue/download.html?idArticle=196

Janic M., 2010. Developing an indicator system for monitoring, analyzing, and assessing airport sustainability. European Journal of Transport and Infrastructure Research, 10(3). http://doi.org/10.18757/ejtir.2010.10.3.2889

Koç S., Durmaz V., 2015. Airport corporate sustainability: An analysis of indicators reported in the sustainability practices. Procedia-Social and Behavioral Sciences, 181, 158-170. http://doi.org/10.1016/j.sbspro.2015.04.877

Kucuyak F., 2001. Havaalanlarında performans analizi için bir model önerisi ve Türkiye'deki havalimanlarında uygulanması [A Proposal for a performance analysis model in airports and application to airports in Turkey], Yüksek Lisans Tezi Anadolu Üniversitesi Sosyal Bilimler Enstitüsü, Eskişehir. Available at: https://tez.yok.gov.tr/UlusalTezMerkezi/ (Thesis No: 101570).

Kumar A., Aswin A., Gupta H., 2020. Evaluating green performance of the airports using hybrid BWM and VIKOR methodology. Tourism Management, 76, 103941. http://doi.org/10.1016/j.tourman.2019.06.016.

Lu M.T., Hsu C.C., Liou J.J., Lo H.W., 2018. A hybrid MCDM and sustainability-balanced scorecard model to establish sustainable performance evaluation for international airports. Journal of Air Transport Management, 71, 9-19. http://doi.org/10.1016/j.jairtraman.2018.05.008.

Olfat L., Amiri M., Soufi J.B., Pishdar M., 2016. A dynamic network efficiency measurement of airports performance considering sustainable development concept: A fuzzy dynamic network-DEA approach. Journal of Air Transport Management, 57, 272-290. http://doi.org/10.1016/j.jairtraman.2016.08.007

Rodoplu Şahin D., Haitmurodov U., Turan P., 2019. Industry 4.0; Opportunities, Challenges of Airport And Airline Management Practices. The European Proceedings of Social & Behavioural Sciences EpSBS, 568–577. http://doi.org/10.15405/epsbs.2019.01.02.48

Sameh M.M., Scavuzzi J., 2016. Environmental Sustainability Measures for Airports. Occasional Paper Series: Sustainable International Civil Aviation, 7. Available from Internet: https://mcgill.ca/iasl/files/iasl/vii_sustainability_and_environmental_protection_measures_for_airports_final.pdf

Sameh M., Scavuzzi dos Santos J., 2018. "Environmental Sustainability Measures for Airports" in A. De Mestral, P. Fitzgerald, & M. Ahmad (Eds.), Sustainable Development, International Aviation, and Treaty Implementation (Treaty Implementation for Sustainable Development). Cambridge: Cambridge University Press. 62-80. http://doi.org/10.1017/9781316594216.005

Tsai W.H., Chou W.C., 2009. Selecting management systems for sustainable development in SMEs:A novel hybrid model based on DEMATEL, ANP, and ZOGP, Expert Systems with Applications, 36: 1444–1458. http://doi.org/10.1016/j.eswa.2007.11.058

Tzeng, G.H., Chiang, C.H., Li, C.W., 2007. Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL. Expert systems with Applications, 32(4), 1028-1044. http://doi.org/10.1016/j.eswa.2006.02.004

Upham P., 2001. A comparison of sustainability theory with UK and European airports policy and practice. Journal of environmental management, 63(3), 237-248. http://doi.org/10.1006/jema.2001.0469

Vreedenburg M., 1999, December 13. International Civil Aviation Organization Airport Privatization Seminar for the N.A.M./C.A.R./S.A.M. Regions. I.C.A.O. Available from Internet: https://www.icao.int/Meetings/AMC/MA/1999/aps/05_pp_vreedenburgh_e.pdf

Wan L., Peng Q., Wang J., Tian Y., Xu C., 2020. Evaluation of Airport Sustainability by the Synthetic Evaluation Method: A

Case Study of Guangzhou Baiyun International Airport, China, from 2008 to 2017. Sustainability, 12(8), 3334. http://doi.org/10.3390/su12083334.

Wu W.W., 2008. Choosing knowledge management strategies by using a combined ANP and DEMATEL approach. Expert Systems with Applications, 35(3), 828-835. http://doi.org/10.1016/j.eswa.2007.07.025

Yuan X.M., Low J.M., Tang L.C., 2010. Roles of the airport and logistics services on the economic outcomes of an air cargo supply chain. International journal of production economics, 127(2), 215-225. http://doi.org/10.1016/j.ijpe.2009.08.005

Zaim S., 2002. "Hedeflerle Yönetim, Balanced Scorecard ve Stratejik Kalite Yönetimi [Management by Goals, Balanced Scorecard and Strategic Quality Management]" Akademik Araştırmalar Dergisi, C: III, 12.

ROZWÓJ APLIKACJI SŁUŻĄCYCH DO ANALIZY ZRÓWNOWAŻONEJ DZIAŁALNOŚCI LOTNISKA

STRESZCZENIE. **Wstęp:** We współczesnej, szybko się zmieniającej globalnej gospodarce, lotniska odgrywają ważną rolę w socjalnym, kulturalnym i ekonomicznym rozwoju społeczności oraz w budowaniu nowych mostów pomiędzy różnymi rynkami. Rozwój zrównoważony oznacza zachowanie balansu pomiędzy ekonomicznymi, społecznymi i środowiskowymi procesami oraz postępem we wszystkich tych trzech wymiarach na optymalnym poziomie. Dlatego też pomiar jak i zarządzanie zrównoważonej działalności odgrywa istotną funkcję w kontroli lotnisk. Zachowanie zasada zrównoważonego rozwoju w inwestycjach lotniskowych, będących odpowiedzią na zwiększający się popyt na ich usługi może być realizowany efektywnie w ramach zracjonalizowanej struktury. Struktura ta powinna odpowiadać zasadom rozwoju zrównoważonego, który to będzie odgrywał coraz istotniejszą rolę i zwiększał swoje znaczenie. Celem pracy jest opracowanie oprogramowania oceny rozwoju zrównoważonego lotnisk poprzez analizę działalności zrównoważonej obejmującą wiele zmiennych.
Metody: Do przeprowadzenia analizy działalności zrównoważonej lotniska, istotne jest uwzględnienie ekonomicznych, społecznych oraz środowiskowych czynników, które są trzema podwymiarami rozwoju zrównoważonego we wszystkich strategicznych, taktycznych i operacyjnych procesach i mechanizmach decyzyjnych. W celu przeprowadzenia analizy, zastosowano metody DEMATEL oraz OMAX (Objectives Matrix), umożliwiające uwzględnienie tych wszystkich czynników równocześnie, poprzez zastosowanie wskaźników wagowych.
Wyniki: Najważniejszym czynnikiem dla lotniska Antalya, jak również o największym znaczeniu, jest czynnik ekonomiczny. Współczynniki działalności zrównoważonych dla lotniska Antalya zostały obliczone dla lat 2018 oraz 2019. Działalność lotniska w 2019 była większa aniżeli w 2018.
Wnioski: Największym osiągnięciem tej pracy jest opracowanie "aplikacji oceny działalności zrównoważonej" dla zarówno krajowych jak i międzynarodowych lotnisk. Praca ta przyczynia się również do pogłębienia prac badawczych nad działalnością innych lotnisk oraz porównania ich działania z poprzednimi ich osiągnięciami.

Słowa kluczowe: porty lotnicze, działalność lotniska, rozwój zrównoważony, analizy działalności, aplikacja oceny rozwoju zrównoważonego

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ORIGINAL PAPER

THE IMPACT OF INITIAL DATA ON THE LOGISTICS PERFORMANCE INDEX ESTIMATION: ESTONIAN AND RUSSIAN STUDY

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ABSTRACT. **Background:** Logistics activities form a network of services that support the physical movement of goods, trade across borders, and commerce within borders. Well-functioning logistics, with its international trade and transport organisation, is a precondition of comprehensive national competitiveness. The World Bank (World Bank Group) Logistics Performance Index (LPI) is a unique benchmarking tool, used since 2007, providing logistics performance measurement for more than 160 countries. As the LPI is a crucial part of global efforts to understand better logistics performance in the context of increasingly complex supply chains, this indicator must be evaluated objectively and adequately. The current paper focuses on studying subjective aspects within current methodology with regards the possible impact of initial data on the LPI estimation. The research aims to ensure a more objective approach to global and cross-countries performance measurement by studying possible constraints mentioned above.

Methods: The paper presents a quantitative case study research strategy based on the evaluation of LPI in Estonia and Russia. The principal component analysis (PCA) as the primary method of analysis is a multivariate statistical technique that can help identify correlations between data points of the study. The primary data was collected by questioning representatives directly involved in the logistics sector by standardized questionnaire of the World Bank.

Results: The modified methodological approach for evaluating LPI draws attention to comprehensive generalization concerning the improved outcome of the score and the final position of both countries. As a criticism, the significant impact of the answer of just one uncommon respondent to the final score of the LPI can be pointed out.

Conclusions: Further research related to the issue of objective and more advanced estimation of LPI should be a continuous process with the focus on improving the quality of input data for the assessment. In addition to LPI as a primary measure, parallel use of alternative figure for evaluation of the development of logistics on a global scale.

Key words: performance measurement, logistics performance index (LPI), country-level logistics, principal component analysis (PCA), initial data.

INTRODUCTION

In modern conditions, logistics plays a key, and in some cases - a decisive role in country development [Ермакова, 2020]. Today, logistics in Customs Union countries form 10-12% of GDP (transport sector - 7-8% of GDP) [Курочкин, 2013]. In the European Union (EU) countries, this number is equal to 20-25% [Eurostat, 2019]. The main goal of logistics development is to reduce logistics costs in the final cost of products, as well as to increase the transit potential.

The digitalization of the economy and social sphere is proceeding dynamically; both from a qualitative and quantitative point of

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view [Saliola and Islam, 2020]. The changes brought about by digital transformation in business, and several sectors of the economy make it necessary to assess logistics processes, both at the level of one country and the world as a whole.

For an adequate assessment of the development of logistics, a high-quality methodology is needed that allows one to assess the current state of the logistics industry in the countries of the world [Ермакова, 2020]. In 2007, the World Bank, together with the University of Turku (Finland), for the first time developed a methodology for assessing the level of logistics development in various countries [Arvis et al. 2018]. As a basis for determining the logistics rating, the experts took six most important criteria for assessing the development of logistics in a particular country, based on which the Logistics Performance Index (LPI) was calculated. The components analyzed in the LPI in 2007 were chosen based on theoretical and empirical research and on the practical experience of logistics professionals involved in international freight forwarding: customs, infrastructure, ease of arranging shipments, competence, tracking and tracing, logistics cost, timeliness [Portugal-Perez, Wilson, 2008]. Today, the LPI consists of six indicators such as customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing. Timeliness ranks the countries in terms of their logistics performance and guides countries aiming at improving their logistics performance [World Bank Group, 2015 (a)]. Analysing the LPI scores in detail, countries can determine challenges and opportunities in their logistics supply chain and improve their performance [Işik et al. 2020].

The study of the efficiency of logistics in various countries is carried out every two years. Taking into the account generally accepted methodology of calculation of logistics efficiency, it the impact of initial data on the estimation of LPI has not been so far under the focus. The current paper aims to study this matter based on Estonian and Russian data and conclude if some fundamental changes in the methodology of LPI could be considered.

LITERATURE OVERVIEW

Similarly, to the many-dimensional concept of logistics, it has the multidisciplinary nature in measuring and summarizing logistics performance across countries. Although the global situation in the scope of logistics and transportation has been changing a lot lately, due to the pandemic situation concerning COVID19, it is vital to measure these changes uninterruptedly to ensure comparability of the same indicator compared to previous periods. To study further the LPI from the scope of its methodology, a review of existing literature is executed on this subject.

Firstly, many literature is available to underline the importance of different factors that are vital for logistics performance or economic gains associated with logistics performance, i.e. customs, infrastructure, quality of services, timeliness, tracking and tracing, and ease of arranging shipments [ITF, 2015; Gillen and Waters II, 1996; Vickerman, Spiekermann and Wegener, 1999; Chapman, Soosay and Kandampully, 2003; Hummels 2001; Korinek and Sourdin, 2011; Hausman, Lee and Subramanian, 2012]. Secondly, previous studies focus on correlations between different focus indicators concerning the LPI:

- Studies showing that logistics is positively correlating to international trade through different analytical approaches.
- Studies linking logistical performance fluctuation with global trade volume changes [Beysenbaev, 2018; Gani, 2017], showing a correlation between key logistical indicators and world trade.
- Studies including analysis of product costs and logistics performance, showing that transport costs and distance between countries majorly contribute towards trade friction [Yip, 2012] and increase total landed costs [Hausman, Lee, and Subramanian, 2012], according to their calculations the effect of 1% cheaper shipping leads to 1.4% more trade and a reduction of 1% in total costs can lead to a 0.4% increase in trade.

Concerning hybrid performance evaluation model-based studies, Statistical Variance (SV) and the Multi-Attributive Border

Approximation area Comparison (MABAC) methods have been used to form a decision-making model in evaluating the logistic performance. The results obtained has demonstrated that timeliness and infrastructure are the most and least significant performance criteria, respectively. The fact that the ranking of the SV and MABA hybrid model is the same as the original LPI ranking of the study suggests that the proposed model is consistent [Işik et al. 2020].

In addition to different approaches within LPI model Transport Intelligence (Ti) developed in 2010, the Agility Emerging Market Logistics Index (AEMLI). The AEMLI reflects the degree of attractiveness of the logistics market for foreign investment by assessing emerging markets offer the best logistics opportunities through three lenses:

- a survey of over 500 logistics executives
- an examination of the largest and fastest-growing emerging market air and sea trade lanes
- the methodology examines three key areas for logistics market development: domestic and International logistics opportunities, business fundamentals [Transport Intelligence, 2020].

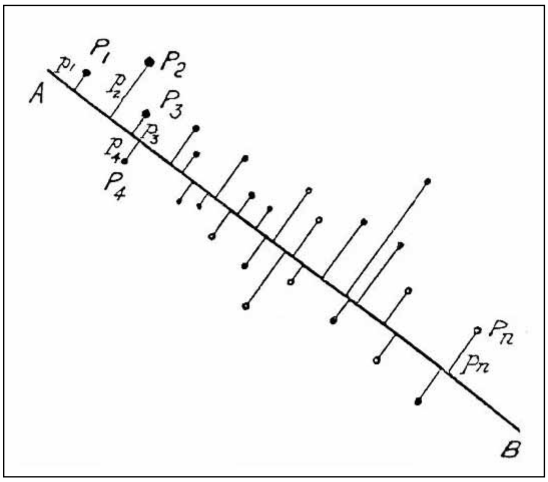
The methodological approach today to LPI is constructed based on a survey with respondents that are experts in the field of international shipping and logistics. For all the countries experts that are not based in that country are asked to give a rating on the six main components of LPI. With regards to proposals for improving the LPI, a modified index has been proposed that qualitatively and quantitatively represents an objective view of countries' logistics systems and subsystems, based on international statistical data [Beysenbaev and Dus, 2020]. The possible constraint of this approach with direct impact on results might be the fact that respondents (the sample) might not give an objective and complete overview of countries due to not having the precise opinion about the local logistics performance. It is therefore vital to examine the impact of the sample on the outcome of the LPI and to summarize logistics performance across countries based on modified methodology.

MATERIALS AND METHODS

In 2010, the World Bank made some changes to the methodology for calculating the index and removed such an assessment criterion as the logistics costs. The fact is that in many countries, there is no statistics on logistics costs, and it is not possible to collect reliable data on this indicator. Besides, the indicator of the competence was transformed and specified into the competence and quality of logistics services. Thus, the number of criteria for assessing the development of logistics was reduced from seven to six final dimensions:

- the efficiency of customs and border management clearance ("Customs");
- the quality of trade and transport infrastructure ("Infrastructure");
- the ease of arranging competitively priced shipments ("Ease of arranging shipments");
- the competence and quality of logistics services - trucking, forwarding, and customs brokerage ("Quality of logistics services");
- the ability to track and trace consignments ("Tracking and tracing");
- the frequency with which shipments reach consignees within scheduled or expected delivery Times ("Timeliness") [World Bank Group, 2015 (a)].

The LPI is constructed from these six indicators using principal component analysis (PCA), a standard statistical technique used to reduce the dimensionality of a dataset [Arvis et al. 2018]. Principal Component Analysis (PCA) by Karl Pearson (invented in 1901) can be used in a wide variety of tasks: when there are many variables, and it is required to present a dataset and visualize it, or to store the maximum information about the data in a minimum number of variables. It is also useful in combating multicollinearity. The key idea of PCA is that it allows reducing the number of variables by choosing the most volatile ones as it is presented below (Figure 1). From the point of view of mathematics, it is just a transition to new variables [Pearson, 1901].



Source: Pearson, 1901

Fig. 1. Illustration of Closest Fit to Systems of Points in Space by Pearson

As an example, there are two-centred variables (mean is equal to zero). So, PCA will provide two new non-correlated variables that represent the original weighted variables. The main requirement is that the sum of the squares of the weights of the principal components equals to one. Since the most volatile variables are selected, the PCA algorithm calculates the weights so that the first principal component will have the maximum sample variance. Then it is possible to build the second principal component. On the one hand, it should be uncorrelated with the first component, and on the other, it should again have the maximum sample variance. And then the weights of each subsequent component can also be found. Further, since the components are selected so that the sample variance of each principal component is maximum, in most cases, it turns out that the first principal component (its sample variance) absorbs a significant part of the total spread of all initial variables (more than 90%). Thus, it turns out that it is possible to replace the initial set of variables with only one new principal component, which contains almost all the information of the original data set. Therefore the key advantages of PCA are the following:

- visualization of a complex dataset;
- determination of the most informative variables;
- determine outliers;
- transition to uncorrelated variables [Karamizadeh et al. 2013].

In the LPI, the inputs for PCA are country scores on questions of a questionnaire, averaged across all respondents providing data on a given overseas market. Scores are normalized by subtracting the sample mean and dividing by the standard deviation before conducting PCA. The output from PCA is a single indicator—the LPI—that is a weighted average of those scores. The weights are chosen to maximize the percentage of variation in the LPI's original six indicators that is accounted for by the summary indicator [Arvis et al. 2018].

The LPI for each country is calculated based on surveys of international, national and regional logistics operators, freight forwarding companies that provide services for organizing the transportation of goods by rail, road, sea, river or air, as well as warehouse operators [Arvis et al. 2018]. This survey consists of two parts. The first part defines the international LPI - respondents rate each of six criteria on a 5-point scale, reflecting the efficiency of the logistics system concerning eight countries with which the company works. The second part of the survey allows to calculate the domestic LPI: respondents assess the logistics system of the country in which they work on a 5-point scale. The result is LPI, which determines the place of the country among other countries of the world participating in the ranking.

The last update of the LPI was made in 2018 for 160 countries altogether. The following report on LPI will be issued on the basis of the year 2020. The position of Russia, according to 2018 rose from 99th to 75th place. The position of Ukraine rose from 80 to 66. The position of Kazakhstan rose from 77 to 71. The position of Finland rose from 15 to 10. Estonia rose from the position 38 to 36.

On the other hand, Lithuania fell from position 29 to 54, Latvia fell from position 43 to 70. The USA fell from position 10 to 14. As a result can be highlighted that higher than Russia according to 2018 results are Philippines, Rwanda, Cote d'Ivoire, Indonesia, India, Iran, Kenya, Egypt. And above Estonia are Chile and Thailand. [World Bank Group, 2015 (b)].

The text of the report opens a table of averaged indices from 2012 to 2018. The authors find it to be an extraordinary practice. After all, the current index is a specific result of activities over the past two years. Averaging intermediate non-material totals is a bizarre practice. Further, non-specified respondents report that in Russia, only 69% of supplies meet the unspecified quality criteria.

On the other hand, in Papua New Guinea, this indicator is already 97% of all supplies. But in Canada, only 57%. In the USA and Great Britain - more than 90%. However, in Ethiopia - again 97%, while in Estonia and Finland - 93%. Accordingly, all the above raises questions concerning respondents giving the valuable input info forming the LPI and the specific criteria that are evaluated.

Many researchers, including Russian, indicate a particular subjectivity of the study of logistics efficiency conducted by the World Bank. The World Bank admits at this point that the developed methodology for assessing the efficiency of logistics is not purely scientific. The World Bank points out in its reports that the LPI is given through the global private sector's view of how countries are interconnected by trade. Therefore, it does not fully reflect the changes taking place at the level of a particular country. Such an assessment complements, rather than replaces, comprehensive studies of the logistics industry: the LPI allows to identify countries with advanced and lagging development of logistics, but a high rating does not necessarily mean equally high indicators of its efficiency throughout the country [Arvis et al. 2018].

It should also be noted that the analysis of the LPI calculation methodology raises certain doubts about the reliability of the research results. First, as stated above, the proposed methodology for assessing the effectiveness of logistics is not scientifically substantiated. The study is based on the results of surveys of mainly international (transnational) logistics companies, and the survey of consumers of logistics services is not conducted. Further, a significant disadvantage of previously conducted studies on assessing the level of logistics in a particular country is the limited calculation of formal indicators, which were mainly associated with the assessment of the level of the information content of one respondent. No attempts were made to evaluate the questionnaire information for accuracy and reliability. Moreover, no attempt was made to find out if the respondents understand the questions correctly.

Based on this, the starting point of the current study is the provision that the respondents being surveyed can and should be considered as important data sources for evaluating logistics processes and their efficiency. To substantiate theses above, the authors conducted their own cross-country field study individually and calculated the LPI according to the World Bank methodology for Estonia and Russia.

The survey for computing LPI for Estonia was conducted in summer 2020, and in winter 2019-2020 it was held in Russia. The World Bank standardized questionnaire is represented as an online form to be filled in by companies operating in the logistics sector or related to the logistics activities (trade, e-commerce, industry, etc.).

An enclosed letter was added to the questionnaire, in which it was briefly described what the LPI means. The questionnaire also contained a remark that if the respondent does not know the exact answer to a question, then the respondent should mark the answer that is considered as closest. To exclude possible extreme impacts of COVID19 on logistics activities of companies in Estonia and for results to be comparable with initial data collected in Russia (winter 2019-2020), the questioning period was planned on economically less critical period. Besides, the respondents we asked to rely on so-called pre-crisis situational with their answers.

In the case of Russia, the data of Refenitiv Eikon was used as the basis for designing the sample, selecting transport and freight transport by road as the main criterion. In the case of Estonia, the data of e-Business Register and the data of Statistics Estonia was used. Next step was to send to selected companies an e-mail asking them to take part in the survey. After sending the questionnaires to the e-mail addresses, some letters came back, as these addresses no longer exist. Several addressees also replied to the note that they were no longer active in the sector. Altogether 47 replies were received for Estonia and 62 for Russia. Questionnaires were sent to respondents 06/15/2020 - 07/31/2020 (Estonia) and 12/12/2019-20/01/2020 (Russia).

After reviewing the answered questionnaires, 23 and 42 responses turned out to be suitable for further use in calculating the LPI for Estonia and Russia, respectively. The tables below (Table 1; Table 2) represent the answers of 23 and 42 respondents, respectively, according to the standards of the World Bank questionnaire for Estonia and Russia. The points are set on a five-point scale.

Table 1. Estonia

No	Position (No 1)	10	11	12	13	14	15
1	Department Manager	5	5	5	3	4	1
2	Operations	4	4	5	4	5	4
3	Department Manager	4	3	3	4	4	4
4	Operations	4	3	3	3	3	3
….	….	….	….	….	….	….	….
15	Owner	5	4	4	4	5	3
16	Supervisor	5	4	3	5	5	2
17	**CEO**	**1**	**1**	**1**	**1**	**2**	**1**
18	Department Manager	5	5	4	4	5	5
….	….	….	….	….	….	….	….
23	Supervisor	4	4	4	4	4	3

Source: own work

Table 2. Russia

No	Position (No 1)	10	11	12	13	14	15
1	Supervisor	3	3	3	3	4	4
2	Operations	3	2	5	3	4	4
3	Department Manager	2	2	3	2	3	4
4	Department Manager	2	2	4	4	3	4
….	….	….	….	….	….	….	….
42	Operations	5	5	3	3	4	5

Source: own work

As it is seen from the table above (Table 1), the answers of respondent no 17 are fundamentally different from all other assessments. Authors of the study assume the respondent misunderstood the assessment scale by evaluating precisely the opposite. This was not observed in the questionnaires for Russia.

Table 3. Estonia

w1*10 - normalized	w2*11 - normalized	w3*12 - normalized	w4*13- normalized	w5*14- normalized	w6*15 - normalized	PC1	Sum
0,2675	0,4231	0,4917	-0,3245	-0,0437	-0,3535	0,4605	0,2121
-0,2058	0,0000	0,4917	0,1145	0,4592	0,2009	1,0605	1,1246
-0,2058	-0,4231	-0,2882	0,1145	-0,0437	0,2009	-0,6454	0,4166
….	….	….	….	….	….	….	….
-1,6256	**-1,2694**	**-1,0681**	**-1,2027**	**-1,0495**	**-0,3535**	**-6,5687**	**43,1481**
….	….	….	….	….	….	….	….
-0,2058	0,0000	0,1017	0,1145	-0,0437	0,0161	-0,0172	0,0003
-	-	-	-	-	-	-	-
-	-	-	-	-	-	**2,3896**	**3,4359**

Source: own work

Table 4. Russia

w1*10 - normalized	w2*11 - normalized	w3*12 - normalized	w4*13- normalized	w5*14- normalized	w6*15 - normalized	PC1	Sum
-0,21130	-0,22462	-0,08045	-0,24961	0,15958	-0,00976	-0,61615	0,37964
-0,21130	-0,80020	0,51927	-0,24961	0,15958	-0,00976	-0,59200	0,35047
-0,69260	-0,80020	-0,08045	-0,93188	-0,38566	-0,00976	-2,90053	8,41309
….	….	….	….	….	….	….	….
0,75129	0,92654	-0,08045	-0,24961	0,15958	0,39020	1,89756	3,60073
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	**2,83688**

Source: own work

The previous tables (Table 3, Table 4) show the results of LPI calculations for two countries. In the case of Russia, the result was relatively close (2.84 versus 2.76), but this is 65th place versus 75 placed in 2018 according to LPI evaluation. For Estonia, the results are much more interesting:

- Option one: 3.44 (versus 3.31) accordingly 30th place, not 36. The countries are different, the respondents are different, the sample sizes are different, but the lag of 6-10 places remains.
- Option two: an alternative calculation for Estonia (taking into account an unusual answer (no 17) and considering the fact that according to the methodology of the World Bank, no answers are rejected [Arvis et al. 2015], gives the total LPI score of 2.39 and places Estonia on 127th place. The difference in ~100 (30th or 127th place) places is resulted due to the impact of the answer of just one "unusual" respondent.

CONCLUSION AND DISCUSSIONS

The study indicated that the respondent's misunderstanding of the rating scale leads to inaccurate and inexplicable results. A natural conclusion from the above example is the recommendation that the methodology should be understandable and focused on obtaining a valid assessment. The respondents must test each block in the questionnaire for the likelihood of errors when filling them out.

As one of the solutions, it is proposed to calculate the LPI of an individual monitored country on a semi-annual basis with a variable set of respondents. Further, the methodology for calculating the index should meet the requirements of completeness, reliability, relevance, and sufficiency of information on the development of digital technologies in individual monitored countries. This will allow in the form of a generalized indicator to compare the logistics indicators occurring in each study region.

For this purpose, it is advisable to develop and regularly evaluate the index by independent institutions from different countries. Besides, it is assumed to conduct a comparative analysis of the results obtained, which will help to compare the level of logistics in a particular country and the index calculated according to the adopted methodology.

In conclusion, authors note that the methodology for assessing the development of logistics, developed by the World Bank, is not the only one. The comprehensive indicator of the AEMLI by the Ti is calculated based on three intermediate indicators: the size and dynamics of market development, market compatibility, and the development of transport communications [Transport Intelligence, 2020]. Improving and monitoring the calculation of the LPI on an ongoing basis will allow investors to objectively track the development of a competitive economy in a particular country and to adjust the work in this region in time.

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REFERENCES

Arvis J.-F., Ojala L., Wiederer C., Shepherd B., Raj A., Dairabayeva K., Kiiski T., 2018. Connecting to Compete 2018 Trade Logistics in the Global Economy. The Logistics Performance Index and Its Indicators. The International Bank for Reconstruction and Development/The World Bank. Available from Internet:: https://openknowledge.worldbank.org/bitstream/handle/10986/29971/LPI2018.pdf.

Arvis J.-F., Saslavsky D., Ojala L., Shepherd B., Bush C., Raj A., 2015. Connecting to Compete 2014 Trade Logistics in the Global Economy. The Logistics Performance Index and Its Indicators. The International Bank for Reconstruction and Development/The World Bank. Available from Internet: https://openknowledge.worldbank.org/bitstream/handle/10986/20399/904190WP0LPI0R00Box385316B00PUBLIC0.pdf?sequence=1&isAllowed=y.

Beysenbaev R., 2018. The importance of country-level logistics efficiency assessment to the development of international trade. British Journal for Social and Economic Research, 3(6), 13–20. http://doi.org/10.22406/bjser-18-3.6.

Beysenbaev R., Dus Y., 2020. Proposals for improving the Logistics Performance Index, The Asian Journal of Shipping and Logistics, 36 (2020), 34-42. http://doi.org/10.1016/j.ajsl.2019.10.001.

Chapman R.L., Soosay C., Kandampally J., 2003. Innovation in logistics services and the new business model: a conceptual framework, International Journal of Physical Distribution & Logistics Management, 33(7), 630-650. http://doi.org/10.1108/09600030310499295

Ермакова Д.А., 2020. Индекс эффективности логистики как показатель уровня развития логистической системы региона [Logistics Performance Index as an Indicator of the Level of Development of The Logistics System in The Region], Global Sceince – 2019. Available from Internet: https://www.xn----7sbzhgab7ageef.xn--p1ai/load/global_sceince_2019/ermakova_d_a_indeks_ehffektivnosti_logistiki_kak_pokazatel_urovnja_razvitija_logisticheskoj_sistemy_regiona/5-1-0-134.

Eurostat 2019. Glossary for Transport Statistics. 5th Edition. Available from Internet: https://ec.europa.eu/eurostat/documents/3859598/10013293/KS-GQ-19-004-EN-N.pdf/b89e58d3-72ca-49e0-a353-b4ea0dc8988f.

Gani A., 2017. The logistics performance effect in international trade. The Asian Journal of Shipping and Logistics, 33(4), 279–288. http://doi.org/10.1016/j.ajsl.2017.12.012

Gillen D.W., Waters II W.G., 1996. Introduction: Transport infrastructure investment and economic development, Logistics and Transportation Review, 32(1).

Hausman W., Lee H., Subramanian U., 2012. The impact of logistics performance on trade. Production and Operations Management, 22, 236–252. http://doi.org/10.1016/j.ajsl.2017.12.012.

Hummels D., 2001. Time as a Trade Barrier. Working paper, West Lafayette, IN.: Purdue University, Department of Economics.

International Transport Forum, 2015. Drivers of Logistics Performance: A Case Study of Turkey, corporate partnership report, OECD Publishing.

Işik Ö., Aydin Y., Koşarolu S., 2020. The Assessment of The Logistics Performance Index of CEE Countries With The New Combination of SV and MABAC Methods. LogForum. 16 (4), 549-559. http://doi.org/10.17270/J.LOG.2020.504.

Karamizadeh S., Abdullah S.M., Manaf A.A., Zamani M., Hooma A., 2013. An Overview of Principal Component Analysis. Journal of Signal and Information Processing, 2013, 4, 173-175, http://doi.org/10.4236/jsip.2013.43B031.

Korinek J., Sourdin P., 2011. To What Extent Are High-Quality Logistics Services Trade Facilitating, OECD Trade Policy Working Papers, No. 108, Paris: OECD Publishing.

Курочкин Д.В., 2013. Оценка эффективности логистики по методологии всемирного банка и ее корректность [Evaluation of The Effectiveness of Logistics and its Correctness According to the World Bank Methodology]. Логистика и управление цепями поставок, 2 (55).

Pearson K.F.R.S., 1901. LIII. On lines and planes of closest fit to systems of points in space, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 2:11, 559-572, http://doi.org/10.1080/14786440109462720

Portugal-Perez A., Wilson J.S., 2008. Why Trade Facilitation Matters to Africa. Policy Research Working Paper; No. 4719. Washington, DC: World Bank. Available from Internet: https://openknowledge.worldbank.org/handle/10986/6321.

Saliola F., Islam A.M., 2020. How to Harness the Digital Transformation of the Covid Era, Harward Business Review. Available from Internet: https://hbr.org/2020/09/how-to-harness-the-digital-transformation-of-the-covid-era.

Transport Intelligence, 2020. The Agility Emerging Markets Logistics index 2020. Agility Emerging Marketing Logistics. Available from Internet: https://logisticsinsights.agility.com/wp-content/uploads/2020/02/Agility-Emerging-Markets-Logistics-Index-2020.pdf.

Vickerman R., Spiekermann K. Wegener M., 1999. Accessibility and Economic Development in Europe. Regional Studies, 33(1), 1-15. http://doi.org/10.1080/00343409950118878

World Bank Group, 2015(a). International LPI. Available from Internet: https://lpi.worldbank.org/international.

World Bank Group, 2015 (b). Aggregated LPI. Available from Internet: https://lpi.worldbank.org/international/aggregated-ranking.

Yip T.L., 2012. Seaborne trade between developed and developing countries. The Asian Journal of Shipping and Logistics, 28(3), 369–390. http://doi.org/10.1016/j.ajsl.2013.01.005.

WPŁYW DANYCH WEJŚCIOWYCH NA WYCENĘ WSPÓŁCZYNNIKA DZIAŁALNOŚCI LOGISTYCZNEJ (LPI): ESTONIA VS ROSJA

STRESZCZENIE. Wstęp: Działalność logistyczna tworzy sieć usług wspomagającą fizyczne przepływy dóbr materialnych, handel międzynarodowy jak i krajowy. Dobrze funkcjonująca logistyka obejmująca swym działaniem handel zagraniczny i transport, jest warunkiem wstępnym przewagi konkurencyjnej danego kraju. Wskaźnik działalności logistycznej Banku Światowego (LPI) jest unikalnym narzędziem dla benchmarkingu, stosowanym od 2007 do oceny działalności logistycznej ponad 160 krajów. Ponieważ LPI jest krytycznym czynnikiem globalnych dążeń dla lepszego zrozumienia i oceny działalności logistycznej, musi on być wyliczany obiektywnie i precyzyjnie. Praca koncentruje się na zbadania aspektów podmiotowych opierając się na obecnej metodologii przy uwzględnieniu możliwego wpływu danych wejściowych na wycenę LPI. Celem pracy jest umożliwienie bardziej obiektywnego podejścia do oceny działalności na poziomie globalnym i międzynarodowym poprzez dokładną analizę wyżej wymienionych czynników ograniczających tą ocenę.

Metody: W pracy zastosowano strategię ilościowej analizy opartej na wycenie LPI w Estonii i Rosji. Analiza PCA (Principal component analysis), jako podstawowa metoda analizy jest wieloczynnikową techniką statystyczną, która umożliwia identyfikację korelacji pomiędzy różnymi danymi. Dane wejściowe zostały zebrane poprzez przeprowadzenie ankiety, stworzonej według standardów Banku Światowego, wśród osób bezpośrednio związanych z logistyką.

Wyniki: Zmodyfikowane metodologiczne podejście do wyceny LPI kładzie nacisk na uogólnienie wyników, poprawiające wynik końcowy oraz pozycjonowanie obu krajów. Ceną negatywną jest fakt dużego wpływu na wynik końcowy odbiegającego wyniku ankiety jednego z badanych respondentów.

Wnioski: Należałoby przeprowadzić dalsze badania zmierzające do lepszej i bardziej obiektywnej wyceny LPI, które powinny być procesem ciągłym, zorientowanych na poprawie jakości danych wejściowych. Niezależnie od LPI, jako podstawowego wskaźnika, równoległe wskazane jest używanie alternatywnego wskaźnika dla oceny rozwoju logistycznej w skali globalnej.

Słowa kluczowe: ocena działania, wskaźnik działalności logistycznej (LPI), logistyka na poziomie krajowym, analiza PCA, dane wejściowe

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ORIGINAL PAPER

ASSESSING SUPPLY NETWORK COMPLEXITY IN MARITIME INDUSTRY IN MALAYSIA: INTER-FIRMS' RELATIONS DRIVES PATTERN OF SUPPLY NETWORK STRUCTURE

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ABSTRACT. **Background:** Complexity has been an interesting research area for academics and businesses practices due to its relevance in determining the best practices and impacts to the supply network. The contribution of this research extend to the literature and put forward solutions for the industry since previous studies are neglecting whole network relations, which is highlighted as source of supply network complexity (SNC). Specifically, this research extends to enriching the literature and recommending solutions to the industry players since previous studies are neglecting important Inter Firm Relation (IFR) elements, formal inter-firm relation (FIFR) and informal inter-firm relations (IIFR), which are highlighted as a pertinent factor in this research. In this study, the Social Network Analysis (SNA) method was adopted to develop valid attribute for the measurement process and the embeddedness theory was used to evaluate the interrelationships among the proposed attributes. This study found that FIFR and IIFR have different effects towards the formation of SNS and consequently towards SNC. Finally, theoretical and industrial implications are also discussed.

Methods: Traditional statistical tools focus on attributes of phenomenon as determinants for occurrence of economic payoff. Thus, traditional statistical analysis is not suitable to measure the impact of relations or connections among member of network contributing to network complexity. For the purpose of this research, the Social Network Analysis methodology was adopted to collect, analyse and interpret network data. Network survey was conducted to collect relational data among members of maritime industry supply network. Network data was analysed and interpreted using specialized social network program i.e. UCINET and NETDRAW. Statistical network measures such as centralization and density was applied to determine the relations between network complexity and network relations.

Results: The findings of this study indicate that Inter Firm Relation (IFR), formal inter-firm relation (FIFR) and informal inter-firm relations (IIFR), which are highlighted as a pertinent factor in this research, have different effects towards the formation of SNS and consequently towards SNC.

Conclusion: The results of the statistical network analysis indicate that, network complexity exist in different forms and structure, depending on the type of relations that formed the network in the first place. Consequently, what these mean are, managing network requires different types of resource and strategy as the level of the network complexity are different at different states of connectivity.

Key words: network analysis, information sharing, supply network, complexity.

INTRODUCTION

Supply network complexity (SNC) has been a major concern worldwide [Nair, Blome, Choi, Lee, 2018]. It is the complexity that naturally arises from the fragmented, yet extensive inter-firm relationships (IFR) existing between firms in the supply network.

However, the complexity of the supply network structure (SNS) is increasingly becoming more difficult to understand due to the unique type of IFR that the firms are embedded in [Nair, Blome, Choi, Lee, 2018].

Furthermore, not all firms in the SNS are engage in relational-based behavior [Ceyhan,

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Dogan, Yildiz, Barca, 2018]. Evidently, numerous decisions and actions in an SNS were performed based on attributes of firms' analysis compared to degree of IFR [Mohd Adnan, Valliappan, 2019]. This is due to the facts that attributes are more visible and easily evaluated compare to IFR. Inter-firms' relation were argued to be more tacit and subtle in nature. Attributes of firms in the SNS can exist between firms because of limit, culture, geological area and long stretches of activity and size and physical elements.

As much as firms' attributes are responsible for producing prudent and effective decisions making, it is also detrimental for firms to elucidate another important element responsible for economic payoff i.e. IFR. [Chakkol, Finne, Raja, Johnson, 2018; Osman, 2018]. In previous studies, SNC is addressed as related to attributes of organizations that make the level of separation among organizations [Turner, Aitken, Bozarth, 2018]. The contention is that, as the quantity of firms inside the supply network (SN) builds, this thusly expands the administrative and operational necessities expected to deal with the distinctive attributes with different firms crosswise over numerous limits.

However, attributes are not the only reasons organizations are embedded in network. Aside from attributes of firms, the SNC also the results of degree of IFR within the supply network [Chakkol, Selviaridis, Finne, 2018]. Literature in the area of operation and supply chain management tended to IFR as ties among the firms from the system structure. IFR inside the SN may be inside the setting of trades or information trades, for example, showcase data or money related streams. What makes IFR more difficult to manage is the fact that IFR may exist in SNS as part of the formal network connections such as contractual obligations or informal network connections such as information sharing, but the knowledge of the existence only relevant to the connected few. Thus, supply network management requires an improved proposition when dealing with SNC. Therefore, there is a need to assess the IFR to improve understanding of SNC.

Because of the complexity of looking as IFR, only a few researches relate the subject of SNC with IFR as driving factors. Therefore, this research proposes elucidating IFR as one of the element to enhance management of SNC [Chakkol, Selviaridis, Finne, 2018].

The objective of this study is to assess the network relations that are related to IFR of maritime industry SNS in Malaysia. In recent years very few studies research into this topic in the Malaysia's market; for example, [Lyon, 2018] described the SNC as being hour glass shaped, with many different stakeholders at the supply and demand ends and a small number of trading companies in the middle. Most members of the SNS saw the numerous and various partners of the SN as representing a significant obstruction to the usage of duties by clouding recognisability and ruining commitment with clients or providers. Meanwhile this research analyses SNC not from the attribute context of the SNS components but from the IFR context. The perspectives used in order to achieve this objective of the study are that of buyer-supplier organizations

This article is composed as pursues. Literature review section developed the framework of this study within the context of SNS and SNC alongside its network relatedness. This is followed by the research methodology sections that discuss the social network methodology and examination of network information relevant for this study. This is followed by the discussion of the outcomes and figures identified with the relations. Finally, the researcher discusses the study contribution both to theory and practice, research impacts and constraints.

LITERATURE REVIEW

To give better understanding dependent on a theoretical point, this segments surveys pertinent literature tending to SNC. The proposed techniques and measures are additionally surveyed.

Supply Network Complexity (SNC)

The definition of SNC is the multifaceted nature that emerges from the connectivity among the embedded components in the SNS towards accomplishing accord objectives. SNC has a wide perspective in understanding it [Hartman, 2016; Osman, 2017].

These portrayals of multifaceted nature would legitimize the contention that the SNS is likewise complex and the IFR speaks to the interconnectivity between the components in the system. These descriptions of complexity would justify the argument that the SNS is also complex and the IFR represents the interconnectivity between the elements in the network.

Chakkol, Finne, et al. [2018] allude to complexity in the network as how much network members interrelate. IFR between firms in the SN could be as physical merchandise trades or data trades advertise information or monetary streams [Hartman, 2016; Osman, 2017].

With regards to the SNS especially, Chakkol, Selviaridis, et al. [2018] and Chakkol, Finne, et al. [2018] have expressed that the SNS have been encountering expanded multifaceted nature through broad IFR. For instance, in the SNS of vehicle producers, a provider may supply parts to a maker, while this maker may simultaneously supply different parts to a similar provider organization. One charming actuality is that a considerable lot of these working relations among providers in the SNS frequently exist past the learning of the central firm.

A firm in the SNS may respect the IFR if the data traded advances better coordination of the SNS [Hamari, Sjöklint, Ukkonen, 2016]. Notwithstanding, it might be unwelcome if the IFR adds to spillage of data in the SN. Thus, an association's observations with respect to a decent accomplice may change unexpectedly. In this manner, IFR among firms in the stockpile system is a significant part of the SNC. The IFR in the SNS (regardless of whether the organizations contend or collaborate with each other) has been found to essentially affect upon the monetary exhibition of the central firm or producer [Kim, Yoon, Zo, 2015].

A firm in the SNS may respect the IFR if the data traded advances better coordination of the SNS [Hamari, Sjöklint, Ukkonen, 2016]. Notwithstanding, it might be unwelcome if the IFR adds to spillage of data in the SN. Thus, an association's observations with respect to a decent accomplice may change unexpectedly. In this manner, IFR among firms in the SNS is a significant part of the SNC. The IFR in the SNS (regardless of whether the organizations contend or collaborate with each other) has been found to essentially affect upon the economic performance of the firm [Kim, Yoon, Zo, 2015].

Another stream of research shows that the development of a SNS makes an increasingly complex structure emerging from the IFR [Kim, Chen, Linderman, 2015]. What makes the SNS increasingly complex is that, until now, current examinations have just been concentrating on the formal materials stream sort of IFR among the organizations in the SNS. In any case, actually, there are different types of IFR which added to the general multifaceted nature in the SNS. This is on the grounds that, as shown by the embeddedness hypothesis and the investigations of researchers such Y. Kim et al. [2015], the conventional business exchanges in the SNS are inserted in a web of informal social exchanges [Chakkol, Finne, et al., 2018].

IFR adds to expanding unpredictability in the SNS, adding to the precursors of the SN. Kim, Chen, and Linderman [2015] have inferred that the IFR is one of the drivers of complexity in the SNS and more profound comprehension is expected to beat the complexity nature coming about because of these IFR. All the more explicitly, the diverse IFR between them makes the degree of complexity which demands effective administration techniques from supervisors. These various causes of complexity demand a reasonable clarification of the SNS for compelling and proficient administration of the SN.

In this way, understanding SNC means understanding the relations among players in the SNS. This research considers SNC as connections which are clarified through how the IFR emerges among firms in the SNS. With that in mind, there are featured IFR that are commonly in the literature that exist among the embedded organizations, for example, formal between firm relations (FIFR) and informal between firm connection (IFFR). Hence, this examination proposes to improve literature on SNC by analysing these IFR to pattern and its relation to level of SNC.

The propose method

There are various complexes IFR with regards to SNS, related to the effort of dealing with the SNC. For instance, Ibrahim, Elias, Saad, and Ramayah [2008] examined the attributes of SN on the effect on procedure advancement in a firm. Kirchoff, Tate, and Mollenkopf [2016] built up the material administration manages in a SNS. The customary reductionist contentions express that organizations may decide on the removal of accomplices who are not meeting the prerequisites of the network participation, specifically when trying to deal with the unpredictability emerging from broad IFR [Miemczyk, Howard, Johnsen, 2016]. Subsequently, this investigation means to survey the IFR that is identified with SNS of a maritime industry by utilizes Social Network Analysis (SNA) procedure to analyze the interrelationship among IFR and SNS, and to delineate causal sociogram to the proposed IFR.

Since the focal point of this research isn't just focused on attributes of firms yet additionally on the relations between firms, this investigation adopted the social network analysis (SNA) methodology by which to get legitimate outcomes for this research. SNA centers around the connections or ties between network members not simply the traits of the network members [Wasserman, Faust, 1994]. As per SNA researchers; a network is comprised of actors which could be people or firms which are interconnected to one another through various sort of social connections [Hanneman, Riddle, 2005]. The collaborations can be as hard ties or delicate ties [Borgatti, Li 2010]. The target of SNA isn't to decide the traits of the actors that effect upon the system, but instead on how the interconnectivity between the network actors' characters' impacts execution [Chakkol, Finne, et al., 2018; Kim, Chen, Linderman, 2015]. Subsequently, SNA enables the research to investigate how firm embeddedness in the SNA would impact the firms' social performance.

Particularly, embeddednesss theory [Granovetter, 1985] is used to conceptualize firms qualitative judgments to the equivocation in uncertainty, while SNA method is to develop and analyze the causal relationship structure of network relations to the structure of the network.

One of the challenges in network research is that of deciding the for the network boundary. An exact boundary will enable accurate determination of target population, just as allowing a compelling depiction of the populace under investigation. An off base boundary determination methodology may deliver wrong network estimations. The challenges related with defining up the correct boundary details in network requests cautious treatment of a specific methodology picked by the researcher. To defeat the deficiencies this investigation at first utilized the nominalist technique and after that enhanced the network with a pragmatist procedure [Diani, 2002].

The proposed measures

There has been an expanding literature on SNC in the previous decades. Numerous variables of SNC have likewise been looked into and examined. In spite of the measure of earlier research and the components considered, there is still new a requirement for new investigations to satisfy the total cognizance of SNC. Increasingly exhaustive investigations are as yet should have been performed with the goal that the consciousness of SNC can be elevated both in the scholarly world and industry. In this investigation the analyst features two components to help the research fundamental measurement. Moreover, the embeddedness theory contends that these connections or IFR can be as formal business exchanges exercises, for example, legally binding relations or a trap of casual social trades, including data sharing and referral exercises [Papadonikolaki, Verbraeck, Wamelink, 2017]. These kinds of IFR can be either integral or substitutes of the other. Thus, an increasingly exact understanding of the SNC is required. Consequently, the measurement embraced for this investigation is to be Inter-Firm Relation (IFR). While the components are Formal Inter-Firm Relation for example legally binds relations (FIFR) and Informal Inter-Firm Relations for example data sharing relations (IFFR).

Fundamentally, SN is for all intents and purposes shaped by the network or connections between firms where the combination logically frames a definitive structure, which is simply the SNS. The relationship is additionally referred to in the literature as the IFR [Chakkol, Finne, et al., 2018; Chakkol, Selviaridis, et al., 2018]. An IFR speaks to a dyad, or two hubs and one connection, in network terms. Every hub can be conceptualized as an actor performing activities to produce value. The firm needs assets from its provider firm, and the provider needs agreements and instalments from the purchaser. Agreements make the SN's Formal Inter-Firm Relation (FIFR) [Chakkol, Finne, et al., 2018]. FIFR directly affects the SNC through ties availability. By formal authoritative relations, the central firms authorize formal relations through legally binding terms (FIFR) and guidelines upon other network members. Over that the FIFR, firms interface to share data with respect to advertise openings and new dangers [Cousins et al. 2006]. As an outcome, these create a connection and structure a dyad or the IFR. Since a firm frequently has connections to different firms, the firm brings to the dyad new by implication associated firms. So also with the provider firm, this will likewise carry to the dyad their connections with different firms either legitimately or in an indirectly way [Choi and Kim 2008]. Indisputably, a FIFR is a dyad; it is additionally part of a network.

Within an SN, the IFR may also take the form of informal information sharing ties (IIFR) [Carter, Ellram, Tate 2007; Galaskiewicz 2011a; Kim et al. 2010; Mueller, Buergelt, Seidel-Lass 2007]. Slack, Chamber and Johnston [1995] identified these ties base on five types of organizing relationships which include short term trade; semi and long term trade; coordinated-profit sharing; long term alliance; and joint venture. According to the authors, short–term trade refers to a formal single transaction after which the relationship ends. Semi and long-term trade agreements refer to the trade agreements without formal contracts that legally bind the firms. Most importantly, it also involves informal forms of relations (IFFR) such as other commercial transactions including information-sharing (IFFR) and referral activities, which create a significant competitive advantage to the firms embedded in such relationship structures.

SNC is a complex concept that can be explained with many dimensions. Prior studies have tried to explain the SNC and propose solutions through merely attribute dimensions. This study uses a different set of dimension and elements that can best answer the research objective.

METHODOLOGY

This section provides an overview of the industrial background and comprehensively presents the Social Network Analysis method.

Industrial Background

An interrelated firms working together in a SN of a maritime industry framed the number of population in this research. The focal firm in this study is the APMMHQ-1 (nom de plume for the motivations behind secrecy). The APMMHQ-1 is an assembling organization in the Malaysian shipbuilding industry engaged with ship fixes, sea works and building. Until this point, the organization has granted agreements to nearby merchants and providers totalling RM31 million for the improvement of little vessels in the locale.

A network of firms operating in a supply network of a small maritime industry company formed the population of this study, i.e. the APMMHQ-1 (pseudonym rounded for the purposes of anonymity). The APMMHQ-1 is a manufacturing company in the Malaysian shipbuilding industry involved in ship repairs, maritime works and engineering. To date, the company has awarded contracts to local vendors and suppliers totalling RM31 million for the development of small vessels in the region.

As a maritime nation, Malaysia potential to be a maritime industry hub is vast. However, despite the supports and encouragements from the government, the industry still operates in limited scopes of productions. It has been argued that, such phenomenon happened because managing the complexity of the supply network has been a difficult task for managers. Currently, at different stages of the transformations process of the APMMHQ1, values are added to the processes. Thus, in its essence, this concept models the supply network as a linear series of value adding stages that transfer raw materials and services to the focal firm. They are then ultimately distributed to the downstream customers through the distribution agents and retailers. Consequently, the overarching linear model of the supply network has been adopted by many managers in the maritime industry in Malaysia.

Researchers placed that the linear perspective on the interconnected firm, one which is contended to be lacking, dismisses the normal manners by which IFR in the SNS are shaped and advanced [Hedvall, Jagstedt, Dubois, 2019]. In this manner, it is contended that the SN now contains a blend of progressively formal and informal IFR, along these lines making a substantially more perplexing network structure [Hedvall et al., 2019]. This unavoidably makes a perplexing structure of connections between the elements in the SNS. It likewise demonstrates that the SN has turned into a progressively complex network due to the exercises and trades that have expanded throughout the years.

The players of the industry did not acknowledge or value the relations with other supply network members. The focus of the industry has been driven towards obtaining fast contracts and maintenance works. Little has been invested into maintaining network relations both domestics and abroad. In the context of the IFR, it can be seen that related parties in the network of relationships encounter conflicts through goal incongruences and suspicions of assets abuse. Consequently, the researcher addressed the issue of IFR in the SNS by investigating the pattern of firm embeddedness through its network structural positions in the two types of IFR.

Social Network Analysis Method

Examination of the ramifications of these structures upon the embedded firms requires a technique that can break down the attributes of the actors, yet in addition the relations between the organizations that structure the structures. Wasserman and Faust [1994] contended that the standard statistical technique and investigation isn't proficient at estimating relations. One significant actuality behind this contention is that standard statistical investigations repudiate the presence of connections between firms in a network through the suspicion of freedom of perception. Be that as it may, the network approach, all the more explicitly the Social Network Analysis (SNA), centres around the relations among firms and the example of the relations and the ramifications of the connections. Organizing of network of relations has significant ramifications for actors of the different network. These structures include the example of ties. A network researcher would try to show these connections to delineate the structure of a gathering. One could then examine the effect of these structures on the working of the network or the impact of these structures on actors inserted inside these network structures. Exploratory network analysis was applied to investigate examples of collaborations among firms which used to decipher the general example of embeddedness of firms in the APMMHQ-1 SNS. This examination was performed utilizing social network software, for example UCINET, NetDraw, Mage and, Pajek [Borgatti, Everett, Freeman, 2002]. Following are the explanatory steps of SNA for this investigation.

Data Analysis

Step 1: Determine study population

The initial step of SNA is to decide the number of population to be studied. There are two inspecting units in this examination, specifically: the organizations that possess the APMMHQ-1 SNA for the item RHIB and the ties or connection between them. In network study, the strategy used to test relations is a piece of the study instrument. In this investigation the analyst applied the pragmatist and nominalist approach so as to decide the suitable study sample.

Step 2: Network data collection

Leading network researchers such Borgatti and Li [2009] declared the power of surveys to get network information on inter-firm relations such as: data transfer, resource transfer and joint activities. A survey is appropriate for this sort of study as a result of it permits the scientist to research the participants' subjective perceptions of interactions [Diani 2002].

The survey form consisted of closed-ended queries and open-ended questions. It begins by asking general queries and is followed by additional specific and inquiring questions. The network survey form was adopted from many network queries of previous network studies on IFR [Borgatti, Li, 2009; Borgatti, Jones, Everett, 1998; Cousins, Handfield, Lawson, Petersen, 2006; Krause, Handfield, Tyler, 2007].

One class of queries investigates the network ties between the corporations within the APMMHQ-1 network. During this section, the survey shows a table with the names of all the corporations listed within the initial column of the table. Supported this, the respondents were asked to point by a check on the table the list of corporations that they need been in communication with for every style of relationship listed within the last sixth months. These styles of ties are necessary so as to grasp each formal and informal relationship among. The kinds of ties investigated were, specifically: contracts, and information-sharing. The written agreement tie queries show however formally coupled one firm is with another within the upstream offer network. The survey instrument asked the key informants to point on the list the list of corporations with that they need formal service contracts concerning the provision of materials for the merchandise RHIB. The corporations may be in tier 2 provision materials to the tier one provider, successively provides the focal firm (i.e. APMMHQ-1) with the materials necessary for the assembly of RHIB [Provan, Kenis, 2008].

The information-sharing ties illustrate the norm of collaboration and cooperation between the organisation/unit that's declared in formal links or ties. Network information on information-sharing ties reveals collaboration in a network. Information-sharing was assessed within the network survey by asking key informants to point on the rosters that of the corporations listed below may need AN exchange of knowledge to accomplish their work.

Step 3: Degree of connectivity index

This study can analyse the degree of SNC obtained in two indexes. First, we'll offer the index score of network density. Density is outlined because the variety of connections a participant has, divided by the overall potential connections a participant might have. As an example, if there are twenty folks collaborating, every person might doubtless hook up with nineteen people. A density of 100 percent (19/19) is that the greatest density within the system. A density of fifty indicates there's just one of nineteen potential connections among the SNS.

Step 4: Pattern of connection index

The second index is that the centrality index. Centrality focuses on the behaviour of participants in network. It measures the extent to that network members interacts with others within the network. The additional a personal connects to others in an exceedingly network, the larger their centrality within the network. The measures also are associate degree indicator of patterns of interactions between actors reckoning on the sort of relationships.

They're applied to holistically describe interaction pattern in network with the various kind of relationship.

Step 5: Mapping the causal IFR diagram

Network measures will form a first half of the data analysis using the UCINET. A second analysis technique captures the other half of the study question. These structural measures are not exhaustive. However, they have been used rather extensively in social network analysis research which involves inter-individual studies. In the second analysis, we present the network plots of the different relationships focusing on both buyer-supplier firms. This analysis is done using NetDraw and Mage. The generated network plots will fully capture the research question as it will graphically indicate the extent of embeddedness of buyer-suppliers firms in the network base on the different type of relationships.

RESULTS AND DISCUSSION

This study collects SNC attributes from the literature to propose for the industrial solutions and theoretical contributions. A group of 37 managers representing the respective firms in a maritime industry supply network were approached. These firms were requested to confirm their ties or relations in evaluating the importance attributes that necessary for the SNC. The analysis result is presented in this section.

Density index score for proposed measured IFR

Density score is the ratio of the actual number of ties in the network (n) to the number of potential ties (2L/g*(g-1), where L and g are the number of ties present in the network and the number of actors (represented by nodes) in the network respectively [Hanneman, Riddle, 2005]. Density scores are presented on a score of 0 or 1. A higher density score indicates a greater degree of interaction among the members in the particular buyer supplier relationship. In Table 1, the first column represents the density scores of the ties or linkages. Because each tie in this study generated its own matrices, the density scores in Table 1 is the density score for each of the contractual ties and information sharing ties. Based on Table 1, we could see that among the IFR density, the information sharing ties (IIFR) has the highest density score of 0.2965. It is followed by contractual ties (FIFR) density with 0.1660. The density scores illustrate that there are more information sharing ties SNS than there is contractual tie linkages between the member firms.

Table 1. SNS Density Index Score

Type of Linkages	Density	IFR Continuum
Contractual	0.1660	FIFR
Information Sharing	0.2965	IIFR

This finding is consistent with findings from studies in other field of inter-firmal studies [Cousins, Handfield, Lawson, Petersen, 2006; Oh, Chung, Labianca, 2004]. It is argued that less formal interactions took place rather frequently among firms and information gathered from the informal ties is more fluent than informal ties. Furthermore, the norm to collaborate among firms minimizes the requirements for formal ties because informal collaboration reciprocity is the yardstick rather than exclusion. Hence firms more often than not involve themselves with informal ties or activities with multiple types of firms than in formal administrative activities based on contracts or transmittal of funds.

Centralization index score for proposed measured IFR

Centralization measures the extent to which a network is around one of few actors. The centralization score is between 0 and 1 with higher values indicating that there is a high degree of centralization in the network around a central actor or actors. Table 2 documented the centralization score of the linkage matrices. In Table 2, the centralization index of contractual ties is 0.31428. The centralization score for information sharing is 0.4724. This score suggests that FIFR such as contract ties are less centralized. It is common in a centrally managed system such as the SNS to have the focal firms to closely monitor the activities within which the network makes up.

Table 1. SNS Centralization Score

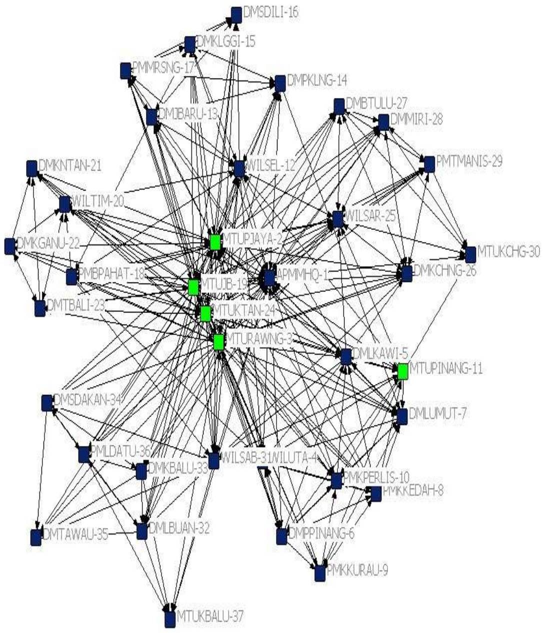
IFR	Network Centralization	IFR Continuum
Contractual	0.3142	FIFR
Information Sharing	0.4724	IIFR

The information sharing matrix linkages centralization score is 0.4724. Although previous studies have found that in other contexts, such as health care firms, the information sharing centralization index displays a very low score, we found that in the context of the SNS the centralization index remains high. This could be due to the fact that, in SNS, the focal firms dictate the flow of resources within the network. Because of that, other firms seek information directly or indirectly from the focal firms in the form of orders and supply on a constant basis. These make the focal firms the centre of information sources and provide the focal firms with a powerful positional advantage.

Description of Network Plot

Network structural measures such as the centralization and density scores are primarily concerned with the pattern of the whole network interaction [Burton, 2010]. They indicate the cohesiveness of the network structure. It is an indication of how connected actors in a network are depending on the type of relationship being considered. In the case of the SNS understanding the pattern of connectivity based on the different types IFR is key to managing the SNC [Choi, Kim, 2008]. Although the network structural measure illustrates the whole network connectivity pattern, it lacks the ability to indicate the dominant type of players in a network. Through our review of the literature, such illustration can be accomplished through either an ego network study, whereby an analysis of each of actor in the network would have to be undertaken or through network plots of the different type of IFR. Because this study population is high, we opted for the latter.

Figure 2 displays the network plot for the information sharing relationship network.

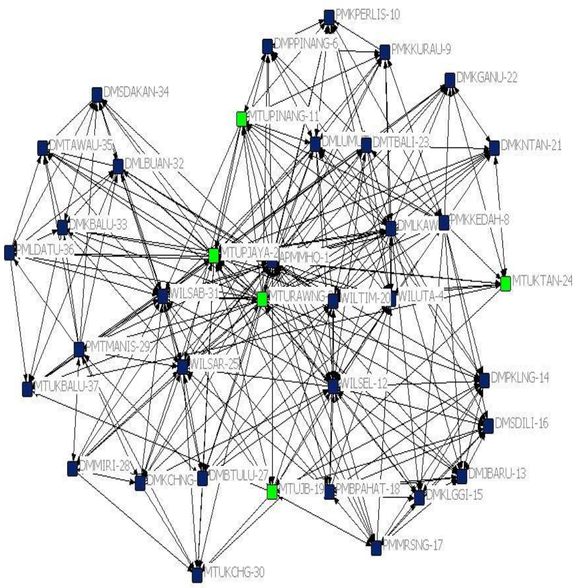


N=37, Suppliers, Buyers

Fig. 1. Network Plot for Contractual Buyer Supplier Relationship

Network structural plots give an interesting approach in describing the structure and the embeddedness of the firms. It shows the extent of connectedness of an actor to other actors in the network through the number of lines. An actor that is more connected to another actor would have more lines connecting it to other actors. Hence, the high number of lines would place the actor in a central position in a network. The Ucinet software external to the whole network structural plot would locate an isolate or actor without any ties to other actors. However, in this preliminary report, we adhered to Kilduff and Tsai [2003] who stated that network plots are only useful to the degree that they complement and assist in answering theoretically motivated questions [Kilduff, Tsai, 2003]. In this study the network plots approach will be used for that purpose. Using NetDraw and Mage, we provide the embeddedness description of firms in a SNS based on the different types of IFR.

In the network plot for the contractual relationship, the network is dominated by the supplier firms, which are coloured in green. Almost all firms have contracts directly with the MTU ISS firms or are indirectly connected through other mediator firms. For example MTURWANG-3 has 33 direct and indirect contractual ties with other member firms in the network. The second most firms with most contractual ties with other firms in the network are the MTUKTAN-24 and MTUJB-19, both with 32 ties. We could see clearly from this network plot that supplier firms are predominantly centrally located in the plot based on the high amount of ties. In this contractual buyer supplier relationship, suppliers are likely to be more involved and more embedded in the central location of the network. The network plot in Figure 1 indicates that in formal buyer supplier relationships, central roles are played by supplier firms. Contractual maintenance activities such as ordering and replenishment activities are actively monitored by supplier firms to ensure a timely supply of materials when needed by the users.



N=37, Suppliers, Buyers

Fig. 2. Network Plot for Information Sharing

Figure 2 is the network plot for the buyer supplier referral relationship network. Based on the diagram, we could see that there are linkages with every firm in the network. This network plot indicates a rather centralized structure of connectivity between member firms in the network.

Furthermore, in this network plot we could also identify that, unlike in a contractual network where the supplier firms are dominant; buyer firms such as APMMHQ-1 have become part of the core firms in the exchange or sharing of information activities. WILTIM-20 and WILSEL-12 have also more information sharing ties with other supplier and buyer firms. Supplier firms such as MTUJB-19 and MTUKTAN-24 have now settled in the periphery of the network structure. The network plot shows that central positions in information sharing buyer supplier networks are dominated more by buyer firms than supplier firms. Hence information sharing buyer supplier relationship of the network is more likely to be dominated by buyer firms than suppliers.

DISCUSSION

This section provides the theoretical insight to contribute to the existing literature and managerial implication for industries.

Theoretical implications

There are two aspects that are prioritized: Formal Inter-Firm Relation (Contract Relations) and Informal Inter-Firm Relation (Information Sharing Relation)

It was evident from the exploratory network analysis of the network maps that firm embeddedness in the SNS was related to the degree of formality of the IFR.

Informal Inter-Firm Relation (Information Sharing) shows to have the strongest effect toward the aspect of IFR and consequently SNC. In prior studies, IIFR plays an important role for obtaining opportunities or new innovations.

This study emphasizes that IIFR should be intensively managed by the firms embedded SNS to tackle SNS because IIFR shows strong effect on SNS and consequently SNC. IIFR approaches through information sharing activities may generate more collaboration and interactions with other members in the SNS. IIFR efforts should emphasize on information sharing activities. Therefore, the impact of IFR sticks more firmly with the members of the network and the resulting SNS. IFR also shows to have included FIFR. This could be because the basis on a SNS usually comes from the FIFR before the IIFR becomes abundance. What is means is that, many IFR in SNS is first forms because firms are embedded in the SNS through the contractual obligation of supply and distribution. Eventually, IIFR becomes more abundance as firms become more connected to other firms through other type of IFR including the IIFR. On the theoretical level, it can be said that, informal relations can be better mechanism for medium of communication in SNS. The more firms can embrace the importance of the IIFR, the more effective it may affect the management of the SNS and consequently the SNC.

Industrial Implications

The elements and dimensions explored provide insights for maritime industry SN management in Malaysia so they can help improve the quality of SN through a voluntary participation from the firms.

In the context of the maritime industry SMS, firms were found to be more embedded or involved in network relations that require less formal coordination approaches than in the network relations that were formally managed through terms and regulations. An example of this is the contract tie, as evidenced through the increased level of connectivity among firms. Network maps indicate that in formal relationships, such as contract ties, the extent of firms' embeddedness is lower. On the other hand, in informally integrated relationships, the results show a high level of embeddedness or involvement, as indicated by the high score of network structural measures of embeddedness.

The finding adds to the views that, at least in the APMMHQ-1 supply network, formal coordinative relations (such as the contract tie) only represent a small part of the actual interaction that exists in the SNS. It was also determined that the other (or maybe the larger) portion of the network economic actions is transmitted through a network of social relations.

Second, the finding of the exploratory network analysis also indicates that in the context of the supply network, firms are embedded through an integrated form of a network of formal and informal inter-firm relations. The existence of an integrated form of relations coincides with Chakkol, Selviaridis, & Finne (2018) who argued that an integrated structure of embedded ties (informal relations) and arms-length (formal relations) is the optimal form of integrated structure.

Consequently, this finding means the existence of a heterogeneous form of firms in the context of the supply network structure. As the firms are embedded in different types of network ties, such as the formal contractual tie network and informal information-sharing tie network, these different ties impact upon the embeddedness nature of the firm in the network. The reason for this is that, although the two ties are distinct, it is essentially an overlapping network structure which created a firm having a distinct characteristic to attend to both the formal and informal ties at the same time in the network. Essentially, we could refer to these firms as heterogeneous firms (of formal and informal characteristics) as they are both formally and informally embedded based on type of ties.

CONCLUSIVE REMARKS

Topics about SNC have not been often associated to the role of IFR. Earlier studies often link SNC with attributes of the firms embedded in the SNS. This study highlights the importance of how firms interact with other firms in the SNS. Therefore using the SNA method, these study asses a set of dimensions and elements to determine the importance of IFR for improving and understanding SNS in maritime industry in Malaysia. These methods enable the researcher to transform relational data in the form of network matrix and produce reliable results for theoretical and industrial applications which have not been discovered in previous studies.

The findings of this study contributed to the context of the SNS, firms' embeddedness or involvement is contingent upon the type of network relations thus creating a new structure other than the traditional linear structure of the supply network. Clearly, the exploratory network analysis has given a strong indication that, in the SNS, more attention and resources (as forming new alliances requires time and even money) of the embedded firms are dedicated to informal networks of relations than to the formal ones.

Thus, overall, the researcher found that, in the context of the supply network structure, firms' embeddedness or involvement is contingent upon the type of network relations. Firms are more embedded in informal networks of relations than in formal ones thus creating a non-linear structure of the supply chain.

In conclusion, by considering the overall implications of our study, we may conclude that supply chain evolves. Managers need to consider their firm's existing embeddedness in order to exploit the competitive advantage of supply network inter-firm relationships. Firms that fail to understand the underpinnings of these relationships stand to face more difficulties within the network itself. For this reason, managers who intend to obtain competitive advantages from the network must engage with other partners more effectively. No doubt, some firms are at an adequate standing, while others are struggling in some areas.

LIMITATION OF THE RESEARCH

There are some limitations to this study. First, the limitation of this study is the context of this research. The sample of this study centres around the maritime supply network in Malaysia. Although this may reduce the generalization of the findings, this study is the first to adopt SNA for supply chain management research. Future research interest may adopt this research framework and apply it in other contexts of research. Second, this study is limited to the information sharing ties as the IIFR. Other IFFR that include referral relations may provide unique sets of findings. Future studies could use other types of IFR that include referral ties of in other form of industry. Further literature on SNC should be enriched depending on the specific relations that are has been used to be analysed in this study.

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REFERENCES

Borgatti, Li, 2009. On Social Network Analysis in a Supply Chain Context*. Journal of Supply Chain Management, 45(2), 5-22. http://doi.org/10.1111/j.1745-493X.2009.03166.x

Borgatti S., Everett M., Freeman L., 2002. UCINET 6 For Windows: Software for Social Network Analysis. Retrieved from http://www.analytictech.com/

Borgatti S.P., Jones C., Everett M.G., 1998. Network measures of social capital'. Semantic Pajek Networks Software, 21(2), 27-36.

Burton P., 2010. Social Network Position and Its Relationship to Performance of IT Professionals. Informing Science: the International Journal of an Emerging Transdiscipline, 13.

Ceyhan S., Dogan I.C., Yildiz M., Barca M., 2018. Boundary conditions for the emergence of relational trust among export-ters and importers. Review of International Business and Strategy, 28(3/4), 358-372. http://doi.org/10.1108/RIBS-01-2018-0009

Chakkol M., Finne M., Raja J.Z., Johnson M., 2018. Social capital is not for sale: a supply network perspective on mergers and acquisitions. Supply Chain Management: An International Journal, 23(5), 377-395. http://doi.org/10.1108/SCM-02-2017-0052

Chakkol M., Selviaridis K., Finne M., 2018. The governance of collaboration in complex projects. International Journal of Operations & Production Management, 38(4), 997-1019. http://doi.org/10.1108/IJOPM-11-2017-0717

Choi, Kim, 2008. Structural Embeddedness and Supplier Management: A Network Perspective. Journal of Supply Chain Management, 44(4), 5-13. http://doi.org/10.1111/j.1745-493X.2008.00069.x

Cousins P.D., Handfield R.B., Lawson B., Petersen K.J., 2006. Creating supply chain relational capital: The impact of formal and informal socialization processes. Journal of Operations Management, 24(6), 851-863. http://doi.org/10.1016/j.jom.2005.08.007

Granovetter M., 1985. Economic Action and Social Structure: The Problem of Embeddedness. American Journal of Sociology, 91(3), 481-510. Retrieved from http://www.jstor.org/stable/2780199.

Hamari J., Sjöklint M., Ukkonen A., 2016. The sharing economy: Why people participate in collaborative consumption. Journal of the association for information science and technology, 67(9), 2047-2059. http://doi.org/10.1002/asi.23552

Hanneman R., Riddle M., 2005. Introduction to social network methods: University of California Riverside, CA.

Hartman S., 2016. Towards adaptive tourism areas? A complexity perspective to examine the conditions for adaptive capacity. Journal of Sustainable Tourism, 24(2), 299-314. http://doi.org/10.1080/09669582.2015.1062017

Hedvall K., Jagstedt S., Dubois A., 2019. Solutions in business networks: Implications of an interorganizational perspective. Journal of Business Research. http://doi.org/10.1016/j.jbusres.2019.02.035

Ibrahim A., Elias E., Saad A., Ramayah T., 2008. Determining Technological Innovation and Competitiveness: A Cross Organizational Analysis of the Malaysian Manufacturing Industry. The Asian Journal of Technology Management Vol, 1(2), 71-89. http://repo.uum.edu.my/id/eprint/20567

Kilduff M., Tsai W., 2003. Social networks and organizations: Sage Publications Ltd.

Kim J., Yoon Y., Zo H., 2015. Why People Participate in the Sharing Economy: A Social Exchange Perspective. Paper presented at the PACIS. http://aisel.aisnet.org/pacis2015/76

Kim Y., Chen Y.-S., Linderman K., 2015. Supply network disruption and resilience: A network structural perspective. Journal of Operations Management, 33, 43-59. http://doi.org/10.1016/j.jom.2014.10.006

Kirchoff J.F., Tate W.L., Mollenkopf D.A., 2016. The impact of strategic organizational orientations on green supply chain management and firm performance. International Journal of Physical Distribution & Logistics Management, 46(3), 269-292. http://doi.org/10.1108/IJPDLM-03-2015-0055

Krause D.R., Handfield R.B., Tyler B.B., 2007. The relationships between supplier development, commitment, social capital accumulation and performance improvement. Journal of Operations Management, 25(2), 528-545. http://doi.org/10.1016/j.jom.2006.05.007

Miemczyk J., Howard M., Johnsen T.E., 2016. Dynamic development and execution of closed-loop supply chains: a natural resource-based view. Supply Chain Management: An International Journal, 21(4), 453-469. http://doi.org/10.1108/SCM-12-2014-0405

Mohd Adnan S.N.S., Valliappan R., 2019. Communicating shared vision & leadership styles towards enhancing performance. International Journal of Productivity and Performance Management.

http://doi.org/10.1108/IJPPM-05-2018-0183

Nair A., Blome C., Choi T.Y., Lee G., 2018. Re-visiting collaborative behavior in supply networks–structural embeddedness and the influence of contextual changes and sanctions. Journal of Purchasing and Supply Management, 24(2), 135-150. http://doi.org/10.1016/j.pursup.2017.11.00

Oh H., Chung M., Labianca G., 2004. Group social capital and group effectiveness: The role of informal socializing ties. The Academy of Management Journal, 47(6), 860-875. http://doi.org/10.5465/20159627

Osman L.H., 2017. The Pattern of Inter-Organizational Level of Connectivity, Formal Versus Informal Ties. Jurnal Komunikasi: Malaysian Journal of Communication, 33(1).

Osman L.H., 2018. Embeddedness Configuration and its' Relations to Inter-Firm connectivity in Supply Network: A Social Network Analysis Approach. Journal of International Trade, Logistics and Law, 4(1), 31.

Papadonikolaki E., Verbraeck A., Wamelink H., 2017. Formal and informal relations within BIM-enabled supply chain partnerships. Construction management and economics, 35(8-9), 531-552. http://doi.org/10.1080/01446193.2017.1311020

Provan K.G., Kenis P., 2008. Modes of network governance: Structure, management, and effectiveness. Journal of Public Administration Research and Theory, 18 (2), 229. http://doi.org/10.1093/jopart/mum015

Reagans R., Zuckerman E., McEvily B., 2004. How to make the team: Social networks vs. demography as criteria for designing effective teams. Administrative science quarterly, 49(1), 101-133. http://doi.org/10.2307/4131457

Turner N., Aitken J., Bozarth C., 2018. A framework for understanding managerial responses to supply chain complexity. International Journal of Operations & Production Management, 38(6), 1433-1466. http://doi.org/10.1108/IJOPM-01-2017-0062

Wasserman S., Faust K., 1994. Social network analysis: Methods and applications: Cambridge Univ Pr.

KOMPLEKSOWOŚĆ ŁAŃCUCHA DOSTAW W PORTACH MORSKICH MALEZJI: WPŁYW RELACJI MIĘDZY FIRMAMI NA STRUKTURĘ ŁAŃCUCHA DOSTAW

STRESZCZENIE. Wstęp: Kompleksowość jest interesującym tematem badań naukowych w połączeniu z tematem stosowania dobrych praktyk oraz jego wpływu na funkcjonowanie łańcucha dostaw. Praca skupia się na obszarze przemysłu, gdyż jest on stosunkowo mało opracowany w ostatnio publikowanych pracach, gdzie są często pomijane aspekty zależności sieciowych, wpływających na kompleksowość łańcucha dostaw (SNC). W szczególności praca skupia się na elementach wewnętrznych relacji firmowych (IFR), formalnych relacjach wewnątrzfirmowych (FIRF) oraz nieformalnych relacjach wewnątrzfirmowych (IIFR), które są szczególnie potraktowane w prezentowanej pracy. W pracy zastosowano metodę analizy sieci socjalnych (SNA) w zmodyfikowanej formie dla oceny procesu oraz teorii zagnieżdżenia, które zostały użyte do oceny relacji wewnętrznych. W pracy stwierdzono, że FIFR i IIFR mają różny wpływ na formowanie SNS oraz w konsekwencji na kształt SNC. Poddano dyskusji również teoretyczne i przemysłowe implikacje.

Metody: Tradycyjne narzędzia statystyczne koncentrują się na wpływu czynników na ekonomiczny wynik. Dlatego też tradycyjna analiza statystyczna nie jest wystarczającą dla pomiaru wpływu relacji i powiązań między członkami sieci na kompleksowość tej sieci. W celu tej oceny, zastosowano metodologię SNA (Social Network Analysis), do zbierania, analizy i interpretacji danych. Dane zebrano na podstawie ankiety pomiędzy członkami łańcucha dostaw obszaru portów morskich. Zebrane dane zostały poddane analizie w specjalistycznym programie UCINET oraz NETDRAW. Do oceny relacji sieciowych oraz kompleksowości zostały użyte wskaźniki statystyczne takie jak centralizacja i gęstość.
Wyniki: Wyniki badań wskazały, że relacje wewnątrzfirmowe (IFR), formalne relacje wewnątrzfirmowe (FIRF) oraz nieformalne relacje wewnątrzfirmowe (IIFR), uwzględnione w pracy jako istotne, mają różny wpływ na kształtowanie się SNS oraz w konsekwencji na SNC.
Wnioski: Wyniki analizy statystycznej wskazują, że kompleksowość sieci występuje w różnej formie i strukturze, w zależności od typu relacji, kształtującej daną sieć. W konsekwencji, różnego rodzaju zasoby i strategie jak i poziom kompleksowości sieci są różne w różnych etapach połączeń.

Słowa kluczowe: analiza sieci, przekazywanie informacji, łańcuch dostaw, kompleksowość

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ORIGINAL PAPER

GREEN LOGISTICS IN E-COMMERCE

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ABSTRACT. **Background:** Along with the very dynamic development of e-commerce, the number of logistics operations involved in order fulfilment is increasing at a similar rate in B2C relationships. Each product must be completed, packed and shipped or handed over for collection by the customer. Although online shopping is very convenient for customers, it has a negative impact on the environment. The problem lays with the transportation of individual shipments, additional packaging and materials used for this purpose, and returns.

The aim of this paper is to present the main logistics challenges related to ecofriendly e-commerce and examine the influence of the green logistics approach in e-commerce on customer satisfaction and loyalty.

Methods: Both computer-assisted telephone interviews (CATI) and computer-assisted web interviews (CAWI) were applied to gather data. In total, 592 correctly completed questionnaires were received – 200 records from CATI and 392 interviews using CAWI. The Pearson correlation coefficient was used to determine the relationship between the variables.

Results: The empirical study confirmed the relationship between green logistics, satisfaction, and loyalty. This means that the more attention online retailers pay to green delivery (parcel lockers, pick up drop off points, click & collect), packaging (environmentally friendly materials and sizing of the packaging) and returns (returnable packaging, return of used products), the more satisfied and willing to buy from the same retailers again the customers are.

Conclusions: For online shoppers, not only price, and wide products selection as well as fast delivery are important, but also environmental aspects matter more and more often. Logistics is of particular importance. If it is not well planned and organised, it can have a negative impact on the environment. The winners are those who invest in ecological solutions. The presented research results encourage further scientific exploration, which would be devoted only to this issue, taking into account other e-commerce stakeholders, i.e. sellers, suppliers and complementors.

Key words: e-commerce, green logistics, logistics value.

INTRODUCTION

Undoubtedly, online shopping is now one of the most important trends in economy. According to Statista, global e-commerce sales in 2020 grew by approx. 18.9% compared with 2019 and amounted to approx. $ 4.2 trillion [Statista, 2021b]. It is growing much faster than the GDP. By 2023, the global sales via the Internet is even expected to reach $ 4.9 trillion [Lipsman, 2019].

Most orders placed online involve products that need to be physically delivered. E-commerce generated around 125 billion CEP (courier, express, parcel) shipments in 2020 [Solomon, 2020]. Only during Singles Day (online shopping festival in China) Alibaba's Tmall and Taobao received 2.3 billion orders [Statista, 2021b], which translated into a similar number of shipments. At peak times, there were even more than half a million orders per second [Chargedretail, 2020]. This is a huge challenge for logistics - both for retailers, logistics and fulfilment companies and CEP operators. This means hundreds of billions of shipment operations, billions of kilometers driven and millions of tons of packaging material.

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E-commerce has shifted the center point of the logistics system from retailer to consumer, a new set of expectations emerges. The consumers are seeking ways to maximize convenience, choice, and price – establishing a completely different shopping experience [Righby, 2011]. As more shoppers buy online, the demand for a seamless shopping experience lands on retailers. They have to look for new possibilities to meet the customer expectations. Recently, more and more attention has been paid to navigating e-commerce sustainably. The biggest challenges in this area are delivery, returns and packaging. Therefore, the question arises how to deal with the logistics challenges of e-commerce, maintaining ecological issues at the same time.

In addition to eliminating the last-mile problem (by introducing different ways to receive shipments), online retailers are increasingly adopting the paperless concept and abandoning printed leaflets and invoices in favour of electronic versions, trying to reduce returns or neutralise their negative impact on the environment, or using eco-friendly packaging and fillers or even reusable packaging [Abukhader, Jönson, 2003].

The Green Generation report shows that some e-customers are willing to wait longer for the delivery, if it is due to the e-store's care for greener delivery, and to pay extra for foil-free packaging. Some customers go further with their expectations and always demand green or sustainable e-commerce shopping [Oláh et al., 2019]. Retailers are trying to respond to these needs. For example, Zalando, one of the biggest fashion e-tailers, reduced its CO_2 per package from their "direct and indirect greenhouse gas emissions in the value chain" [Hischier, 2018; Zalando, 2021], from 2.8 kg to 1.8 kg between 2016 and 2019. For the presented reasons the very dynamic e-commerce growth cannot be considered without its sustainability [Fedorko et al., 2017; Dabija, 2016].

Third-party logistics serving retailers also care about environmental protection. Transport companies are investing in modern means of transport and the development of a fleet of electric cars and charging stations. In addition, they are building or using warehouses that rely on renewable energy sources, energy-efficient lighting, rainwater utilisation systems, etc. This also applies to the way they work. Companies are training employees to keep the environment in mind when performing their daily routine duties, e.g. by reducing the consumption of office materials, etc. [DHL, 2021].

Numerous authors [Liu et al., 2012; Heiskanen, 2005; Zhang, 2015] prove that the consumers' environmental awareness is increasing and their expectations in this respect will grow. Therefore, research is needed to show what is important for customers and what the directions of development of green logistics in e-commerce are.

In recent years, sustainability implications of e-commerce have been attracting more attention from researchers and practitioners [Mangiaracina et al., 2015; Abukhader, Jönson. 2003]. However, research into the environmental effects of e-commerce is still in its infancy and requires a deeper insight. This follows from a systematic literature review conducted by Mangiaracina et al. [2015], who indicated that the publications they reviewed focused mainly on some drawbacks but did not present a structured discussion; no key topics, such as the measurement of the ecological impact of e-commerce or green solutions, were analysed in detail or addressed at all.

Therefore, the aim of this paper is to present the logistics challenges in navigating e-commerce sustainably and examine the influence of the green logistics approach in e-commerce on customer satisfaction and loyalty.

LAST MILE

Many people associate e-commerce with convenience - placing an order at any time, anywhere with access to the Internet is possible. After some time the customer can enjoy the ordered product. This is often done without leaving one's home at all. By not moving, the customer does not release any pollutants and does not consume much energy or natural resources. However, someone else has to deliver the product, and as we know, transport (especially road transport) increases pollution, emissions and congestion, which negatively affects the environment [Oláh et al., 2019; Mangiaracina et al., 2015]. That is why picturing the negative impact of e-commerce on the environment is very tricky [Tiwari, Singh, 2011].

According to the United Nations Environment Programme, which has published extensive research on both European and global impacts on the environment, the transport sector is responsible for 23-24 % of global CO_2 emissions from fossil fuel combustion and is expected to grow to one-third by 2050. That is why consumer-friendly services are needed which allow customers to modify their delivery times and locations, as well as provide access to an extensive network that supplies customers with new ways of receiving deliveries at an alternative location.

The most popular forms of delivery are courier services. The biggest advantages of courier services are the door-to-door option and short delivery time. Neither the sender nor the recipient has to leave their office or home to use this service. Delivery within a given country usually takes one working day. The disadvantage of this solution for the customer is the price of the service, which is the most expensive one among all forms of delivery. Besides, couriers usually deliver shipments when e-customers are at work and some employers prohibit collection of private parcels in the workplace.

Instant or same-day deliveries are also a major challenge. If the process of such deliveries is not well optimised, couriers have empty runs or only partially filled transport vehicles. This significantly increases fuel consumption [Sui, Rejeski, 2002; Tiwari, Singh 2011]. According to the research from MIT's Center for Logistics and Transportation, fast deliveries generate more than double carbon dioxide emissions per shopper, increasing by nearly 0.75kg [Jiang, 2016].

A solution to the last mile problem is to allow customers to pick up and drop off shipments at specially designated points (PUDO). These are places to which access is relatively easy, such as newsagents, shopping malls, petrol stations, grocery shops. An advantage of parcel delivery or collection points is a lower price than in the case of door-to-door courier services. However, their disadvantage is that the availability of the service is limited by the opening hours of the points. A solution to this problem are parcel lockers, where customers can collect and send a parcel at any time of day or night. Deliveries in the PUDO model and parcel lockers are characterised by greater flexibility of the place and time of delivery. This is an advantage for customers who are more mobile and want to have the freedom to choose where and when to send or collect their parcel, and a cost for those who live a long way from such a point, e.g. in rural or less populated areas. Parcel lockers largely eliminate the last mile problem [Mangiaracina et al., 2015]. Both reliability and efficiency are increased. Almost 100% of deliveries are made the first time. With home deliveries, there are more undelivered parcels. Besides, a courier is able to deliver approx. 100 parcels to customers daily, whereas in the case of parcel lockers, there may be over 1000 of such deliveries per day. InPost, which delivers parcels to lockers, reduces harmful emissions in cities by 60%, and in villages by 90% [InPost, 2021].

RETURNS

Another problematic issue related to greenhouse gas emissions is the return of products. E-commerce return rates are between 20% and 30%, which is more than double the 9% traditional retail return rate [Pierce, 2017]. Returns may concern damaged products and those to be repaired. Most frequently, goods purchased via the Internet are returned because they do not meet the buyer's expectations, have technical faults, are delayed or ordered by mistake. These are called consumer returns [XiaoYan et al., 2012]. In the case of online shopping, the customer has the right to withdraw from the contract without giving any reason and return the ordered product [Kawa, 2019].

Returns require additional processes. The goods must first be picked up by a courier or delivered by the customer to a PUDO, parcel locker or click & collect point, then transported to the seller or a company that handles returns. The products are then prepared for resale, which sometimes requires repairs or refreshment. Then there is the packaging, which is used for transport and often not reused. Each of these processes involves additional costs and has an impact on the environment. Nevertheless, there are researchers who argue that despite the high rate of return, e-commerce logistics operations seemed to have a lower environmental impact, especially if private cars were used for offline shopping [Mangiaracina et al., 2015]. In addition, with the return service, waste can be reduced because one can return products unwanted for some reason. In traditional trade, returning products without giving a reason is not widely available. As can be seen, the environmental impact of returns can be both positive and negative. Additionally, returns are a challenge for logisticians because it is difficult to plan and forecast them in the supply chain [Mollenkopf, et al., 2007; Srivastava, Srivastava, 2006]. Since returns are an inherent part of e-commerce, they need to be properly addressed.

The number of returns can be limited. In the case of clothing and shoes, returns are due to the product being a different size or appearance than the customer expected. That is why it is important to have an accurate description of the sizes, including the length, width and height of individual items, or the exact parameters of equipment such as electronics. It is also advisable to present accurate photographs without unnecessary retouching, as well as three-dimensional visualisations. This gives the customer more information and allows him/her to check whether the product fits or not, and the seller can thus reduce the number of returns [Powers, Jack, 2015].

In addition, the return procedure should be simple. Ideally, it should not require generation of additional paper documents. Also, the packaging is very important and it should be designed in such a way that the return of the products is possible in the same box or bag (see next section).

PACKAGING

The next challenge is packaging. As mentioned earlier, e-commerce deals with individual orders which are packed in separate boxes. Due to the transport, the product is often additionally protected, thus generating additional packaging material which is often not recycled [Mangiaracina et al., 2015].

The design and functionality of the packaging are very important, as the consignment of goods is subject to a large number of operations. The logistics system of e-commerce engages more service providers and processes, resulting in significantly more touchpoints than the traditional retail environment. Products are handled four times more in the e-commerce network than in a traditional retail supply chain [Pierce, 2017].

Properly packaged goods have a better chance of arriving intact, reducing the number of returns and the overall environmental footprint [Oláh et al., 2019]. Moreover, packaging made from sustainable materials also helps to further reduce the environmental impact and reduce waste, while demonstrating to customers that the company uses ethical and thoughtful practices.

Packaging is the element that customers see and have physical contact with it. This is important because other processes in the entire e-commerce supply chain are either not seen by the customer at all or only to a limited extent (e.g. delivery). Research shows that customers pay attention to packaging, particularly to the unecological practices of online retailers. In particular, consumers pay attention to non-optimal packaging of shipments, i.e. packaging that is too large in relation to the product. This affects not only the protection of the parcels but also the transport. Moreover, the packaging is also wrapped in plastic or stretch film and there is a lot of filler inside. This is the waste that ends up at consumers' homes. It is often not segregated and, on the other hand, it is not biodegradable [Oláh et al., 2019].

As e-commerce generates a very large amount of packaging waste in the form of additional packaging, fillers, foils, tapes, etc., there is a need to introduce reusable packaging that will be utilised by all stakeholders in the ecosystem. Consumers will receive products in specially designed, durable packaging that will be collected, cleaned and reused for loading and shipping after the delivery. Packaging should provide the best protection, but also fulfil a marketing and informational function. In the future, packaging should be 'intelligent', i.e. it should collect information from the environment and pass it on, but also react to various incidents. An example of such packaging is ePack, which is being developed at Łukasiewicz Research Network - Institute of Logistics and Warehousing and two other Łukasiewicz institutes. It is based on the concept of the physical Internet, allowing all players in the e-commerce ecosystem that handle or transport goods to share resources.

However, before we can see a large-scale use of such packaging, final packaging, which is suitable for transport without additional packaging and protection, should already be used by producers in the first instance. If necessary, the fillings and packaging tape should be made of environmentally friendly materials. In addition, as previously noted, the packaging should be designed in such a way that the product can be returned in it. Besides, sales documents (e.g. invoice) should be sent electronically or be available in the order panel of the online shop.

GREEN LOGISTICS, SATISFACTION, AND LOYALTY

Previous research shows that greening is an investment that pays off. The effect is not always visible immediately and everywhere. Undoubtedly, green logistics can increase customer satisfaction, but also loyalty to the retailer [Kawa, 2019; Rashid, Rahman, Khalid, 2014] (Figure 1).

Satisfaction is treated as “a pleasant feeling that you get when you receive something you wanted, or when you have done something you wanted to do” or “the act of achieving a need or wish” [Cambridge University Press, 2021]. In the case of management studies, satisfaction is understood as the customer's needs fulfillment [Olivier, 1999]. In turn, loyalty is related to as a feeling of support or duty towards someone or something and faithfulness to commitments or obligations [Cambridge University Pres, 2021]. In With respect to management studies, loyalty is understood as the customer’s willingness to buy the product of a given brand or to use a service again [Oliver, 1999].

On the basis of the above considerations, we formulated the following hypotheses:

H1: Green logistics positively influences customer satisfaction.

H2: Green logistics positively influences customer loyalty.

H3: Satisfaction positively influence loyalty.

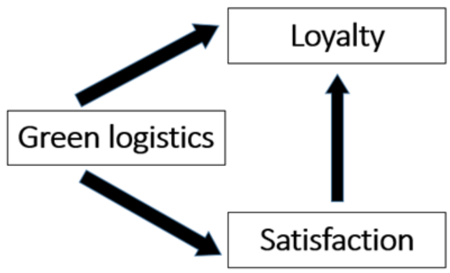

Fig. 1. Model for testing relationship between green logistics, satisfaction, and loyalty

RESEARCH METHODOLOGY AND RESULTS

Research stages and data gathering

The study was conducted in several stages. Based on the literature review, a scenario was prepared for 3 FGIs (focus group interviews). The results of this research enabled the design of a measuring instrument for a quantitative study.

We used a structured questionnaire for the study. In addition to questions about the availability of products, returns, cross border buying, status order, questions were asked about green issues of logistics. In particular, they covered the following aspects possibly offered by the online retailers: deliveries parcel lockers and PUDO (pick up drop off) points, returnable packaging, return of used products, using environmentally friendly materials for packing their parcels. Apart from the issues related to green logistics, the respondents were asked about customer satisfaction with the purchases made and their loyalty to the online sellers.

We used the database of e-tailers as the sample. It included data from the Regon database kept by the Central Statistical Office in Poland and commercial databases, such as DBMS, Bisnode.

Approximately 13.7 thousand respondents took part (44% of the total population of e-tailers in Poland). Non-random purposeful sampling was applied. The sample was selected from those entities that had relevant experience in selling products via the Internet for at least one year. Both computer-assisted telephone interviews (CATI) and computer-assisted web interviews (CAWI) were applied to data gathering between November 2017 and May 2018. In total, 592 correctly (N=592) completed questionnaires was received – 200 records from CATI and 392 interviews using CAWI.

Measures

Green logistics, satisfaction, and loyalty are multi-faceted constructs. There are variables that are not directly observed, but affect the observed variables. Because it is a deficit of empirical research on green logistics in e-commerce, it was necessary to prepare indicators of this latent variable. Based on an in-depth literature review and the results of the FGI, ob-servable indicator was developed and included in the questionnaire in the form of statements (Table 1).

Table 1. Constructs, items and scales of green logistics, satisfaction, and loyalty

Green logistics. Cronbach's alpha = 0.719
Customers buy from online sellers who offer deliveries to self-service terminals (e.g. parcel locker)
Customers buy from online sellers who offer deliveries to PUDO (pick up drop off) points (eg. a traffic kiosk. gas station)
Customers buy from online sellers who offer pickup at their branches
Customers buy from online sellers who use environmentally friendly materials for packing their parcels
Customers buy from online sellers who match the size of the packaging to the size of the product
Customers buy from online sellers who offer returnable packaging
Customers buy from online sellers who offer return of used products
Satusfaction. Cronbach's alpha = 0.720
My customers feel that we understand their needs.
My customers will recommend their nearest and dearest or friend to buy from these us
My customers are satisfied with their purchases.
Loyalty. Cronbach's alpha = 0.724
My customers will continue to buy from us, even if their payment for products offered by other sellers is more competitive.
My customers will continue to buy from us, even if the shipments offered by other sellers are more competitive.
My customers will continue to buy from us, even if the products offered by other sellers are more competitive.

We studied our model from the seller perspective. The respondent was to look at the green logistics value, satisfaction, loyalty and evaluated them through the final customer's "eyes". This approach is in line with what is presented in the literature [Kawa and Światowiec-Szczepańska, 2020].

We adopted a five-point Likert-type scale to assess the statements in the questionnaire where 1 meant "strongly disagree" and 5 – "strongly agree".

We used the Cronbach's α as a method of the reliability analysis. All Cronbach's α were above 0.7 indicating satisfactory internal consistency of variables.

Results and discussion

The Pearson correlation coefficient was used to study the relationship between the variables. In addition to the strength of the relationship, it was very important to determine whether the correlation was statistically significant. Our study showed that the correlations between all variables were positive and statistically significant. The strongest relationship was found between satisfaction and loyalty, which is very well supported in the literature. The relationships between green logistics and satisfaction, and green logistics and loyalty were a little weaker. The results of the research indicate that green logistics influences satisfaction and loyalty. Therefore, online retailers who pay more attention to the ecological aspects have satisfied and more loyal customers. The green approach is primarily about developing delivery methods alternative to courier deliveries, i.e. deliveries to parcel lockers, PUDO points or pickup at branches. It also means taking greater care of the packaging, in particular using environmentally friendly materials for packing parcels and matching the size of the packaging to the size of the product. Returns are also a very important aspect, which should reduce additional packaging by selling products in returnable packaging and enabling the return of used products. It is important that these green logistics elements are included in the offer of online retailers. Some of them result from other needs, e.g. OOH, and we wrote about this in another article. The same is true for returns. They can all be treated as separate issues or, more broadly, as logistics value. It should also be noted that it is not always possible to implement all components of green logistics. Not all companies have their own branches. Not every shipment is suitable for PUDO and parcel lockers - for example large goods (bulk) or fresh or temperature-controlled products. The same applies to the return of used products - some items cannot be returned after being used, such as underwear, cosmetics, etc. Some products do not need to or cannot be packed in ordinary packaging, let alone packaging made of environmentally friendly materials - e.g. tyres, which are transported without any packaging or additional protection.

Table 2. Correlations between green logistics, satisfaction, and loyalty

	Green logistics	Satisfaction	Loyalty
Green logistics		.396**	.363**
Satisfaction			.630**
Loyalty			

** indicates p<0.01

CONCLUSIONS

E-commerce has been growing rapidly for several years. The pandemic period has further accelerated this growth. During the lockdown, the necessary products are picked, packed, shipped and delivered to the customer's chosen location. This reduces unnecessary car traffic, which decreases the carbon footprint. E-commerce also generates inconvenience not found in traditional retail. The problems include the last mile, excess packaging and packaging materials and product returns. There is also a view that e-commerce has caused a very large increase in mass production, because anyone can buy almost anything. This stimulates customers to buy more and more, which in turn often leads to generating waste [Tiwari, Singh 2011]. The final effect is not yet known, as research to date has not clearly answered the question of whether Internet shopping increases or decreases environmental impacts [Matthews et al. 2001; Abukhader, Jönson, 2003; Sui, Rejeski, 2002; Tiwari, Singh, 2011].

However, it is inevitable that the Internet will gain importance in trade, and therefore it must be organised immediately in such a way that it has as little impact as possible on the environment. This approach also has direct positive effects for sellers. Our research has shown that customers pay attention to the ecological aspects of logistics. The more they appreciate green logistics, the more satisfied they are with their purchases and the more likely they are to repeat purchases from the same retailer.

The slogan of one of the e-commerce leaders that "the efficiencies of online shopping result in a greener shopping experience than traditional retailing" [Amazon, 2021] needs to be backed up by many additional measures. Customers expect real change, so companies must choose initiatives that have a positive environmental impact.

The research results presented here have limitations that can be addressed in further studies. Firstly, attention was focused only on selected aspects of green logistics as perceived by online retailers. A more thorough and deeper study on a larger sample involving different stakeholders (sellers, customers, suppliers) would be needed. Establishing sustainability for e-commerce requires a holistic approach that examines the entire logistics system. Secondly, it was limited to the simplest statistical analyses. A multifaceted and more detailed study would require the use of more advanced analytical methods, such as structural modelling equations. Thirdly, the customers' environmental awareness has recently been growing more and more rapidly, and our study was conducted some time ago. It is worth repeating this research soon.

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REFERENCES

Abukhader S.M., Jönson G., 2003. The environmental implications of electronic commerce: A critical review and framework for future investigation. Management of Environmental Quality: An International Journal, 14(4), 460-476. http://doi.org/10.1108/147778303104886685

Amazon, 2021, https://www.amazon.co.uk/Amazon-and-our-Planet/b?ie=UTF8&node=299737031.

Cambridge University Press, 2021. https://dictionary.cambridge.org/dictionary/english/.

Chargedretail, 2020. Alibaba's Singles Day sees record peaks of 583,000 orders per second raking in $56bn, https://www.chargedretail.co.uk/2020/11/11/alibabas-singles-day-sees-record-peaks-of-583000-orders-per-second-raking-in-56bn/.

Dabija D.C., Pop N.A., Postelnicu C., 2016. Ethics of the garment retail within the context of globalization and sustainable development. Industria Textilă, 67(4), 270-279.

DHL, 2021, Green logistics, https://www.dhl.com/pl-en/home/logistics-solutions/green-logistics.html.

Fedorko R., Bacik R., Kerulova V., 2017. The analysis on the importance of the reputation management in relation to e-commerce subjects. Polish Journal of Management Studies, 15. http://doi.org/10.17512/pjms.2017.15.1.05

Gorgani M.R.N., 2014. Electronic Commerce as a Sustainable Business. European Journal of Sustainable Development, 3(3), 141-141. http://doi.org/10.14207/ejsd.2014.v3n3p141

Heiskanen E., 2005. The performative nature of consumer research: consumers' environmental awareness as an example. Journal of consumer policy, 28(2), 179-201, http://doi.org/10.1007/s10603-005-2272-5

Hischier R., 2018. Car vs. packaging—a first, simple (environmental) sustainability assessment of our changing shopping behaviour. Sustainability, 10(9), 3061. http://doi.org/10.3390/su10093061

InPost,2021. https://www.inpost.co.uk/greener-delivery/

Jiang E., 2016. Is E-Commerce Really Better For the Environment Than Traditional Retail?, https://www.businessoffashion.com/articles/intelligence/is-e-commerce-really-better-for-the-environment

Kawa A., Światowiec-Szczepańska J., 2020. Logistics Value and Perceived Customer Loyalty in E-commerce: Hierarchical Linear Modeling Analysis. Nguyen N., Jearanaitanakij K., Selamat A., Trawiński B., Chittayasothorn S. (eds) Intelligent Information and Database Systems. ACIIDS 2020. Lecture Notes in Computer Science, Springer, Cham. pp. 417-427; http://doi.org/10.1007/978-3-030-42058-1_35

Kawa A., 2019. Returns In E-Commerce As A Value For Customers From Different Perspectives. Business Logistics in Modern Management.

Lipsman A., 2019. Global Ecommerce 2019, https://www.emarketer.com/content/global-ecommerce-2019.

Liu Z.L., Anderson T.D., Cruz J.M., 2012. Consumer environmental awareness and competition in two-stage supply chains. European Journal of Operational Research, 218(3), 602-613. http://doi.org/10.1016/j.ejor.2011.11.027

Mangiaracina R., Marchet G., Perotti S., Tumino A., 2015. A review of the environmental implications of B2C e-commerce: a logistics perspective. International Journal of Physical Distribution & Logistics Management, 45(6), 565-591. http://doi.org/10.1108/IJPDLM-06-2014-0133

Mollenkopf D., Russo I., Frankel R., 2007. The returns management process in supply chain strategy. International Journal of Physical Distribution and Logistics Management, 37(7), 568-592. http://doi.org/10.1108/09600030710776482

Oláh J., Kitukutha N., Haddad H., Pakurár M., Máté D., Popp J., 2019, Achieving sustainable e-commerce in environmental, social and economic dimensions by taking possible trade-offs. Sustainability, 11(1), 89. http://doi.org/10.3390/su11010089

Oliver R. L., 1999. Whence consumer loyalty?. Journal of marketing, 63(4_suppl1), 33-44. http://doi.org/10.1177/00222429990634s105

Pierce L., 2017. The sustainability of ecommerce packaging is in question, https://www.packagingdigest.com/sustainability/sustainability-ecommerce-packaging-question

Powers T.L., Jack E.P., 2015, Understanding the causes of retail product returns. International Journal of Retail & Distribution Management, 43(12), 1182-1202. http://doi.org/10.1108/IJRDM-02-2014-0023

Rashid N.R.N.A., Rahman N.I.A., Khalid S.A., 2014. Environmental corporate social responsibility (ECSR) as a strategic marketing initiatives. Procedia-Social and Behavioral Sciences, 130, 499-508. http://doi.org/10.1016/j.sbspro.2014.04.058

Rigby D., 2011. The future of shopping. Harvard business review, 89(12), 65-76.

Solomon M., 2020. Global parcel volumes could reach 132 billion this year: Pitney Bowes, Freight Waves, https://www.freightwaves.com/news/global-parcel-volumes-could-reach-132-billion-this-year-pitney-bowes.

Srivastava S., Srivastava R., 2006. Managing product returns for reverse logistics. International Journal of Physical Distribution and Logistics Management, 36,(7), 524-546. http://doi.org/10.1108/09600030610684962

Statista, 2021a. https://www.statista.com/statistics/364780/number-of-orders-alibaba-singles-day/.

Statista, 2021b. Retail e-commerce sales worldwide from 2014 to 2023, Retrieved from https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/.

Sui D.Z., Rejeski D.W., 2002. Environmental impacts of the emerging digital economy: the e-for-environment e-commerce?. Environmental Management, 29(2), 155-163. http://doi.org/10.1007/s00267-001-0027-X

Tiwari S., Singh P., 2011. E-commerce: prospect or threat for environment. International Journal of Environmental Science and Development, 2(3), 211.

XiaoYan Q., Yong H., Qinli D. Stokes P., 2012. Reverse logistics network design model based on e-commerce. International Journal of Organizational Analysis, 20(2), 251-261. http://doi.org/10.1108/19348831211227864

Zalando, 2021. https://corporate.zalando.com/en/sustainability/reducing-our-carbon-footprint.

Zhang L., Wang L.J., You J., 2015. Consumer environmental awareness and channel coordination with two substitutable products. European Journal of Operational Research, 241(1), 63-73. http://doi.org/10.1016/j.ejor.2014.07.043

ZIELONA LOGISTYKA W E-HANDLU

STRESZCZENIE. **Wstęp:** Wraz z bardzo dynamicznym rozwojem e-commerce w relacjach B2C, w podobnym tempie rośnie liczba operacji logistycznych związanych z realizacją zamówień. Każdy produkt musi zostać skompletowany, zapakowany i wysłany lub przekazany do odbioru przez klienta. Choć zakupy online są bardzo wygodne dla klientów, mają negatywny wpływ na środowisko. Problemem jest transport poszczególnych przesyłek, dodatkowe opakowania i materiały użyte do tego celu oraz zwroty.
Celem niniejszego artykułu jest przedstawienie głównych wyzwań logistycznych związanych z ekologicznym e-handlem oraz zbadanie wpływu podejścia zielonej logistyki w e-handlu na satysfakcję i lojalność klientów.
Metody: Do zebrania danych zastosowano zarówno wywiady telefoniczne wspomagane komputerowo (CATI), jak i wywiady internetowe wspomagane komputerowo (CAWI). W sumie otrzymano 592 poprawnie wypełnionych kwestionariuszów - 200 wywiady z CATI i 392 z wykorzystaniem CAWI. Do określenia zależności między zmiennymi wykorzystano współczynnik korelacji Pearsona.
Wyniki: Przeprowadzone badanie empiryczne potwierdziło istnienie zależności pomiędzy zieloną logistyką, satysfakcją i lojalnością. Oznacza to, że im więcej uwagi detaliści internetowi poświęcają ekologicznej dostawie (skrytki na paczki, punkty odbioru i odbioru, click & collect), pakowaniu (materiały przyjazne środowisku i wielkość opakowania) oraz zwrotom (opakowania zwrotne, zwrot zużytych produktów), tym bardziej klienci są zadowoleni i skłonni do ponownych zakupów.
Wnioski: Dla kupujących w Internecie ważna jest nie tylko cena i szeroki wybór produktów oraz szybka dostawa, ale coraz częściej liczą się także aspekty środowiskowe. Szczególne znaczenie ma logistyka. Jeśli nie jest ona dobrze zaplanowana i zorganizowana, może mieć negatywny wpływ na środowisko. Wygrywają ci, którzy inwestują w ekologiczne rozwiązania. Przedstawione wyniki badań zachęcają do dalszych eksploracji naukowych, które byłyby poświęcone tylko temu zagadnieniu, z uwzględnieniem innych interesariuszy e-commerce, tj. sprzedawców, dostawców i komplementorów.

Słowa kluczowe: e-commerce, zielona logistyka, wartość logistyczna.

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ORIGINAL PAPER

COMPARISON OF DOMESTIC LOGISTICS PERFORMANCES OF TURKEY AND EUROPEAN UNION COUNTRIES IN 2018 WITH AN INTEGRATED MODEL

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ABSTRACT. **Background:** The Logistics Performance Index (LPI), created by the World Bank, is a benchmark tool used to determine the threats and opportunities faced by countries in their logistics performances and to improve their performances. Countries aim to increase their LPI scores and rank higher on the LPI list while developing their strategies.
Methods: In this study, it was aimed to compare the domestic logistics performances of Turkey and the European Union countries with an integrated model using the domestic logistics performance index data for 2018, which was recently published by the World Bank. In this direction, firstly, the importance levels of the criteria were determined with the CRITIC (Criteria Importance Through Intercritera Correlation) method, and then, using the importance levels of the criteria, the countries were ranked according to the domestic logistics performance score with the COPRAS (Complex Proportional Assessment) method.
Results: As a result of the CRITIC method, the most important criterion in the ranking according to the importance levels of the criteria was "without physical examination", which is the sub-criterion of the customs clearance period, while the Netherlands was the country with the best performance in the ranking performed by the COPRAS method, using the importance levels of the criteria determined by the CRITIC method.
Conclusions: The study differs from current studies in the literature in that it is the first study to perform a domestic logistic performance comparison using CRITIC and COPRAS methods with an integrated model. The results of the current study can be compared with the results obtained by using different integrated models and different data in the studies to be conducted.

Key words: Logistics Performance Index (LPI), Multi Criteria Decision Making (MCDM), CRITIC, COPRAS.

INTRODUCTION

With the rise of world trade as a result of factors such as globalization, technological developments, widespread use of the internet, increase in virtual market and e-commerce, changing consumption habits and urbanization, companies and countries have entered the race to gain competitive advantage. As a result of increasing competition in the global dimension today, logistics has become one of the most important sectors for countries to come to the forefront in international trade. Logistics, which provides cost savings as well as facilitating the mobility of goods, creates an important service network for both companies and countries and plays a key role in gaining competitive advantage in international markets [Civelek et al., 2015; Erkan, 2014].

Germany's logistics sector, which has the largest logistics service sector in Europe, accounts for about 7% of annual Gross Domestic Product (GDP), the United States' logistics sector accounts for about 8% of annual (GDP) [Dijkman, 2009]. Effective logistics activities in international trade not only increase the reliability of the supply chain of countries, but also contribute to the

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development of commercial relations between countries by helping countries to compete globally [Rashidi, Cullinane 2019]. In addition, the logistics sector also plays a vital role in environmental and social aspects. In many countries, about 3-5% of the total workforce is employed in logistics [Rashidi and Cullinane, 2019].

Inefficient logistics services, on the other hand, can damage the foreign trade balance of countries and cause disruption to the activities of all sectors of the economy. This can mean increased operational costs for both firms and countries and disrupted relationships in the supply chain [Marti et al., 2014]. Therefore, the performance of logistics needs to be assessed and improved.

The objective of the LPI developed by the World Bank is to reveal differences in logistics activities between countries. LPI ranks countries in terms of their logistics performances and guides them to improve it. Countries that analyze LPI scores in detail can identify challenges and opportunities in their logistics supply chains and improve their performances [Işik et al., 2020].

The World Bank evaluates logistics performance from two different perspectives, international and domestic. International LPI; ranks countries according to six trade dimensions as “customs performance, infrastructure, ease of arranging shipments, quality of logistics services, tracking and tracing, timeliness”. Domestic LPI provides both qualitative and quantitative assessments of a country by logistics experts of 100 countries. To measure performance, four main determinants of overall logistics performance are used as “infrastructure, services, boundary procedures and time, supply chain reliability”.

In the literature, there are many different studies evaluating the international logistics performances of countries. However, it has been determined that there is no study comparing the domestic logistics performances of the countries. This study contributes to the current literature at two points. First, it is the first study to compare the domestic logistics performances of Turkey and the European Union countries, and second, it is the proposal of CRITIC and COPRAS methods with an integrated model for logistics performance evaluation. In the literature; there is no study that compares domestic logistics performances with an integrated model using CRITIC and COPRAS methods.

This study consists of five main sections, first section is introduction, review of the literature in the second section, methodology in the third section, research findings in the fourth section, and finally conclusion and recommendations in the fifth section.

REVIEW OF THE LITERATURE

In the literature, there are many and different studies on the LPI.

Sofyalioglu and Kartal [2013] compared performance index of Turkey and Eurasian Economic Community countries.

Uca et al. [2015] examined the relationship between Gross National Product (GNP) and logistics performance index and the impact of logistics performance indicators on the GNP of countries.

Başar [2017] addressed the logistics performance of the Central Asian Turkic Republics.

Yapraklı and Unalan [2017] examined Turkey’s position in the international market in terms of logistics with the global status of logistics on a country-by-country basis according to LPI data between 2007-2016.

Imamoglu [2019] identified similarities and differences between countries by comparing the logistics performance of Turkey with the member countries of the Shanghai Cooperation Organization.

Çatuk [2019] used LPI data to identify the factors that negatively affect Turkey’s logistics performance and the areas that needed to be improved, and examined the impact of highway on logistics performance.

Erturgut and Gürler [2019] found Austria in the fourth place and Denmark in the eighth place in terms of LPI sub-components in the last LPI published.

Yangınlar [2019] used annual data between Turkey and G7 countries, and examined logistics performances and GDP ratios.

Emanet [2017] examined the logistics performances of the Central Asian Turkish Republics (Azerbaijan, Kazakhstan, Kyrgyz Republic, Turkmenistan, Uzbekistan) within the scope of LPI.

Bozkurt and Mermertas [2019] addressed the current situation of Turkey and G8 countries in the LPI, and advantages and disadvantages of countries.

Kılınç et al. [2019] evaluated the main logistics activities of Turkey, China and the Russian Federation according to LPI data and examined the development strategies over the years.

Yıldız et al. [2020] determined Turkey's international LPI position between 2012-2018.

Görgün [2020] revealed the situation of Turkey in the LPI assessment and determined the reasons for the poor performance shown.

Aksungur and Bekmezci [2020] aimed to determine the changes in Turkey's LPI position as of 2007-2018 and improvements that can be made according to the LPI score in 2018.

In Table 1, the studies assessed especially the LPI by using MCDM methods are shown. These studies cover OECD countries, European Union countries, G20 countries, Asian countries, Balkan countries and selected Central and Eastern European countries. It is noticeable that studies covering OECD countries are more common.

Table 1. Literature Review

Author (s)/Year	Aim	Method	Criteria	Finding
Marti et al. (2017)	Calculating the overall logistics performance (DEA-LPI) and to propose a DEA approach to compare the LPI with the logistics performance of countries, to analyze the differences when using different variables such as income and geographic area	DEA	Customs Infrastructure Logistics competence Timeliness Tracking and tracing International shipments	It has been determined that logistics performance is largely influenced by revenue and geographical area, high-income countries are in the group of best-performing countries, and the group of ten best-performing countries is highly managed by the European Union.
Bayır and Yılmaz (2017)	Measuring the logistics performance of 20 European countries with LPI data for 2016	AHP, VIKOR	Customs Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	Among the criteria, timeliness was found to be more important than other criteria; Luxembourg, Germany, Sweden, Netherlands and Austria are ranked as the top five countries in logistics performance, respectively.
Çakır (2017)	Measuring the logistics performance of OECD countries according to World Bank 2014 LPI data	CRITIC, SAW, Fuzzy Regresyon	Customs Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	The most important criterion was tracking and tracing, while the most insignificant criterion was logistics competence. According to the ranking results of the countries, it was determined that the ranking of Peters ' FLR model did not resemble the ranking of MCDM methods .
Rezaei et al. (2018)	Finding the weights of six components used in LPI with a survey with 107 experts from different countries using BWM, which is the MCDM method.	BWM	Customs Infrastructure Logistics competence Timeliness Tracking and tracing International shipments	According to the results, infrastructure has been recognized as the most important criterion for logistics performance.

Author (s)/Year	Aim	Method	Criteria	Finding
Candan (2019)	Assessing the logistics performance of 10 OECD member countries	Fuzzy AHP, Gray Relational Analysis	Export delivery time Import delivery time Quality of infrastructure related to trade and transportation Frequency of shipments reaching the recipient within the planned or expected time Ability to track shipments	While export delivery time was the most important criterion by weight obtained, Australia was the country with the highest Logistics Performance. Australia was followed by Austria, Germany, Belgium, the United Kingdom, Turkey, Italy, Greece, Spain and the Czech Republic respectively.
Orhan (2019)	Comparing the logistics performance of Turkey and European Union countries using World Bank 2018 LPI data	ENTROPİ, EDAS	Customs Infrastructure International shipments Logistics competence Timeliness Tracking and tracing	The most important criterion has been determined as the customs criterion. Germany ranked first in the logistics performance ranking of countries.
Kısa and Ayçin (2019)	Assessing the logistics performance of OECD countries between 2012 and 2018	SWARA, EDAS	Customs Infrastructure International shipments Logistics service quality Tracking and tracing Timeliness	While the most important criteria are logistics service quality, infrastructure and international shipment, Germany, the Netherlands and Sweden are the top three countries in the logistics performance ranking.
Oğuz et al. (2019)	Ranking the logistics performance of selected Asian countries (South Korea, Hong Kong, Singapore, Indonesia, Malaysia, Taiwan and Thailand)	TOPSİS	Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	In the logistics performance ranking, the country with the best performance is Singapore, and the country with the worst performance is Indonesia.
Ulutaş and Kara-köy (2019a)	Proposing a model for ranking G20 countries according to the logistics performance index	SD, TOPSIS	Customs Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	While the most important criterion is the efficiency of the customs clearance process; Germany, Japan, United Kingdom, United States of America and France ranked in the top five in logistics performance ranking.
Kara-köy and Ölmez (2019)	Comparing the logistics performance indices of Balkan countries	OCRA, ENTROPI	Customs Infrastructure International shipments Logistics quality and competence Tracking and tracing Timeliness	According to the entropy method, the most important criteria are logistics quality and competence, and according to the OCRA method, the top three countries with the best logistics performance are identified as Slovenia, Greece and Turkey.
Ozmen (2019)	Evaluating the logistics competitiveness of OECD countries	MD, TODIM	Customs Infrastructure International shipments Logistics quality and competence Tracking and tracing Timeliness Freight transport volume Container transport volume Passenger transport volume	While the most important criterion in Group A was logistics quality and competence, the most important criterion in Group B was freight transport volume. Differences occurred in the order of countries obtained with Traditional TODIM and Improved TODIM. In both methods, Germany ranked first and France second in logistics performance ranking.
Ulutaş and Kara-köy (2019b)	Integrating SWARA and CRITIC methods in determining the weights of the criteria in the logistics performance index of the European Union countries and making the logistics performance ranking of the countries with the PIV method	SWARA, CRITIC, PIV	Tracking and tracing Logistics competence International shipments Customs Timeliness Infrastructure	While the most important criterion in the criteria weights obtained by combining CRITIC and SWARA methods is infrastructure, the top ten countries in logistics performance ranking are Germany, Sweden, Netherlands, Austria, Belgium, United Kingdom, Denmark, Finland, France and Spain.
Yıldırım and Mer-cangöz (2020)	Analyzing the logistics performance of OECD countries between 2010 and 2018 and comparing them with current logistics performance index rankings	ARAS-G, Fuzzy AHP	Customs Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	Among the criteria, the most important criterion is infrastructure, the most insignificant criterion is tracking and tracing; the top five countries in the logistics performance ranking are Germany, the Netherlands, Sweden, Japan and the United Kingdom.
Mer-cangöz et al. (2020)	Ranking the member states of the European Union and the 5 candidate countries of the European Union by COPRAS-Gray method according to the logistical performance scores	COPRAS-G	Customs Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	According to the logistic performance ranking results, Germany ranked first, Holland second and Sweden third.

Author (s)/Year	Aim	Method	Criteria	Finding
Işik et al. (2020)	Analyzing and ranking the logistics performance of 11 selected Central and Eastern European countries	SV, MABAC	Customs Infrastructure International shipments Logistics competence Tracking and tracing Timeliness	Timeliness has been identified as the most important, infrastructure as the least important performance criteria. In the performance ranking of the countries according to the MABAC method, the first three places were Czech Republic, Poland and Hungary.

In some studies in the literature, the importance levels of the criteria are considered equal; in others, the importance levels of the criteria were determined by methods based on subjective evaluations (AHP, SWARA, Fuzzy AHP) or by methods based on objective evaluations (ENTROPI, CRITIC).

METHODOLOGY

Purpose and Importance

In the study, the importance levels of criteria are determined by CRITIC method using domestic LPI data published by World Bank every two years. It is aimed to rank Turkey and European Union countries according to domestic logistics performances by using COPRAS method and to compare the logistics performances of countries. The findings of this study will be useful in terms of improving of Turkey's logistics performance.

Sample

2018 domestic LPI data for Turkey and the European Union which was published by the World Bank is used in this study. Estonia, the Greek Cypriot Administration of Southern Cyprus, Hungary, Ireland, Malta, Slovakia and Croatia were excluded due to the lack of data.

Table 2. Data On Criteria Used

Criteria	**Export time and distance**				**Import time and distance**				% of shipments meeting quality criteria	Number of agencies		Number of forms		Clearance time (days)		Physical inspection	Multiple inspection
	Port or airport supply chain		**Land supply chain**		**Port or airport supply chain**		**Land supply chain**										
	Distance (km) **(K1)**	Lead time (days) **(K2)**	Distance (km) **(K3)**	Lead time (days) **(K4)**	Distance (km) **(K5)**	Lead time (days) **(K6)**	Distance (km) **(K7)**	Lead time (days) **(K8)**	% of shipments meeting quality criteria **(K9)**	Imports **(K10)**	Exports **(K11)**	Imports **(K12)**	Exports **(K13)**	Without physical inspection **(K14)**	With physical inspection **(K15)**	% of import shipments **(K16)**	% of shipments physically inspected **(K17)**
	Min	Min	Min	Min	Min	Min	Min	Min	Max	Max	Max	Min	Min	Min	Min	Min	Min
Countries																	
Austria	332	2	496	3	344	3	486	3	86	2	2	2	2	0	1	2	2
Belgium	160	2	245	3	186	3	216	3	82	1	1	2	2	1	1	3	1
Bulgaria	438	2	1136	3	276	2	1256	3	86	2	2	3	3	1	1	7	3
CzechRepublic	300	7	750	3	474	5	300	3	88	1	1	2	2	1	1	1	1
Denmark	43	3	75	2	52	3	75	3	92	1	1	1	1	1	2	1	1
Finland	230	2	785	5	172	3	553	5	93	1	1	2	1	0	1	2	1
France	261	2	673	3	177	3	439	3	79	2	2	2	2	1	1	3	2
Germany	212	2	569	2	350	2	559	3	95	1	1	1	1	1	1	2	2
Greece	219	3	841	3	302	3	783	7	95	2	2	3	3	1	2	2	1
Italy	269	3	541	5	210	4	519	5	90	2	2	3	2	1	2	3	2
Latvia	25	1	2000	46	25	1	3500	53	89	3	2	2	2	0	1	4	11
Lithuania	150	2	1581	4	43	2	1581	4	97	3	3	2	2	0	1	6	2
Luxembourg	96	2	471	3	101	2	393	3	89	2	2	2	2	1	1	3	2
Netherlands	48	2	265	1	99	1	453	2	82	2	1	1	1	0	0	2	1
Poland	75	1	750	4	300	1	750	5	73	2	1	3	3	1	2	3	1
Portugal	141	3	1601	3	157	3	1738	6	82	3	2	3	3	1	2	6	2
Romania	203	2	835	3	482	2	1249	4	86	2	2	4	5	1	2	8	5
Slovenia	300	1	256	2	300	3	474	3	96	3	3	2	2	0	1	4	2
Spain	143	2	298	2	101	3	326	2	75	2	2	2	2	1	2	4	2
Sweden	474	1	1025	1	300	3	1025	5	97	2	2	3	3	1	2	2	1
Turkey	252	3	1267	6	332	3	1087	6	77	3	3	4	4	1	2	12	6

Data Collection Method and Tool

The indicators contained in the domestic LPI of World Bank were used as criteria in this study. Domestic LPI data of Turkey and European Union countries was obtained from the World Bank website (https://lpi.worldbank.org/domestic) and it is shown in Table 2. In this study, CRITIC and COPRAS methods were used for finding the weights of criteria and ranking the countries in terms of their LPI. First, the importance levels of the criteria were determined by the CRITIC method, and then the comparison was made by the COPRAS method according to the domestic logistics performance rankings of Turkey and the European Union countries using the determined criteria importance levels.

CRITIC Method

The CRITIC method was introduced into the literature in 1995 with a study by Diakoulaki et al [Diakoulaki et al., 1995]. It is a weighting method in which the standard deviation of the criteria and the correlation values between the criteria are used together. Both the standard deviation of each criterion of the normalized matrix and the correlation relationship between other criteria are used in calculating the significance levels of the criteria [Ayçin, 2019].

The variables in the application stages of the method are defined as follows.

The variables in the application stages of the method are defined as follows.

i. decision alternative (i = 1,2,…,m)

j. evaluation criteria (j = 1,2,…., n)

z_{ij} : j. according to the evaluation criteria i. the value of the alternative

z_j^{max} : j. maximum value of decision alternatives according to criteria

z_j^{min} : j. minimum value of decision alternatives according to criteria

r_{ij} : j. according to the evaluation criteria i. normalized value received by the alternative

σ_j. : j . standard deviation value of the criterion (j = 1,2,…n)

y_{jk} : correlation coefficients of criteria j and k relative to each other

w_j : j. weight of evaluation criteria (j = 1,2,…n)

CRITIC method consists of 3 steps (Madić and Radovanović, 2015):

Step 1. The decision matrix with all alternatives and criteria is organized. The decision matrix is shown in equation 1 below.

$$C = [Z_{ij}]_{m\times n} = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{bmatrix} \quad (1)$$

Step 2. All values in the decision matrix are normalized with the help of equation 2 (utility-based criteria) and equation 3 (cost-based criteria).

$$r_{ij} = \frac{z_{ij} - z_j^{min}}{z_j^{max} - z_j^{min}} \quad (2)$$

$$r_{ij} = \frac{z_j^{max} - z_{ij}}{z_j^{max} - z_j^{min}} \quad (3)$$

Step 3. The weight (w_j) of each criterion is calculated with the help of equation 4, taking into account the standard deviation of the criterion and the correlations of the criteria with each other.

$$w_j = \frac{s_j}{\sum_{k=1}^{n} s_k} \qquad j= 1,2, \ldots\ldots n \quad (4)$$

The (s_j) value in the above equation is calculated with the help of equation 5.

$$s_j = \sigma_j \sum_{k=1}^{n} (1-y_{jk}) \qquad j= 1,2, \ldots n \qquad (5)$$

COPRAS Method

The COPRAS method was introduced into the literature in 1996 with a study by Zavadskas and Kaklauskas [Zavadskas and Kaklauskas, 1996]. The most important feature that makes the COPRAS different from other MCDM methods is that when comparing decision alternatives to each other, it gives a percentage of how good or bad one alternative is than the other [Ayçin, 2019]. COPRAS method can be used to evaluate quantitative and qualitative criteria, maximizing useful criteria in terms of criteria evaluation and minimizing useless criteria [Özbek, 2017].

The variables in the application stages of the method are defined as follows.

i. decision alternative (i = 1,2,…,m)

j. evaluation criteria (j = 1,2,…n)

w_j : j. weight of the evaluation criterion (j = 1,2,…n)

x_{ij} : j. according to the evaluation criteria i. the value of the alternative (j = 1,2,….,n)

d_{ij} : j. according to the evaluation criteria i. normalized value received by the alternative (j = 1,2,….,n)

COPRAS method consists of 6 steps (Kaklauskas et al., 2010) :

Step 1. The decision matrix is organized. This matrix is shown in equation 1.

$$D = [x_{ij}]_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \qquad (1)$$

Step 2. The decision matrix is normalized with the help of equation 2.

$$x_{ij}{}^{*} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \forall_j = 1, 2, \ldots n \qquad (2)$$

Step 3. The weighted normalized decision matrix (D ') is calculated with the help of equation 3 by multiplying the weight value (w_j) of each evaluation criterion with the elements of the normalized decision matrix.

$$D' = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mn} \end{bmatrix} \qquad (3)$$

Equation 4 is used for weighting the normalized decision matrix.

$$d_{ij} = x_{ij} * . w_j \qquad (4)$$

Step 4. For the criteria in the decision problem, the sum of the values in the weighted normalized decision matrix is found. The sum of the values in the normalized decision matrix weighted for maximization-oriented criteria is calculated using (S_{+i}) equality 5, and the sum of the values in the normalized decision matrix weighted for minimization-oriented criteria is calculated using (S_{-i}) equality 6.

$$S_{+i} = \sum_{j=1}^{k} d_{+ij} \, ; \, j = 1,2, \ldots k \qquad (5)$$

$$S_{-i} = \sum_{j=k+1}^{n} d_{-ij} \, ; \, j = k+1, k+2, \ldots, n \qquad (6)$$

Step 5. The relative importance value (Q_i) for each decision alternative is calculated with the help of equation 7.

$$Q_i = S_{+i} + \frac{S_{-min} \sum_{i=1}^{m} S_{-i}}{S_{-i} \, . \, \sum_{i=1}^{m} \frac{S_{-min}}{S_{-i}}} \qquad (7)$$

Step 6. Performance index values (P_i), for each decision alternative are calculated with the help of equation 8.

$$P_i = \frac{Q_i}{Qmax} \, . \, 100 \qquad (8)$$

RESEARCH FINDINGS

The significance levels of the criteria used to compare the domestic logistics performances of the countries were determined with the CRITIC method using the domestic LPI data of 2018, and then, the domestic logistics performances of the countries were ranked with the COPRAS method by using the criterion significance levels determined by the CRITIC method, and the results obtained were presented.

CRITIC Method Results

The CRITIC method was used to objectively determine the importance levels of criteria used in comparing domestic logistics performance levels of countries. The importance levels of the CRITIC method are given in Table 3. As a result of the ranking among the criteria according to importance levels, the most important criterion was determined as "without physical inspection" (K14), which is the sub-criterion of the customs clearance period. It has been found that physical inspection is much more common in underperforming countries.

Table 3. Criteria Significance Levels

	w_j
K1	0,060604
K2	0,046264
K3	0,051099
K4	0,045472
K5	0,059181
K6	0,055446
K7	0,045032
K8	0,045669
K9	0,067671
K10	0,092936
K11	0,088799
K12	0,050275
K13	0,044904
K14	0,093868
K15	0,057992
K16	0,048216
K17	0,046571

COPRAS Method Results

Evaluation scores and rankings of domestic logistics performances of Turkey and European Union countries are shown in Table 4. According to the results, the country with the best performance at the domestic logistics performance level was the Netherlands. Slovenia ranked second, third place in Denmark, while Turkey was ranked 18th in the ranking.

Table 4. Assessment Scores and Rankings of Countries

Countries	P_i	Ranking
Austria	50,91754	7
Belgium	46,14621	9
Bulgaria	36,86953	17
Czech Republic	34,12591	19
Denmark	54,51353	3
Finland	51,05663	6
France	45,51814	10
Germany	44,59158	11
Greece	39,92498	14
Italy	39,96112	13
Latvia	28,85904	21
Lithuania	53,042	4
Luxembourg	52,08858	5
Netherlands	99,99969	1
Poland	41,84792	12
Portugal	38,55304	16
Romania	33,84727	20
Slovenia	58,6326	2
Spain	47,86049	8
Sweden	39,16315	15
Turkey	35,55607	18

CONCLUSIONS AND RECOMMENDATION

In the world where global economies affect each other, one of the most important factors that enable countries to compete in national or international trade is the efficiency and productivity of their logistics performance. Logistics is one of the fastest growing sectors in the world, which has significant positive effects on a country’s economic and social development. It is very important to make regulations in the logistics sector in order to improve the trade capability of countries and increase international competitiveness [Çakır, 2016: 185; Yıldız et al., 2020].

LPI, created by the World Bank, is a comparing tool created to identify the threats and opportunities countries face in their logistics performance and improve their performance. Countries aim to increase their LPI scores and rank higher on the LPI list as they develop their strategies [Yildirim and Mercangoz, 2019]. LPI 2018 data of European Union countries and Turkey published by the World Bank was used in order to compare the performance of the domestic logistics of these countries by using CRITIC and COPRAS methods. Although there are many studies related to international LPI in the literature, no other studies using CRITIC and COPRAS methods have been found based on domestic LPI data. This aspect of the study is thought to make a new contribution to the literature.

Using the CRITIC method, the most important criterion was determined as "without physical examination", which is the sub-criterion of the customs clearance period. Countries with low logistics performance need to reduce bureaucratic procedures, physical inspections and excessive and non-transparent procedures. In addition, in order to improve the performance of these countries, it is necessary to improve customs practices in particular and to reform non-customs institutions.

As a result of the domestic logistics performance ranking obtained by the COPRAS method, the top three countries have been found to be the Netherlands, Slovenia and Denmark, while Turkey was 18th. Domestic logistics performance ranking of 18th among 20 European Union countries located in Turkey, unfortunately, is not at the desired level logistics performance in the domestic rankings. The desired level can be reached by eliminating the coordination deficiencies in state institutions, having sufficient training level of logistics personnel, ensuring efficient and fast operations by reducing customs procedures, widespread use of information technology and eliminating infrastructure deficiencies.

In Turkey, especially many ports and organized industrial zones do not have railway connections, about 95% of the transportation is carried out by road. The use of railways in the transportation of cargo handled in Hamburg Port is 70%, in Anvers Port 19%, and 1% in Alsancak Port. Due to the lack of infrastructure, combined transport, which allows fast and economical transport, cannot be made, and road-weighted transport, which is the most expensive mode of transport, becomes a necessity. At this point, the share of rail freight transport should be increased, the shortcomings of the sea and airline should be eliminated and combined transport, which is the cheapest and most economical transport model in transport, should be made more common. However, adapting to the logistics sector of the industry 4.0 technology and logistical advantages which have naturally within the scope of the work carried out by the Logistics Master Plan of Turkey, it will be possible to take more market share in international trade and logistics.

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REFERENCES

Aksungur M., Bekmezci M., 2020. Logistics Performance Evaluation of Turkey: A Dimensional Research. Toros University Faculty of Economics and Administrative Sciences Journal of Social Sciences,7(12), 20-40.

Ayçin E., 2019. Multi Criteria Decision Making: Computer Applied Solutions. Nobel Academic Publishing.

Başar S.İ., 2017. Evaluation of Logistic Performance of Central Asian Turkish Republic. TURAN-SAM, 9(35), 192-198, http://dx.doi.org/10.15189/1308-8041.

Bayır T., Yılmaz Z., 2017. Assesment of Logistic Performance Indexes of EU Countries By AHP And VIKOR Methods. Middle East Journal of Education (MEJE) 3(2), 73-92.

Bozkurt C., Mermertaş F., 2019. Comparison of Turkey and the G8 Countries According to the Logistics Performance Index. Journal of Business and Economics Studies, 7(2), 107-117.

Candan G., 2019. Integrated Approach of Fuzzy AHP and Grey Relational Analysis For Logistic Performance Evaluation. Anemon Muş Alparslan University Journal of Social Sciences, 7(5), 277-286, http://doi.org/10.18506/anemon.506769.

Civelek M.E., Uca N., Cemberci M., 2015. The Mediator Effect of Logistics Performance Index on the Relation Between Global Competitiveness Index and Gross Domestic Product. European Scientific Journal 11 (3), 368–375.

Çakır S., 2017. Measuring Logistics Performance of OECD Countries via Fuzzy Linear Regression. Journal of Multi-Criteria Decision Analysis, 24(3-4), 177-186, http://doi.org/10.1002/mcda.1601.

Çatuk C., 2019. The Effect of Highway on Logistics Performance in International Trade. Al Farabi International Journal of Social Sciences, 3(4), 120-125.

Diakoulaki D., Mavrotas G., Papayannakis L., 1995. Determining Objective Weights in Multiple Criteria Problems: The CRITIC Method. Computers and Operations Resarch, 22(7), 763-770, http://doi.org/10.1016/0305-0548(94)00059-H.

Dijkman J., 2009. Germany Real Estate Yearbook 2009: Assets, Industry Trends and Market Players. Real Estate Publishers BV.

Emanet H., 2017. Analysis of Logistics Performances of Central Asian Turkish Republics within the Context of Logistics Performance Index. International Conference on Eurasian Economies, Session 2C, 302-309.

Erkan B., 2014. The Importance and Determinants of Logistics Performance of Selected Countries. Journal of Emerging Issues in Economics, Finance and Banking, 3(6), 1237-1254.

Erturgut R., Gürler H.E., 2019. The Relationship Between Civilization and Logistics Performance of the Countries in the Logistics Performance Index: The Example of Denmark-Austria. In 8th Eurasian Conference on Language and Social Sciences, 252, http://doi.org/10.35578/eclss.52775.

Görgün M.R., 2020. The Situation of Turkish Logistics Sector in Logistics Performance Criteria. EKEV Academy Journal, 24(81), 229-246.

İmamoğlu İ.K., 2019. Comparison by Turkey and Logistics Performance of The Shanghai Cooperation Organization (Sco) Member Countries. The Journal, 12(68), 1143-1154, http://doi.org/10.17719/jisr.2019.3901.

Isik O., Aydin Y., Kosaroglu S.M., 2020. The Assessment of The Logistics Performance Index of CEE Countries with the New Combination of SV And MABAC Methods. LogForum, 16(4), 549-559, http://doi.org/10.17270/J.LOG.2020.504.

Kaklauskas A., Zavadskas E.K., Naimavicienė J., Krutinis M., Plakys V., Venskus D., 2010. Model for a Complex Analysis of Intelligent Built Environment. Automation in Construction, (19), 326–340, http://doi.org/10.1016/j.autcon.2009.12.006

Karaköy Ç., Ölmez U., 2019. Evaluation of the LPI Values of Balkan Countries. SETSCI Conference Proceedings 4 (8), 178-180, https://doi.org/10.36287/setsci.4.8.031.

Kılınç E., Fidan O., Mutlu H.M., 2019. Comparison of Turkey, China and Russian Federation According to the Logistics Performance Index. International Journal of Economic Studies, 5(2), 17-34.

Kısa A.C.G., Ayçin E., 2019. Evaluation of the Logistics Performance of OECD Countries with EDAS Method Based on SWARA. Çankırı Karatekin University Faculty of Economics and Administrative Sciences Journal, 9(1), 301-325, http://doi.org/10.18074/ckuiibfd.500320.

Madic M., Radovanović M., 2015. Ranking of Some Most Commonly Used Nontraditional Machining Processes Using ROV and CRITIC Methods. UPB Sci. Bull., Series D, 77(2), 193-204.

Martí L., Puertas R., García L., 2014. The Importance of the Logistics Performance Index in International Trade. Applied Economics 46 (24), 2982–2992, http://doi.org/10.1080/00036846.2014.916394.

Martí L., Martín J.C., Puertas R., 2017. A DEA-Logistics Performance Index. Journal of Applied Economics, 20(1), 169-192, http://doi.org/10.1016/S1514-0326(17)30008-9.

Mercangoz B. A., Yildirim B., Yildirim S.K., 2020. Time Period Based COPRAS-G Method: Application on The Logistics Performance Index. LogForum, 16(2), 239-250, http://doi.org/10.17270/J.LOG.2020.432.

Oğuz S., Alkan G., Yılmaz B., 2019. Evaluation of Logistics Performance of

Selected Asian Countries' by TOPSIS Method. IBAD Journal of Social Sciences, (Special Issue), 497-507, http://doi.org/10.21733/ibad.613421.

Orhan M., 2019. Comparison of the Logistics Performance Between Turkey and European Union Member Countries with ENTROPY Weighted EDAS Method. European Journal of Science and Technology, (17), 1222-1238, http://doi.org/10.31590/ejosat.657693.

Ozmen M., 2019. Logistics Competitiveness of OECD Countries Using an Improved TODIM Method. Sādhanā, 44(5), 108, http://doi.org/10.1007/s12046-019-1088-y.

Özbek A., 2017. Performance Evaluation of Turkey Diyanet Foundation By SAW, COPRAS and TOPSIS Method. Journal of Management and Economics Studies, 15(1), 66-84, http://doi.org/10.11611/yead.277484.

Rashidi K., Cullinane K., 2019. Evaluating the Sustainability of National Logistics Performance Using Data Envelopment Analysis. Transport Policy, (74), 35-46, http://doi.org/10.1016/j.tranpol.2018.11.014

Rezaei J., van Roekel W.S., Tavasszy L., 2018. Measuring the Relative Importance of the Logistics Performance Index Indicators Using Best Worst Method. Transport Policy, (68), 158-169, http://doi.org/10.1016/j.tranpol.2018.05.007

Sofyalıoğlu Ç., Kartal B., 2013. A Comparison and Some Suggestions for Turkey's and Eurasian Economic Community Countries' Logistic Performance Index Scores. In International Conference on Eurasian Economies, Session 7B, 524-531, http://doi.org/10.36880/C04.00766.

Uca N., Civelek M.E., Çemberci M., 2015. The Effect of the Components of Logistics Performance Index on Gross Domestic Product: Conceptual Model Proposal. Eurasian Business & Economics Journal, (1), 86-93, http://doi.org/10.17740/eas.econ.2015-V1-04.

Ulutaş A., Karaköy Ç., 2019a. The Measurement of Logistics Performance Index of G-20 Countries with Multi-Criteria Decision Making Model. Cumhuriyet University Journal of Economic and Administrative Sciences, 20(2), 71-84.

Ulutaş A., Karaköy Ç., 2019b. An Analysis of the Logistics Performance Index of EU Countries with an Integrated MCDM Model. Economics and Business Review, 5(4), 49-69, http://doi.org/10.18559/ebr.2019.4.3.

Yangınlar G., 2019. The Comparison Logistics Performance and GDP Between G7 Countries and Turkey. V. European Congress on Economic Issues 2019 Proceedings Book, 68-80.

Yapraklı T.Ş., Ünalan M., 2017. The Global Logistics Performance Index and Analysis of The Last Ten Years Logistics Performance of Turkey. Journal of Economic and Administrative Sciences, 31(3), 589-606.

Yildirim B.F., Mercangoz B.A., 2020. Evaluating the Logistics Performance of OECD Countries by Using Fuzzy AHP and ARAS-G. Eurasian Economic Review, 10(1), 27-45, http://doi.org/10.1007/s40822-019-00131-3.

Yıldız A., Aydoğan K., Kartum G., 2020. An Investigation of Turkey's Position in International Logistics Performance Index By Cluster Analysis. Turkish Studies - Social, 15(3), 1659-1679, http://doi.org/10.29228/TurkishStudies.41640.

Zavadskas E., Kaklauskas, 1996. A Multiple Criteria Evaluation of Buildings; Technika: Vilnius, Lithuania.

PORÓWNANIE KRAJOWEJ DZIAŁALNOŚCI LOGISTYCZNEJ W TURCJI ORAZ KRAJACH UNII EUROPEJSKIEJ W 2018 W STOSUNKU DO ZINTEGROWANEGO MODELU

STRESZCZENIE. **Wstęp:** Wskaźnik Logistics Performance Index (LPI), utworzony prze Bank Światowy, służy do benchmarkingu w określaniu zagrożeń i możliwości dla krajów w ich działalności logistycznej oraz dla działań w celu poprawy tej działalności. Państwa dążą do poprawy wartości swojego wskaźnika LPI poprzez ciągła poprawę swojej strategii działania.
Metody: Celem pracy jest porównanie wskaźników krajowej działalności logistycznej Turcji oraz krajów Unii Europejskiej ze zintegrowanym modelem w oparciu dane za 2018 rok, opublikowane niedawno przez Bank Światowy. W tym celu wpierw określono ważność poszczególnych kryteriów przy pomocy metody CRITIC (Criteria Importance Through Intercritera Correlation), a następnie utworzono ranking krajów dotyczących ich działalności logistycznej przy użyciu metody COPRAS (Complex Proportional Assessment).
Wyniki: Używając metodę CRITIC, ustalono, że najważniejszym kryterium w ranking było kryterium „bez badania fizycznego", które jest podkryterium w okresie odpraw celnych. Holandia umiejscowiła się na pierwszym miejscu rankingu stworzonego przy użyciu metody COPRAS.
Wnioski: Prezentowana praca różni się od prac obecnie publikowanych użyciem metody porównawczej, wykorzystującej metody CRITIC oraz COPRAS w odniesienie do zintegrowanego modelu. Jednak otrzymane wyniku mogą być porównywane z wynikami uzyskanymi przy zastosowaniu innych modeli zintegrowanych oraz na podstawie innego zestawu danych.

Słowa kluczowe: Logistics Performance Index (LPI), wielokryterialne podejmowanie decyzji (MCDM), CRITIC, COPRAS

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ORIGINAL PAPER

INNOVATION STRATEGIES IN THE CONTEXT OF THE PARADIGM OF THE FIVE DIMENSIONS OF INNOVATION STRATEGY

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ABSTRACT. **Background:** As a concept that is owned and discussed by many business disciplines the terms innovation and innovation strategy can have many different definitions. This paper aims to provide an overview of innovation strategies in the context of the paradigm of the five dimensions of innovation strategy first introduced by Trilling & Blaeser-Benfer. A literature review was used to generate a representative pool of definitions of the term innovation, including definitions from the different disciplinary literature sources of economics, innovation and entrepreneurship, business and management, and technology. In a second step the core essences of the accumulated definitions are synthesized into a final definition of innovation. In a third step the synthesized definition of innovation is applied to the context of the paradigm of the five dimension of innovation strategy to allow the establishment of a coherent and cohesive overview of the resulting innovation strategies.

Methods: This paper utilizes a first analysis of literature on innovation and innovation strategies which includes a number of academic journal articles and books, in total 23 sources, published between the years 1987 to 2019 to achieve its mentioned aim.

Results: The central aim of this paper can be identified in providing a comprehensive overview of the topic of innovation strategies in the context of the paradigm of the five dimensions of innovation strategy and the presented definition of the term innovation.

Conclusions: The information presented in this paper can serve as a clarifying starting point for further research activities in the field innovation and innovation strategy by providing a general overview of the topics mentioned. Based on the findings of this paper it appears reasonable to recommend further research to specify the characteristics and practical applicability of possible innovation strategies in different innovation dimensions.

Key words: innovation, strategy, innovation strategy, definition of innovation, five dimension of innovation, review innovation.

INTRODUCTION

Innovation is one of the key factors of the success of a company and is an essential strategic component to survive in a growing competitive market environment. Innovation does not have to be an accident, with a well-defined strategy a company can control and manage the generation of innovation [Disselkamp 2017, Janjić, Rađenović 2019, Jia, 2019]. But there are many definitions of the term innovation and a variety of meanings and approaches for innovation strategies exist [Baregheh, Rowley, Sambrook 2009]. At first this paper introduces a possible definition for the term innovation by describing and synthesizing relevant definitions that can be found in the reviewed academic literature. After this, this paper is concerned with the definition of the terms strategy and innovation strategy. As the final result of this paper a description for the five dimensions of innovation strategies and an exemplary approach for each innovation strategy dimension is provided in an overview. Therefore, the central aim of this paper can be

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identified in providing a comprehensive overview of the topic of innovation strategies in the context of the paradigm of the five dimensions of innovation strategy and the presented definition of the term innovation in this paper. This paper utilizes a review of literature on innovation and innovation strategies to achieve its mentioned aim. Therefore, a number of academic journal articles and books, in total 23 sources, published between the years 1987 to 2019 have been analyzed in the light of innovation and innovation strategies. This literature review is a critical foundational analysis of published sources and literature on the particular topic of innovation and strategies for innovation.

DEFINITION OF INNOVATION

The term innovation is of Latin origin and means renovation or change. In general innovation stands for the three-step process of an idea, invention and diffusion (Fadiah et.al., 2016). Therefore, in a business context innovation can be conceptualized as an incidence (idea) for a product or a service (invention) which has not been there before and which results in a high market acceptance (diffusion) [Dörr and Müller-Prothmann 2014]. Notation 1 results for this article to define the term innovation.

idea + invention + diffusion = innovation (1)

This definition is in agreeance with most of the definitions shown in Table 1 and shall be applied for this paper. Notation 1 makes clear that in the context of innovation the differentiation and separation between the terms invention and innovation is of high relevance [Dörr and Müller-Prothmann 2014]. The difference between the terms can be identified in the circumstance that invention only means the creation of a product or service based on an idea, but innovation always includes the successful diffusion of a solution for an existing problem which results in a high market acceptance of the idea and its manifestation in the form of an invention. Thus, the novelty of an invention is not necessarily the key factor of an innovation. The important aspect is that the included invention has not necessarily to be novelty but the change it causes has to be [Granig and Hartlieb and Lercher 2014]. Therefore, notation 2 results.

The change an invention causes must be novel. (2)

To analyze innovation strategies, it is of high importance to provide a clear definition for all relevant terms. Therefore, the following section presents definitions for the terms innovation and strategy and the combination innovation strategy. As already mentioned in the introduction, the term innovation can be defined in various ways. Table 1 provides an overview about established definitions of the term innovation of the last 90 years.

An example is now introduced to demonstrate the described main characteristics of innovation as established by notation 1 and 2. An employee from the company 3M, Mr Silver, got the task to evolve a glue for several applications (idea). In 1968, he developed a slightly adhesive glue (invention), but at this point there was no interest of the market for this specific glue. After six years a colleague, Mr Fry, has searched for something which could be helpful to mark something but can be removed. He improved the idea of Mr Silver and developed the post-it-note. Caused by a high market acceptance (diffusion) the idea became an innovation and it is still used [Hutzschenreuter 2009]. The provided example illustrates the described the process of idea, invention und diffusion which results in the creation of an innovation.

DEFINITION OF INNOVATION

According to N. Fadiah et.al. [2016] and C. Li [2020] there are two main dimensions of innovation in which innovation could be arised: Technological innovation and administrative/managerial innovation [Fadiah et.al. 2016, C. Li 2020].

The dimension of technological innovation shall be defined as the development of a technological idea to an invention which has a direct and successful impact on the economic performance of the company offering the invention to the market. Technological innovation can be represented by new technologies manifesting in new physical products or new service products [Fadiah et.al. 2016]. The innovation dimension administrative / managerial innovation shall now be defined as innovations which have an impact on the social aspects of a company. The social aspect has a major influence on the general performance of a company. Administrative/managerial innovation involves changes of elements associated with the organization's social structure. This innovation dimension could be new policies, new procedures, organizational forms, encourage expansions, reward staff's creativity, exploring best method to achieve corporate goals.

The differentiation between the two dimensions of innovation therefore involves the extent of the change impacting company core operations. Technological innovation affects all object- or service-related innovations and reflects changes in the end product or service offered by the company while administrative/managerial innovation involves changes in the social structures of a company which only indirectly impact the end product or service offered [Fadiah et.al. 2016]. Notation 3 results.

Innovation can manifest in the innovation dimension of technological or administrative/managerial innovation. (3)

As a summary, the following notations are established as a foundation to define the term innovation for this paper.

idea + invention + diffusion = innovation (1)

The change an invention causes must be novel. (2)

Innovation can manifest in the innovation dimensions of technological or administrative / managerial innovation. (3)

A definition of term innovation can now be established through the synthesis of the established notation 1, 2, and 3: An innovation is an idea located either in the technological or administrative/managerial dimension and which is developed to an invention which again has a concrete solution for an existing problem, is well-accepted by a high number of people and causes novel change. Based on this definition it is now possible to discuss the term innovation strategy in a coherent and precise fashion.

INNOVATION STRATEGY

In the context of defining strategy, Henry Mintzberg states that a strategy is a plan which has some sort of consciously intended course of action and furthermore a strategy is a guideline to deal with a situation [Mintzberg 1987]. If a company wants to develop an innovation, it needs a plan in the form of precise course of action to generate innovation for a given corporate context. Since the previous section defined the term innovation, the term innovation strategy is now defined as: An innovation strategy can be described as a scope of actions for all innovative procedures in an organization which includes strategic goals and guidelines which have the vision to develop innovation [Goffin, Herstatt, Mitchell 2012].

According to Trillig and Blaeser-Benfer [2014], an innovation strategy can be achieved within a paradigm of five dimensions: Technological-orientated, time-orientated, market-orientated, competition-orientated and cooperation-orientated [Trillig, Blaeser-Benfer 2014]. The following now describes the different dimensions of an innovation strategy and provide concrete approaches for each dimension.

A **technological-orientated innovation strategy** contributes to the development of new products or services. In this context Varadarajan states that innovation of a product means an idea for a new product which meets a currently unmet need of customers or an idea which is better than existing products or represents an improvement of an available product [Varadarajan 2018]. One possible approach to generate technologic al-orientated innovation is the technological-push strategy. This strategy firstly emanates from a company by developing a specific product or service and then "pushing" it in the market hoping for diffusion [Corniani 2008]. The most common approach of companies for this strategy is focusing on research and development (R&D) activities.

A **time-orientated innovation strategy** is defined based on the diffusion theory of Rogers. In his diffusion of innovation approach, he defines diffusion as the process in which an innovation is spread over a certain time through several communication channels among of members of a social system. According to Rogers [1993] diffusion consists out of four elements: innovation, communication channels, time and the social system [Rogers 1993]. The pioneer strategy is one possible approach to realize a time-orientated innovation strategy. It is also known as the "first-to-market" approach and it is the strategy for the first element of diffusion, the innovation element. It describes the idea, that a company wants to generate innovation and wants to be the first market participant (inventor) which offers a new innovation to the market and aims to capitalize from a first mover advantage that outweighs the costs of being a first mover. The first mover advantages can span over a long time and can be helpful for generating higher market shares or brand proliferation [Robison, Urban, Kalyanaram 1994].

The **market-orientated innovation strategy** could be defined as the opposite of the technological-orientated strategy. It has the focus on understanding and defining the most relevant needs of a specific market and to develop an innovation which fits the identified market needs [Corniani 2008]. The most common approach is the pull strategy which focuses on the customer needs. Through intensive customer surveys a company wants to obtain information about the most important customer needs. After an understanding process of the needs an innovation is generated which fits the identified customer needs.

The position of a company in comparison to its competitors is one major success factor. The theory which underlies the competition-orientated strategy is the approach from M. E. Porter. He describes the strategy of companies in comparison to its competitive environment. In Porters theory there are two dimensions which are of high importance to define a **competition-orientated strategy** [Porter 2013]: Strategic advantage (separated into unique perceived by customer and low-cost position) and strategic target (separated into industrywide and particular segment only). By putting these dimensions into relationship three main competition-orientated strategies may result: Differentiation, overall cost leadership and focus strategy [Porter 2013].

Differentiation (unique perceived by customer/industrywide): A company with a differentiation strategy is outstanding in comparison to its competitors through a high standard of quality. All innovations underlay the permission of quality and have to please the customer [Porter 2013].

Overall cost leadership (Low cost position/industrywide): A company with an overall cost leadership strategy is confronted with a high number of competitors. Its success factor is represented by low cost production which allows the company to offer their products or services for a low price. For this strategy companies have to develop especially innovations which simplify processes or products to get the opportunity to decrease the production cost [Porter 2013].

Focus (Particular segment): The idea of this strategy is to serve a specific market segment and not the overall market. The number of competitors is low and a company which follows this strategy must generate a combination of differentiation and cost leadership with the focus on the specific needs of the customer in the market segment. Therefore, all innovations have to consider customer needs [Porter 2013].

The general approach of **cooperation-orientated innovation strategies** is that a company opens itself to the environment and thus consults external influences for the innovation process. This strategy is mostly used by small and medium-sized enterprises which have imitated resources for the innovation process and need help form external partners [Sarpong, Teirlinck 2017]. There is a high diversity of collaboration types, for example research joint ventures, non-equity contractual collaborations and joint projects, formal and informal arrangements [Antonioli, Marzucchi, Savona 2016]. One popular approach for a cooperation-orientated innovation strategy is the open innovation approach. This approach is proposed by H. W. Chesbrough. The open innovation concept provides insights into how firms can harness inflows and outflows of knowledge to improve their innovation success [Enkel, Gassmann, Chesbrough, 2009]. The next section now summarizes all described strategic dimensions and their resulting strategies. Table 2 gives an overview about the mentioned innovation strategy dimensions and each concrete innovation strategy.

CONCLUSIONS

This paper introduces, reviews and discusses possible definitions for the terms innovation and innovation strategy which are extracted out of a selection of relevant academic sources. Through this, it is shown that both terms can have various meanings for different contexts. Based on the reviewed literature a precise definition of the term innovation is introduced and applied to definition of the term innovation strategy for this paper. This is achieved by synthesizing the identified main characteristics of the term innovation and applying it to Mintzbergs definition of the term strategy. Five dimensions of innovation strategy are identified and for each dimension one possible innovation strategy was described.

This article shows that the research topic innovation and innovation strategy have a high level of diversity and variety. The information presented in this paper can serve as a clarifying starting point for further research activities in the field innovation and innovation strategy by providing a general overview of the topics mentioned. Based on the findings of this paper it appears reasonable to recommend further research to specify the characteristics and practical applicability of possible innovation strategies in different innovation dimensions. Furthermore, the varying origins and perspectives impacting the definition of innovation make it appear reasonable to further analyze how these differences can be described and specified, for example in terms of geographical and cultural differences in the definitions of innovation.

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REFERENCES

Antonioli D., Marzucchi A., Savona, M., 2016. Pain shared, pain halved? Cooperation as a coping strategy for innovation barriers. Springerlink 42, 841-864. http://doi.org/10.1007/s10961-016-9545-9

Baregheh A., Rowley J., S. Sambrook, 2009. Towards a multidisciplinary definition of innovation. Management Decision 27 (8), 1323-1339. http://doi.org/10.1108/00251740910984578

Bogers M, Chesbrough H., Moedas C., 2018. Open Innovation: Research, Practices, and Policies. California Management Review 60 (2), 5-16.

Corniani M., 2008. Push and Pull Policy in Market-Driven Management. SYMPHO-NYA Emerging Issues in Management 1. http://doi.org/10.4468/2008.1.05

Disselkamp M, 2017. Innovationen und Veränderungen [Innovation and Changes]. Stuttgart: Kohlhammer.

Dörr N., Müller-Prothmann T, 2014. Innovationsmanagement: Strategien, Me-thoden und Werkzeuge für systematische Innovationsprozesse. [Innovation Management: Strategies, methods and tolls for systematical innovation processes], München: Hanser.

Enkel E., Gassmann O., Chesbrough H., 2009. Open R&D and open innovation: exploring the phenomenon. R&D Management 39 (4), 311-316.

Fadiah N. et.al., 2016. Defining the Concept of Innovation and Firm Innovativeness: A Critical Analysis from Resorce-Based View Perspective. International Journal of

Business and Management 11 (6), 87-94. http://doi.org/10.5539/ijbm.v11n6p87.

Goffin K., Herstatt C., Mitchell R., 2012. Innovationsmanagement: Strategien und effektive Umsetzung von Innovationsprozessen mit dem Pentathlon-Prinzip [Innovation management: Strategies and efficient implementation of innovation processes through Pentathlon principle], München: Finanzbuchverlag.

Granig P., Hartlieb E., Lercher, H., 2014. Innovationsstrategien: Von Produkten und Dienstleistungen zu Geschäftsmodell-innovationen [Innovation strategies: From product to services for innovations of society models], Wiesbaden: Springer.

Hutzschenreuter T., 2009. Strategisches Management und Innovationsmanagement, Allgemeine Betriebswirtschaftslehre: Grundlagen mit zahlreichen Praxis-beispielen [Strategic management and innovation management: General business studies and case studies], Wiesbaden: Gabler. 394.

Janjić I., Rađenović T., 2019. The importance of managing innovation in modern enterprises. Ekonomika 65 (3), 45-54. http://doi.org/10.5937/ekonomika1903045J

Li C., 2020. Enhancing or inhibiting: The impact of investment in political ties on the T link between firm innovation and productivity. International Business Review 29 (2). http://doi.org/10.1016/j.ibusrev.2019.101636

Mintzberg H., 1987. The Strategy Concept 1: 5 Ps for Strategy. California Management Review 30 (1), 11-24.

Jia N., 2019. The impact of accounting restatements on corporate innovation strategy. Journal of Account. Public Policy 38 (3). http://doi.org/10.1016/j.jaccpubpol.2019.05.004

Popa I. L., Preda G., Boldea M., 2018. A theoretical apporoach of the concept of innovation. Philosophical Journal of Conflict and Violence 2 (1).

Porter M. E., 2013. Typen von Wettbewerbsstrategien in Wettbewerbsstrategie: Methoden zur Analyse von Branchen und Konkurrenten [Types of competition strategies in competition strategies: Methods for analyzing of industries and competitors], Frankfurt am Main, Campus, 73-87.

Quintane E., et. al, 2011. Innovation as a knowledge-based outcome. Journal Of Knowledge Management 15 (6), 928-947. http://doi.org/10.1108/13673271111179299

Robison W.T., Urban G.L., Kalyanaram G., 1994. First-Mover Advantages from Pioneering New Markets: A Survey of Empirical Evidence. Review of Industrial Organization 9, 1-23.

Rogers E.M., 1993. Diffusion of innovations. New York, London: The free Press.

Trillig E., Blaeser-Benfer A., 2014. Erfolgsfaktor 1: Die Innovationsstrategie [Factor of success, strategy of innovation]. RKW Rationalisierungs- und Innovationszentrum der Deutschen Wirtschaft e. V.

Sarpong O., Teirlinck P., 2017. The influence of functional and geographical diversity in collaboration on product innovation performance in SMEs. Springer Science+Business Media 43, 1667-1695. http://doi.org/10.1007/s10961-017-9582-z

Varadarajan R., 2018. Innovation, innovation strategy, and strategic innovation. Review of Marketing Research 15, 143-166. http://doi.org/10.1108/S1548-643520180000015007

STRATEGIE INNOWACJI W KONTEKŚCIE PARADYGMATU PIĘCIU WYMIARÓW STRATEGII INNOWACJI

STRESZCZENIE. **Wstęp:** Na podstawie wielu istniejących dyscyplin terminy innowacja i strategie innowacji mogą mieć wiele definicji. Niniejsza praca ma na celu przedstawienie przegląd strategii innowacji w kontekście paradygmatu pięciu wymiarów strategii innowacji wprowadzonej po raz pierwszy przez Trilling & Blaeser-Benfer. Przeprowadzony przegląd literatury miał na celu stworzenie takiego terminu innowacja, który byłby interdyscyplinarny, tworzony na podstawie źródeł literaturowych z dziedziny ekonomii, przedsiębiorczości, biznesu i zarządzania oraz technologii. Kolejny etap pracy to sformułowanie ostatecznej definicji innowacji. Ostatni etap pracy to zastosowanie definicji innowacji w kontekście paradygmatu pięciowymiarowej strategii innowacji, aby umożliwić ustanowienie spójnego przeglądu powstałych strategii innowacji.

Metody: W niniejszej pracy dokonano analizy światowej literatury na temat strategii innowacji i innowacji. Przeanalizowano łącznie 23 pozycje literaturowe, które zostały opublikowane w latach 1987-2019.

Wyniki: Głównym celem niniejszej pracy był przegląd literatury w temacie strategii innowacji w kontekście paradygmatu pięciu wymiarów strategii innowacji i wyjaśnienie przedstawionej definicji innowacji.

Wnioski: Informacje przedstawione w niniejszej pracy mogą służyć jako punkt wyjścia dla dalszych działań badawczych w dziedzinie innowacji i strategii innowacji poprzez podsumowanie aktualnego przeglądu we wspomnianych tematach. Na podstawie wniosków zawartych w niniejszej pracy uzasadnione wydaje się prowadzenie dalszych badań w celu określenia cech i praktycznego zastosowania możliwych strategii innowacji w różnych wymiarach innowacji.

Słowa kluczowe: innowacje, strategia, strategia innowacji, definicja innowacji, pięciowymiarowy wymiar innowacji, przegląd innowacji

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ORIGINAL PAPER

IMPACT OF REVERSE LOGISTICS BARRIERS ON SUSTAINABLE FIRM PERFORMANCE VIA REVERSE LOGISTICS PRACTICES

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ABSTRACT. **Background:** Due to the industrial revolution, extensive production, more raw materials are consumed, which are enough for landfills and disturbing environmental integrity. RL is an established concept in developed countries in comparison to developing countries. RL implementation is in its infancy due to some barriers. Therefore, the purpose of this study is to identify the RL barriers through literature review and to check their effect on the adoption of RL practices and to explain either they influence the firm performance or not.

Method: Data were collected from the employees of manufacturing companies and relevant government institutes and later were analyzed by using the structural equation modelling technique. A novel structural model connecting all study variables was developed to verify the impact of RL barriers on sustainable firm performance.

Results: Study results show that Infrastructure & technology, Financial & economic, Knowledge & experience-based barriers are critical and negatively affect the adoption of RL practices. The adoption of RL practices has a positive effect on the company's economic and environmental performance both. Further, the mediating role of adoption of RL practices between RL barriers and firm performance was also found.

Conclusion: The results of this research help to extend literature presenting that the ecological modernization and new environmental laws and regulation should be integrated with enterprises to mitigate infrastructure & technology, financial & economic and knowledge & experience related barriers by conducting proper training programs and promoting sustainability among company's top management.

Key words: sustainability, reverse logistics adoption, barriers, manufacturing companies, Pakistan.

INTRODUCTION

The reverse logistics (RL) started to get attention from the mid-1980s. The primary focus of these studies was to promote sustainability through internal, external and practical integration of RL processes and procedures. Since customers have become more sensitive in their buying and using, the demand for innovative and environmentally friendly products has been increased. In the current era, competitiveness is becoming more powerful tool in manufacturing sectors that directs to produce innovative products and services and bringing significant improvement in firms. However, world's concern about climate changes is becoming an indispensable issue. More recently, the impact of manufacturing industry has significantly increased on soil, water, and air pollution, to cope with this situation, RL is considered as an effective tool to recover these aspects [Waqas, Dong et al. 2018].

Reverse flow of different used products, recycling and reusing it as a raw material by manufacturing industry has been getting attention from past few decades. Developing the reverse flow of used products is not only

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the responsibility of manufacturing industry, but consumers may also have the responsibility as being the integral part of industrial manufacturing and recycling process. Recently, RL is start attracting both scholars and manufacturers in whole world but unfortunately it is at early stages in developing economies especially in Pakistan due to various constraints.

Rapid urban population, development in technology, the production, and utilization of shortening lifecycle products and services have increased worldwide. Massive production required massive raw material consumption in production process, which is enough for landfills and are filling up. However, the cost of used product reprocessing is higher than the cost of landfilling in Europe. Therefore, manufacturing firms in developing world preffered to dumped it in open environment without any proper treatment [Abdulrahman, Gunasekaran et al. 2014] . "Reverse logistics (RL) is a process of dealing with products and services that have been retuned by customers to the company with the objective of worth creation, cost reduction and environmental protection" [Govindan and Bouzon 2018]. Implementation of RL practices can assist the manufacturers how to reduce their impact on world ecological system by lessening the effect of end-of-life goods on the atmosphere. Furthermore, the companies have been influenced by various constraints to implementing the RL practices. However, it's not easy to overcome these barriers [Abdulrahman, Gunasekaran et al. 2014].

Commonly, barriers and issues related to RL tend to be a forward step to bring sustainability within the industry [Govindan and Bouzon 2018] and all those manufacturing companies that protect and meet the environmental standard may confront various challenges in their operations. Though, in literature, very few studies identify the barriers to adoption of RL practices.

Practices of RL includes many activities e.g. waste management, recycling, reusing, reprocess, material recovery and design for RL which can help any organizations to convert their opportunities into profit [Wang, Jiang et al. 2019]. Therefore, adoption of RL practices have more potential for increasing the performance of RL and also add a greater impact on firms' economic performance (ECP) and environmental performance (ENP) in manufacturing industry. RL practices are the main drivers for application of sustainable development in manufacturing firms. Moreover, the research articles that provide the discussion of RL practices and barriers and drivers, focus on reverse logistics performance, product transformation and innovation [Cordano, Marshall et al. 2010]. Therefore, the direct link among RL barriers and RL practices is still ambiguous. The direct and indirect impact of RL barriers and RL practices on manufacturing firm's performance indicators also needs better understanding in literature, because till present the majority of scholars evaluated the RL barriers and RL practices from the economic viewpoint [Waqas, Dong et al. 2018]. Unfortunately, after searching the comprehensive literature review a few research articles were found on adoption of RL practices and manufacturing industry performance in perspectives of ECP and ENP indicators.

On the behalf of above-mentioned studies and in association with Subramanian and Abdulrahman [2017], who has developed a framework to understand the role of RL barriers in application of RL activities and to enhance the manufacturing industry performance in perspective of ECP and ENP. The key determination of current paper is to evaluate the barriers and issues to RL and to check their impact on adoption of RL practices and to explain either they influence the firm performance or not. Barriers to reverse logistics may differ from context to context and as well as may differ from company to company and country to country [Govindan and Bouzon 2018]. The major contribution of the article is as follow:

According to authors best knowledge and literature, the current study gathered various significant concepts in one conceptual framework including, till present that were treated individually in the previous researches. Theoretical and hypothetical implications are applied on environmental modernization, ECP and ENP with the glance of manufacturing firms of Pakistan. This study develops a complete understanding of barriers to RL that can be related to improving RL practices helping concern authorities to implement reverse logistics and to attain a better fit among RL practices and firm performance.

This study is conducted on manufacturing industry of Pakistan, a most populous country at the face of earth with 211 million inhabitants and positioned at number 6th in world population. In South Asia, Pakistan is the second largest economy with 988.2 billion GDP with 4.7 growth rate [US.CIA 2016]. Identifying the barriers affecting adoption of RL practices and its role in improving firm performance is necessary because Pakistan is standing at number 7th in the world which is most affected by global warming. On the other hand, due to environmental threats to Pakistan, Pakistan environmental protection agency (PAK-EPA) has introduced the new policy environment which is national policy on solid waste of Pakistan (NPSWP) under the section 13 & 14 of Pakistan environmental protection Act, Hazardous Substance Rule (2003) and its new contracts with European Union (EU) at Generalised Scheme of preferences (GPS+) to "promote sustainable development and good governance" in beneficiary nations. Furthermore, recent research in other developing countries evaluated barriers to RL in China, Indian [Chaudhary, Mathiyazhagan et al. 2017] and Brazil [Govindan and Bouzon 2018], but unfortunately there is no such kind of empirical research exist in Pakistan. As, Pakistani managerial style is different from other developing countries in term of cultural attitude toward adopting new environmentally friendly practices. Pakistani manufacturing companies may face more obstacles at the time of adopting new managerial practices as their directors are reluctant to adopt change and green management practices [Waqas, Dong et al. 2018]. Unique cultural characteristics of country and reluctance to adopt new managerial practices is developing a strong foundation of empirical study.

Further, structure of paper is arranged in given sections: literature review and hypothesis development are located section 2. Research methodology is presented in section 3. Section 4 describes results and data analysis and discussions are shown in section 5. Section 6 and section 7 presents conclusions and practical implication and future research direction respectively.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Barriers to RL adoption and RL practices

Due to environmental degradation, Pakistan is developing new environmental laws and regulation such as national policy on the solid waste of Pakistan (NPSWP), and struggling to protect the environment to reduce pollution and promote RL practices between public and manufacturing firm's. This situation could be improved with the help of environmental modernization and formulation of new environmental laws and regulations that can enforce manufacturing firms to bring green innovations in their production processes. In developing countries, ecological modernization can be utilized to understand a greener and sustainable context. Manufacturing firms must adopt green practices to bring sustainability, that can be done using their capabilities and resources to attain competitiveness on the base of environmental management and improve firm performance. Investing on green product development, waste reduction and controlling carbon emission and may help to maintain the manufacturers competitive andvantages among competitors, while the firm performance might also be improve by better dealing with green issues. Therefore, according to the resource-based view, the manufacturing firms should look inside of their resources to mitigate barriers to achieve the competitive advantage rather finding for a competitive environment. Integrating sustainability and ecological modernization into green reverse logistics practices to gain competitive advantage is difficult, still facing multiple barriers and require more research Giunipero, Hooker et al. [2012].

Table 1A. Study categories and variables

Construct	Barriers	References
Infrastructure & technology (ITB)		Abdulrahman, Gunasekaran et al. [2014]; Govindan and Bouzon [2018]; Waqas, Dong et al. [2018]; Rameezdeen, Chileshe et al. [2016]; Satapathy [2017]
B1	Lack of modern technology and information system	
B2	Lack of logistics infrastructure facilities	
B3	Lack of modern technology for waste management and recycling	
B4	Poor service quality of local 3PL provider	
B5	Lack of a system to monitor return	
B6	Lack of enough in-house facilities	
B7	Deficiency of road conditions	
Financial & economic (FEB)		
B8	Lack of initial capital	
B9	Higher costs of adopting RL	
B10	Lack of bank loans to encourage green products/ processes	
B11	Uncertainty related to economic issues	
B12	Lack of funds for products return monitoring systems	
B13	Higher investments and less return-on-Investments	
B14	Lack of funds for training	
B15	Financial burden of tax	
Laws & regulations (LRB)		
B16	Lack of government supportive policies for RL	
B17	Changing regulations due to changing political climate	
B18	Lack of regulatory restrictions	
B19	Lack of enforceable laws on products return of end-of-life	
B20	Lack of environmental laws awareness	
B21	Lack of effective environmental measure	
B22	Difficulty in identifying environmental opportunities	
B23	Lack of international or U.S environmental standards	
B24	No specific environmental goals	
B25	Lack of community pressure	
Knowledge & experience (KEB)		
B26	Lack of skilled professionals in RL	
B27	Lack of awareness about RL practices	
B28	Immaturity and low investment in knowledge management	
B29	Lack of responsiveness about RL	
B30	Wrong forecasting	
B31	Lack of taxation knowledge on returned products	
B32	Lack of information about RL channels	
B33	Lack of waste management practices	
Policy (PB)		
B34	Lack of corporate social responsibility and ethical standards	
B35	Companies policies against RL	
B36	Lack of clarity regarding sustainability	
B37	Limited forecasting and planning in RL	
B38	Lack of motivational laws and regulations	
B39	Lack of government supportive polices	
B40	Misuse of environmental laws	
B41	Lack customers awareness about environmental protection	
Reverse logistics practices (RLP)		Lai, Wu et al. [2013]; Graham, Graham et al. [2018]; Anne, Nicholas et al. [2016]
RLP1	Waste management	
RLP2	Design for RL	
RLP3	Recycle	
RLP4	Reprocess	
RLP5	Reuse	
RLP6	Material recovery	
Firm performance (FP)		Ye, Zhao et al. [2013]; Agrawal, Singh et al. [2016]; Huang, Jim Wu et al. [2012]
FP1	Economic performance	
FP2	Environmental performance	

According to [Kaviani, Tavana et al. 2020] RL barriers have significant positive impact on green product innovation and environmental performance, also influences the depletion of resources with tight environmental laws. [Abdullah, Zailani et al. 2016] found that internal and external barriers to reverse logistics and supply chain management has negatively influence on green system innovation and green product innovation while technical and knowledge barriers to logistics and supply chain management have no impact on adoption green product innovation and green system innovation. Moreover, according to [Jabbour, de Sousa Jabbour et al. 2016] internal barriers have more significant positive effect on adoption of green operational practices than external barriers and also indirectly influenced the firms performance while green operational practices have direct association with firm performance in Brazilian manufacturing industry context. [Phochanikorn, Tan et al. 2020] empirically deducted top five barriers in his study to RL implementation in Thailand palm oil industry to reduced this industry impact on environment. [Waqas, Qianli et al. 2020] examined contextual relationship among 25 barriers of Pakistani manufacturing industry by applying MICMAC and interpretive structural modeling (ISM). On one hand, the barriers associated with RL practices can be recognized most related approach when developing sustainability within the firm [Prakash and Barua 2015]. Moreover, it seems difficult to understand the barriers restraining the implementation of RL practices in manufacturing companies of developing countries like Pakistan [Govindan and Bouzon 2018]. Although, the researchers have been discussing barriers, drivers, and motivational factors, opportunities are still available to develop the understanding with problems and issues to adoption of reverse logistics practices in manufacturing industry of developing countries specially in Pakistan.

In order to ensure the comprehensive literature evaluation barriers and drivers to reverse logistics, these research papers presented as few as 2 as many as 38 barriers and drivers [Prakash and Barua 2015]. In this study, barriers are divided into five main categories that avoid the adoption of RL practices, environmental protection, and sustainability within and outside manufacturing firms such as infrastructure & technology, financial & economic, laws & regulations, knowledge & experience and policy-related barriers constructs. Table 1A shows the main factors related to RL practices concentrate production process at manufacturing organizations.

Based on above-mentioned categories, following hypotheses are proposed:

H1- infrastructure & technology barriers construct negatively effect of adoption of RL practices

H2- financial & economic barriers construct negatively effect of adoption of RL practices

H3- laws & regulations barriers construct negatively effect of adoption of RL practices

H4- knowledge & experience barriers construct negatively effect of adoption of RL practices

H5- policy barriers construct negatively effect of adoption of RL practices

Reverse logistics practices and firm performance

Reverse logistics practices promote the system within organizations to decrease the environmental problems by introducing policies and procedures to improve existing infrastructure and to align it with the sustainability. Table 1A demonstrates the notions, factors, and references utilized in current study to describe RL practices and measure the firm performance.

The RL practices motivate the sustainable development and green practices in organizations. In literature, some recent researchers discovered a significant relationship between RL practices and firm ECP and ENP [Ye, Zhao et al. 2013]. Agrawal, Singh et al. [2016] uncovered the issues inducing the implementation of RL activities considering organizational, environmental and technical dimensions. It is important to invest in RL practices and envir onmental practices for improving sustainable policies and procedures for developing business competitive advantages, it would also be substantial for manufacturing firms to bulit distinctive position through linking environmental and quality investment. Therefore, the integration of green issues in firm operations are essential to advance the firm performance. Though, the literature review has yet to achieve consensus on this issue. Ye, Zhao et al. [2013] described that, ecological system management can expand the firm performance, however, some environmental practices negatively effect on it. Huang, Jim Wu et al. [2012] perceived the adoption of RL practices have a strong positive impact on manufacturing firm performance and could have some influence from contextual and external factors. Therefore,

H6- RL practices positively affect ECP.

H7- RL practices positively affect ENP.

Barriers to RL adoption and firm performance

The association between RL practices and firm performance is still important and blinking research area [Satapathy 2017]. If barriers and drivers to RL negatively influence the RL practices as confirmed by literature, it also can be considered that barriers and drivers to RL may have an indirect influence on manufacturing firm performance. [Jabbour, de Sousa Jabbour et al. 2016] used green operational practices as mediator in barriers performance link in Brazilian manufacturing companies, however, RL practices adoption has not been considered as mediator in the literature of barriers performance link. For instance, lack of awareness about RL practices is treated as barrier and driver, it can be avoided by the exact adoption of RL practice in advance and accordingly can negatively effect on RL practices.

Therefore based on above discussion and literature evidence, we hypothesized that:

H8- *infrastructure & technology barriers construct negatively mediate the ECP through adoption of RL practices.*

H9- *financial & economic barriers construct negatively mediate the ECP through adoption of RL practices.*

H10-*laws & regulations barriers construct negatively mediate the ECP through adoption of RL practices.*

H11- *knowledge & experience barriers construct negatively mediate the ECP through adoption of RL practices.*

H12- *policy barriers construct negatively mediate the ECP through adoption of RL practices.*

Mediating role of RL practices

Abdulrahman, Gunasekaran et al. [2014], Bouzon, Govindan et al. [2018] studies are related to barriers and drivers to RL practices adoption and performance. A very few researchers have examined the link among issues to reverse logistics and firm performance and more research is needed. Developing the clear association among RL barriers and performance could help to concern authorities choose exact practice to avoid specific barrier and to increase firm performance [Bouzon, Govindan et al. 2016].

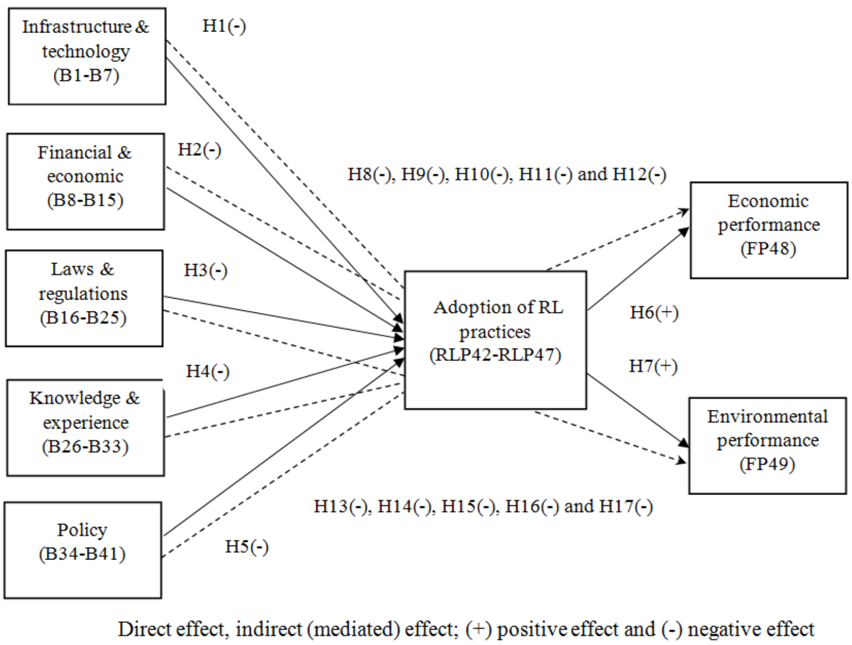

Fig. 1. Conceptual model presented in this study with direct and indirect effect

In developing countries especially in Pakistan, more research on sustainability and barriers evaluation are required [Abdulrahman, Gunasekaran et al. 2014].

Therefore, we hypothesized that:

H13- infrastructure & technology barriers construct negatively mediate ENP through adoption of RL practices.

H14- financial & economic barriers construct negatively mediate ENP through adoption of RL practices.

H15- laws & regulations barriers construct negatively mediate ENP through adoption of RL practices.

H16- knowledge & experience barriers construct negatively mediate ENP through adoption of RL practices.

H17- policy barriers construct negatively mediate ENP through adoption of RL practices.

Direct hypothesis based on literature are (H1, H2, H3, H4, H5, H6, and H7) and indirect hypothesis are (H8, H9, H10, H11, H12, H13, H14, H15, H16, H17), as mention in section 2 and Figure 1 empirically tested the conceptual framework of current research.

RESEARCH METHODOLOGY

Definition of constructs measurement

The key determination of current paper is to test a new conceptual model based on quantitative research base survey strategy presented in figure 1. Barriers to RL are measured into five categories such as:

- Infrastructure & technology barriers construct; this barriers construct contains the information about barriers related infrastructure & technology for example lack of modern technology for waste management, poor logistics infrastructure, deficiencies of roads, lack of monitoring systems for return and poor infrastructure & technology for development of RL practices within the country.
- Financial & economic barriers construct; this group of barriers has the information about barriers and drivers related to financial & economic obstacles such as a loan, investment, and adoption cost and return funding etc.
- Laws & regulation barriers construct; this category including the information about barriers related to laws & regulations.
- Knowledge & experience barriers construct; this construct refers to the barriers and drivers related to knowledge & experience to reverse logistics.
- Policy barriers construct; this barriers construct includes the information about issues that are related to policy.

41 barriers and drivers are included above mention five categories presented in Table 1A. The five-point Likert scale was utilized to estimate each barrier and driver, ranging from 1 (strongly disagree) to 5 (strongly agree).

- RL practices; variables related to RL practices are offered in Table 1A. The five-point Likert scale was utilized to estimate each of the item, ranging from 1(not applied) to 5 (fully applied).
- Firm performance; variables related to firm performance are presented in Table 1A. Again five-point Likert scale was utilized to estimate the firm performance variables, ranging from 1 (much poorer) to 5 (much improved).

In the end, company size is treated as a controled variable. Big companies more actively participate in sustainable practices, comparatively, they face more pressure from stakeholder to participate in environmental activities because big companies are considered as a trendsetter in their sectors. Adoption of RL practices has more concern with bigger companies rather than smaller. Normally, in four categories the firm size is measured; micro, small, medium, and large size firms which based on a number of firm employees. Micro size firms have 19 workers, small size firms have 20 to 99 workers, medium size firms have 100 to 499 and big companies have 500 or more workers. According to [Darnall, Henriques et al. 2010] firm size undeniable fact when discussing ecological system management and corporate social responsibility. Therefore, it is considered as a key variable when discussing organizational problems and barriers, as many variables were not measured because of irrelevant to firm size.

Sample size and data collection

Research in the field of SCM can avail the more authentic results through survey because the advantage of the survey is to collect empirical research evidence related to real world including the perception of knowledge experts in particular research field. A comprehensive questionnaire was developed on behalf of section 3.1. Companies listed with the securities & exchange commission of Pakistan (SECP) were preferred from the manufacturing sector for data collection including automobile, textile, electronics, apparel, fertilizer, plastics, and food manufacturing companies etc. The facilitator arranged the meetings with potential respondents like (supply chain expert, business owner, directors, and managers) to deliver them the questionnaires and calls were made for a higher response rate. In total, 1000 questionnaires were distributed among respondents of relevant companies in Pakistan during Decembers to May 2018. From the government side, the data was gathered from the employees of PAK-EPA and sustainable development policy institute (SDPI). These institutes are focal institutes in Pakistan for successful implementation of NPSW within the country. Finally, 485 questionnaires were received back, 19 questionnaires were eliminated due to missing values, therefore, 466 questionnaires responses were considered as usable.

DATA ANALYSIS

Structural Equation Modelling (SEM) was applied to verify the hypothesis of conceptual model on the behalf of empirical data [Kaufmann and Gaeckler 2015] and AMOS 22.0 (trial version) was used to test indirect effect because AMOS is very useful to calculate the multicollinearity problems as well as some statistical indices.

Delphi method (DM) was used to evaluate all measures by the group of professionals. Initially, a meeting was arranged with professionals on DM procedure [Linstone and Turoff 1975] to evaluate the weight of measures to RL. Moreover, the board of experts including RL professionals, supply chain supervisors, financial experts, ecological experts, managerial specialists, social experts, and supply chain managers from different manufacturing industry of Pakistan was requested to participate in decision-making process. Initially, the pre-defined survey was filled by professionals independently according to their best knowledge about measures in Table 1A. After the completion of this first iteration, the response was gathered by the facilitator. According to their first iteration response, the anonymous summary of results prepared and again distributed among professionals for the objective of further amendment in selected measures list. After completion of three iteration consensus was developed among all professional experts, selecting the final set of barriers to become quite easy affecting the adoption of RL practices in Pakistani manufacturing industry.

Table 2. Details of respondents

Demographic	Count	Percentage%
Gender		
Male	356	76
Female	93	24
Age group		
20-35 years	108	23
36-50 years	273	59
>50 years	85	18
Education		
Bachelor	246	53
Master	199	43
Ph.D.	21	4
Industry category		
Automobile industry	45	10
Electronic products manufacturing	30	6
Textile mills	55	12
Plastic bags manufacturing	25	5
Apparel mills	34	7
Cement manufacturing	20	4
Fertilizer companies	38	8
Beverage companies	49	11
Paper manufacturing	20	4
Rubber and plastics mills	23	5
Food industry	74	16
Lubricants companies	22	5
Government Employees (PEPA, SDPI)	31	7
Work status		
Top level	53	11
Middle level	280	60
Low level	133	29
Total	**466**	**100**

Finally, the board of expert suggested deleting following 10 barriers from given five barriers categories (B4, B7, B10, B12, B17, B23, B28, B33, B37, and B39) due repetition and ambiguity. In the end, 39 variables were considered under eight constructs for defining the model of study. Initially, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) was applied to analyse reliability and validity instruments. Internal consistency was measured with Cronbach's Alpha outcomes, the findings of Cronbach's Alpha were fluctuate between 0.731-0.868 that verified the inner consistency of each constructs, and meets the standard criteria. Reliability of developed scale is supported by the values of Cronbach's Alpha.

EFA was implemented to eight constructs having 39 variables to expose the latent variables. The keen objective of EFA to check relationship among observed and latent factors whether the factors are unknown or uncertain. In this research, the principle component analysis (PCA) with varimax rotation was utilized to apply EFA on 39 variables. EFA starts with examining the suitability of data, Bartlett test and Kaiser-Meyer-Olkin (KMO) checks sample adequacy. To perform the factor analysis the value of KMO should be 0.60 or more. The value of KMO was 0.835 that fulfil the stated standards and finding of Bartlett test was X2=3365.453 and P>0.000 which is showing substantial and satisfactory inter-correlation. Factor loading of all variables should be 0.40 or more, commonalities and cross-factor loading values should be 0.40 or more criteria. Eigenvalues should be 1 or more, as finding of EFA showing that all seven constructs eigenvalues are more than 1 with 73.34% total variance and factor loading values were ranging between 0.567-0.865 that meet the given criteria. EFA findings are shown in Table 3A.

Barriers are arranged according to their highest factor loading for each category presented in (Table 3A), infrastructure & technology construct the barriers with highest factor loadings are B6>B1>B3>B2>B5. According to the finding of study lack of enough in-house facilities (B6), lack of new technology and information system (B1) and lack of modern technology for waste management and recycling are dominant barriers of the category.

In Financial & economic construct the barriers with highest factor loadings are B8>B15>B14>B13>B9>B11 respectively. Study findings reveal that lack of initial capital (B8), the financial burden of tax (B15) and lack of funds for training (B14) are main barriers of the category.

In law & regulation construct the barriers B22>B24>B19>B25>B21>B20>B18>18 are with highest factor loadings. Following three barriers, difficulty in identifying environmental opportunities (B22), no specific environmental goals (B24) and lack of enforceable laws on products return of EOL (B19) are identified as most critical barriers of the category.

Knowledge & experience construct the barriers with biggest factor loading are B29>B26>B27>B30>B31>B32 respectively. Lack of responsiveness about RL (B29), lack of trained professionals in RL (B26) and Lack of awareness about RL practices (B27) are the dominant issues of the construct.

In policy construct the barriers are B38>B36>B34>B41>B35>B40 with their highest factor loadings. According to results, Lack of motivational laws and regulations (B38), lack of clarity regarding sustainability (B36) and Lack of corporate social responsibility and ethical standards (B34) have strong factor loadings.

In the adoption of RL, practices construct the barriers with highest factor loadings are RLP44>RLP47>RLP45>RLP42>RLP46>RLP 43 respectively. Results show that recycle (RLP44), material recovery (RLP47) and reprocess (RLP45) are the main variables of the category.

Finally, firm performance variables with their factor loading are FP48>FP49, economic performance, and environmental performance.

Table 3A. Results of Exploratory Factor Analysis

Constructs	Variables	Reliability	AVE	Composite Reliability	1	2	3	4	5	6	7
Infrastructure & technology	B1	0.850	0.532	0.890	0.832						
	B2				0.751						
	B3				0.820						
	B5				0.735						
	B6				0.855						
Financial & economic	B8	0.822	0.575	0.923		0.865					
	B9					0.705					
	B11					0.667					
	B13					0.764					
	B14					0.832					
	B15					0.855					
Laws & regulations	B16	0.731	0.602	0.856			0.679				
	B18						0.767				
	B19						0.803				
	B20						0.756				
	B21						0.790				
	B22						0.854				
	B24						0.810				
	B25						0.798				
Knowledge & experience	B26	0.785	0.566	0.876				0.843			
	B27							0.820			
	B29							0.862			
	B30							0.770			
	B31							0.746			
	B32							0.699			
Policy	B34	0.868	0.643	0.887					0.805		
	B35								0.730		
	B36								0.832		
	B38								0.840		
	B40								0.680		
	B41								0.769		
RL practices	RLP1	0.815	0.510	0.901						0.751	
	RLP2									0.567	
	RLP3									0.830	
	RLP4									0.815	
	RLP5									0.732	
	RLP6									0.823	
Firm performance	FP1	0.798	0.530	0.897							0.865
	FP2										0.817

Table 4. Correlation and discriminant validity

Latent variables	Mean	S. D	ITB	FEB	LRB	KEB	PB	RLP	FP
ITB	3.43	1.854	1						
FEB	4.17	1.516	0.534**	1					
LRB	2.78	1.095	0.335**	0.476**	1				
KEB	3.80	1.475	0.498**	0.567**	0.365**	1			
PB	2.25	0.902	0.278**	0.326**	0.565**	0.235**	1		
RLP	4.68	1.690	0.576**	0.287**	0.271**	0.426**	0.525**	1	
FP	2.66	1.076	0.389**	0.384**	0.178**	0.501**	0.213**	0.374**	1

The values of convergent and discriminant validity are enough good. Convergent validity proved that the most barriers have better loadings in the origin of the construct are presented in Table 3A and table 4 respectively.

Constructs validity was checked by CFA applying on 39 variables under eight constructs. CFA is one of significant research methods of SEM that is largely applied in supply chain management and RL field to calculate covariance structure and linear structural relationship models. When scholars have limited or inadequate information toward latent variables, they prefer to utilize this kind of multivariate research technique to discover the significant association among variables. Eight model constructs scrutinized with 39 variables using different model fitness indices. According to the model findings the values of squared multiple correlations (SMCs) ranged between 0.468-0.759 which meets the recommended criteria. The final findings of CFA, correlation among variables and model fitness of the research paper is presented in tables 5.

Table 5. Model fitness results

Fit indices	Statistics	Recommended Criteria
NFI	0.93	>0.90
NNFI	0.92	>0.90
CFI	0.95	>0.90
GFI	0.91	>0.80
AGFI	0.96	>0.80
RMSEA	0.053	>0.08

Source: Hair, Black et al. 2010

Adoption of RL practices, in turn, affect the firm's performance (economic and environmental performance). Moreover, Economic performance is more focused, than environmental performance based on factor loadings values. In term of mediation relations, Law & regulation and policy barriers constructs are not tending to be associated significantly to firm performance.

Path diagram model is presented in figure 1 and table 6 presenting relationships among variables. Direct and mediated significant relationships are presented in Tables 6, considering P-value <0.05 as the standard for defining the level of significance. On the behalf of table 6 results, from seventeen proposed hypotheses, six has been rejected and eleven has accepted findings are presented in table 7. Next section explains the results of hypotheses in details and also discusses.

Table 6. Hypothesis testing

Hypothesis	**Standard error**	**P-value**	**Acceptance Yes/No**
Infrastructure & technology → adoption of RL practices	0.085	0.000	Yes
Financial & economic → adoption of RL practices	0.047	0.000	Yes
Law & regulation→ adoption of RL practices	0.126	0.235	No
Knowledge & experience → adoption of RL practices	0.034	0.000	Yes
Policy → adoption of RL practices	0.099	0.219	No
Adoption of RL practices → economic performance	0.087	0.000	Yes
Adoption of RL practices → environmental performance	0.053	0.000	Yes
Infrastructure & technology → adoption of RL practices → Economic performance	0.087	0.000	Yes
Financial & economic → adoption of RL practices → Economic performance	0.065	0.000	Yes
Law & regulation → adoption of RL practices → Economic performance	0.115	0.236	No
Knowledge & experience → adoption of RL practices → Economic performance	0.043	0.000	Yes
Policy → adoption of RL practices → economic performance	0.131	0.237	No
Infrastructure & technology → adoption of RL practices → Environmental performance	0.072	0.000	Yes
Financial & economic → adoption of RL practices → environmental performance	0.036	0.000	Yes
Law & regulation → adoption of RL practices → environmental performance	0.153	0.275	No
Knowledge & experience → adoption of RL practices → environmental performance	0.045	0.000	Yes
Policy → adoption of RL practices → environmental performance	0.132	0.238	No

Table 7. Test of hypotheses results

Hypotheses	Results	Reasons
H1- infrastructure & technology barriers construct negatively effect of adoption of RL practices (when barriers and drivers will be more than the adoption of RL practices will be less).	Accepted	Beta 0.51; P-value<0.001
H2- financial & economic barriers construct negatively effect of adoption of RL practices (when barriers and drivers will be more than the adoption of RL practices will be less).	Accepted	Beta 0.57; P-value<0.000
H3- laws & regulations barriers construct negatively effect of adoption of RL practices (when barriers and drivers will be more than the adoption of RL practices will be less).	Rejected	Beta 0.057; P-value<0.235
H4- knowledge & experience barriers construct negatively effect of adoption of RL practices (when barriers and drivers will be more than the adoption of RL practices will be less).	Accepted	Beta 0.51; P-value<0.000
H5- policy barriers construct negatively effect of adoption of RL practices (when barriers and drivers will be more than the adoption of RL practices will be less).	Rejected	Beta 0.68; P-value<0.219
H6- RL practices positively affect economic performance.	Accepted	Beta 0.83; P-value<0.001
H7- RL practices positively affect environmental performance.	Accepted	Beta 0.55; P-value<0.001
H8- infrastructure & technology barriers construct negatively mediate economic performance.	Accepted	Beta 0.51; P-value<0.000
H9- financial & economic barriers construct negatively mediate economic performance.	Accepted	Beta 0.55; p-value<0.001
H10-laws & regulations barriers construct negatively mediate economic performance.	Rejected	Beta 0.042; P-value<0.236
H11- knowledge & experience barriers construct negatively mediate economic performance.	Accepted	Beta 0.85; P-value<0.000
H12- policy barriers construct negatively mediate economic performance.	Rejected	Beta 0.058; P-value<0.237
H13- infrastructure & technology barriers construct negatively mediate environmental performance.	Accepted	Beta 0.68; P-value<0.000
H14- financial & economic barriers construct negatively mediate environmental performance.	Accepted	Beta 0.75; P-value<0.001
H15- laws & regulations barriers construct negatively mediate environmental performance.	Rejected	Beta 0.044; P-value<0.275
H16- knowledge & experience barriers construct negatively mediate environmental performance.	Accepted	Beta 0.85; P-value0.001
H17- policy barriers construct negatively mediate environmental performance.	Rejected	Beta 0.074; P-value<0.238

RESULTS AND DISCUSSION

According to the finding of study infrastructure & technology, financial & economic and knowledge & experience barriers constructs are more relevant to adoption RL practices than law & regulation and policy barriers constructs. Finding proves that if firms need to achieve distinctive advantages as recommended by the resource-based view of firms, they need to deal with above mention three barriers constructs concentrate on growing level of green awareness among top management by introducing enough green training program. Our study suggests that simple publications on NPSW are not enough to encourage sustainability in the manufacturing industry of Pakistan. It is the duty of government proposing, assigning and producing sustainable knowledge among all size of companies. Therefore, the organizations must develop the connection between environmental modernization problems and natural resource-based view to overcoming above-mentioned barriers constructs to upgrade the performance of firms.

The finding of the study framework proved that the firm size has no important effect on ECP and ENP. Therefore, companies of different sizes have confronted different barriers in the same way, because of the presence of barriers in the similar scenario, i.e. Pakistan. Current study adds to addressing existing literature and confirm that bigger companies have good resources to manage their sustainability and ecological management as compared to smaller companies. This study confirmed that higher performance does not depend on company size, thus, small companies also can adopt RL practices for developing sustainability.

When verifying hypotheses of study, out of seventeen hypotheses, eleven were accepted and six were rejected. H1-infrastructure & technology barriers construct negatively affect the adoption of RL practices. In simple words, stronger the barriers to infrastructure & technology construct resulted in a lower tendency for adopting RL practices. Because

Pakistan under developing country, therefore, there is a lack of new technology and logistics infrastructure facilities to managing the solid waste and the monitor return. H2-financial & economic barriers construct negatively affected the adoption of RL practices. Presence of financial & economic barriers also resulted in a lower tendency for the adoption of RL practices. A very few companies in manufacturing industry of Pakistan have operational RL department and they allocate budget for it. Therefore, Pakistani manufacturing firms need financial assistance to establish reverse logistics infrastructure and to overcome major impeding barriers. H3-law & regulation barriers construct negatively affect the adoption of RL practices but don't have a significant association to the adoption of RL practices. Because Pakistan is independent in the field of laws and regulation, every kind of laws are available in the constitution of Pakistan related to every field but unfortunately, there has no proper implementation. H4-knowledge & experience construct barriers are also negatively correlated with the adoption of RL practices. More the knowledge and experience barriers lead, the adoption of RL practices is less. Education institutes in the country are failed to cope with the expectations of industry in the field of reverse logistics. However, Pakistani companies are struggling to spend on recruiting experienced and foreign technical experts in the related field. In some cities of Pakistan, foreigner skilled professional demand security for providing their services, sometimes companies face difficulties to arrange proper security for them. H5-policy barriers construct is negatively affecting the adoption of RL practices but had no significant association to the adoption of RL practices

H6 and H7 proposed a significant positive association among adoption of RL practices and ECP and ENP of Pakistani manufacturing firm's. implementation of RL practices in manufacturing industry create an important role in environmental degradation and improving environmental quality. Along with environmental sustainability, RL is packed with multiple economic benefits as it develops an infrastructure for products recycling and solid waste management which improves an organisation's productivity and ECP performance.

This research also contributes to analyzing the mediating effect of RL practices adoption. Results found that (H8, H9, and H11) infrastructure & technology, financial & economic and knowledge & experience barriers construct respectively to reverse logistics adoption have an indirect negative effect on firm's economic performance through RL practices adoption. Thus, firms tending to improve economic performance should not only consider RL practices adoption but should also deal with above mentioned three barriers constructs to RL. (H10 and H12) law & regulation and policy barriers construct respectively to RL adoption also have a negative indirect impact on firm's ECP through adoption of RL practices, as results found, these two hypotheses do not have a significant effect on ECP.

The mediation analysis also found that (H13, H14, and H16) infrastructure & technology, financial & economic and knowledge & experience barriers construct respectively to reverse logistics adoption have an indirect negative impact on firm's ENP through RL practices adoption. Therefore, results found that the existence of above-mentioned three categories barriers is impeding the firm's environmental performance. Companies should take remediation actions to eradicates these barriers during their operations. (H15 and H17) law & regulation and policy barriers construct respectively to RL adoption also have a negative indirect impact on firm's ENP through adoption of RL practices, as results found, these two hypotheses do not have a significant effect on ENP. Supporting mediating relationships provide more insights into the implementation of RL in Pakistan. It is one of the key theoretical contributions of the current article is to check the mediating role of RL practices in the barriers-implementation relationship.

Study findings proved that infrastructure & technology, financial & economic and knowledge & experience barriers constructs are more significant to manage the sustainability at the time of adoption RL practices and their implications for firm's economic and environmental performance. As previous studies in literature indicate that infrastructure & technology, financial & economic and knowledge & experience barriers categories are more significant to sustainable development and adoption of RL practices as compared to law & regulation and policy barriers constructs is confirmed by [Abdulrahman, Gunasekaran et al. 2014, Bouzon, Govindan et al. 2016]. Therefore, organization top management, when willing to adopt RL practices for the enhancement of firm's ECP and ENP, firstly should deal with infrastructure & technology, financial & economic and knowledge & experience barriers constructs because these three barriers constructs should be eradicated at the initial level for effective implementation of RL practices [Govindan, Kaliyan et al. 2014]. Managers and directors should develop the solid understanding of barriers to prioritize them according to their rank for the purpose of better utilization of the firm's resources.

Lastly, evaluating each barriers category, law & regulation and policy barriers categories containing the barriers related to environmental legislation and environmental modernization initiative will work only when infrastructure & technology, financial & economic and knowledge & experience related barriers should be mitigated first and the attention should be paid by upper management to create awareness on sustainability problems and conduct proper training system within organizations as expressed through literature [Rameezdeen, Chileshe et al. 2016]; [Satapathy 2017]. RL practices, the focus should be paid toward the production process and the selection of environmental friendly suppliers [Wong, Lai et al. 2012]. Selection of green supplier the results has been emphasized by literature [Genovese, Lenny Koh et al. 2013]. In term of firm's performance, it is compulsory to reduce the waste generation and hazardous/toxic materials because of environmental modernization in Pakistan is enforcing eradication of waste due to NPSW.

CONCLUSIONS

This research advances the knowledge of environmental and sustainability management in RL practices to enhance the manufacturing industry performance. The key purpose of current research is to validate the direct and indirect association among different barriers constructs (infrastructure &technology, financial & economic, laws & regulations, knowledge & experience and policy) and explore the adoption of RL practices and firm's performance (economic and environmental) on the behalf of data collected from Pakistani manufacturing industry. Following are the key conclusions based on study findings and implications:

Infrastructure & technology, financial & economic and knowledge & experience related barriers are more significant than laws & regulations and policy related barriers during the adoption of RL practices and these practices help to increase firm's ECP and ENP.

The results of this research help to extend literature review presenting that the ecological modernization and new environmental laws and regulation should be integrated with enterprises to mitigate infrastructure & technology, financial & economic and knowledge & experience related barriers by conducting proper training programs and promoting sustainability and environmental protection among company's top management. Universities and different Pakistani manufacturing associations (PMA) can create the partnership to consider and promote this process. Companies looking forward to creating company competitive advantages can upgrade the firm's ECP and ENP through the adoption of RL practices in promoting the greening manufacturing processes. Without considering the firm's size, a strong understanding should develop with barriers to RL will important to move forward the Pakistani manufacturing industry toward greening production in a timely manner.

PRACTICAL IMPLICATIONS AND FUTURE RESEARCH DIRECTION

This research has a substantial contribution to the adoption of RL practices in the manufacturing industry of developing republics, as it has included the barriers to RL from an international context. Furthermore, current research also contains the managerial implications, particularly for Pakistani manufacturing context, as the selection of main barriers by the team of professionals from the manufacturing industry and scholars in Pakistan. However, the finding of this research might be beneficial for manufacturing industries situated in the rest of developing economies. The findings might be beneficial for the adoption of RL practices in India, China and Iran, which are the most emerging economies of the region.

Internationally, there are a lot of issues related to waste management that is alarming the ecological system of the world and now, these issues must be considered by scholars. A considerable portion of EOL products are incinerated or untreated that is polluting the environment. To reduce the impact of used products, the companies must activate the RL operations in their manufacturing system to put used products at the proper destination. For this, the companies must highlight the barriers to RL and deal with them at priority basis. Better knowledge on barriers to RL make easy the adoption of RL practices that encourage the product return and product recycling management help to realize the manufacturers to realize their corporate social responsibility toward environmental protection. Moreover, the identification of critical barriers, as well as having the information about factors affecting them or being affected by them, might be helpful for concern authorities and decision makers.

This research is related to manufacturing industry interested in adoption of RL practices for Pakistani context and prioritize the barriers to RL in different categories in way of adoption of RL practices. It might useful for industrial managers to eliminate the most critical barriers to RL at priority basis at the time of the adoption of RL practices. It can also guide the policy makers to enhance the usage of resources by the adoption of RL practices.

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REFERENCES

Abdullah, M., et al., 2016. Barriers to green innovation initiatives among manufacturers: the Malaysian case. 10(4): 683-709. http://doi.org/10.1007/s11846-015-0173-9

Abdulrahman, M. D., et al., 2014. Critical barriers in implementing reverse logistics in the Chinese manufacturing sectors. International journal of production economics 147: 460-471. http://doi.org/10.1016/j.ijpe.2012.08.003

Agrawal, S., et al., 2016. Triple bottom line performance evaluation of reverse logistics. Competitiveness Review 26(3): 289-310. http://doi.org/10.1108/CR-04-2015-0029

Anne, M., et al., 2016. Reverse Logistics Practices and Their Effect on Competitiveness of Food Manufacturing Firms in Kenya. http://41.89.227.156:8080/xmlui/handle/123456789/524

Bouzon, M., et al., 2018. Evaluating barriers for reverse logistics implementation under a multiple stakeholders' perspective analysis using grey decision making approach. Resources, conservation and recycling 128: 315-335. http://doi.org/10.1016/j.resconrec.2016.11.022

Bouzon, M., et al., 2016. Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. Resources, conservation and recycling 108: 182-197. http://doi.org/10.1016/j.resconrec.2015.05.021

Chaudhary, K., et al., 2017. Analysis of barriers hindering the implementation of reverse supply chain of electronic waste in India. International Journal of Advanced Operations Management 9(3): 143-168. http://doi.org/10.1504/IJAOM.2017.088241

Cordano, M., et al., 2010. How do small and medium enterprises go “green”? A study of environmental management programs in the US wine industry. Journal of Business Ethics 92(3): 463-478. http://doi.org/10.1007/s10551-009-0168-z

Darnall, N., et al., 2010. Adopting proactive environmental strategy: The influence of stakeholders and firm size. Journal of management studies 47(6): 1072-1094. http://doi.org/10.1111/j.1467-6486.2009.00873.x

Genovese, A., et al., 2013. Greener supplier selection: state of the art and some empirical evidence. International Journal of Production Research 51(10): 2868-2886. http://doi.org/10.1080/00207543.2012.748224

Giunipero, L. C., et al., 2012. Purchasing and supply management sustainability: Drivers and barriers. Journal of Purchasing and Supply Management 18(4): 258-269. http://doi.org/10.1016/j.pursup.2012.06.003

Govindan, K. and M. Bouzon, 2018. From a literature review to a multi-perspective framework for reverse logistics barriers and drivers. Journal of cleaner production. http://doi.org/10.1016/j.jclepro.2018.03.040

Govindan, K., et al., 2014. Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. International journal of production economics 147: 555-568. http://doi.org/10.1016/j.ijpe.2013.08.018

Graham, S., et al., 2018. The relationship between downstream environmental logistics practices and performance. International journal of production economics 196: 356-365. http://doi.org/10.1016/j.ijpe.2017.12.011

Hair, J., et al., 2010. Multivariate Data Analysis, Secondary,Multivariate Data Analysis, Prentice-Hall.

Huang, Y.-C., et al., 2012. The task environment, resource commitment and reverse logistics performance: evidence from the Taiwanese high-tech sector. Production Planning & Control 23(10-11): 851-863. http://doi.org/10.1080/09537287.2011.642189

Jabbour, C. J. C., et al., 2016. Barriers to the adoption of green operational practices at Brazilian companies: effects on green and operational performance. International Journal of Production Research 54(10): 3042-3058. http://doi.org/10.1080/00207543.2016.1154997

Kaufmann, L. and J. Gaeckler, 2015. A structured review of partial least squares in supply chain management research. Journal of Purchasing and Supply Management 21(4): 259-272. http://doi.org/10.1016/j.pursup.2015.04.005

Kaviani, M. A., et al., 2020. An integrated framework for evaluating the barriers to successful implementation of reverse logistics in the automotive industry. 272: 122714. http://doi.org/10.1016/j.jclepro.2020.122714

Lai, K.-h., et al., 2013. Did reverse logistics practices hit the triple bottom line of Chinese manufacturers?, International journal of production economics 146(1): 106-117. http://doi.org/10.1016/j.ijpe.2013.03.005

Phochanikorn, P., et al., 2020. Barriers analysis for reverse logistics in Thailand’s palm oil industry using fuzzy multi-criteria decision-making method for prioritizing the solutions. 5(4): 419-436. http://doi.org/10.1007/s41066-019-00155-9

Rameezdeen, R., et al., 2016. A qualitative examination of major barriers in implementation of reverse logistics within the South Australian construction sector. International Journal of Construction Management 16(3): 185-196.

http://doi.org/10.1080/15623599.2015.1110275

Satapathy, S., 2017. An analysis of barriers for plastic recycling in the Indian plastic industry. Benchmarking: An International Journal 24(2): 415-430. http://doi.org/10.1108/BIJ-11-2014-0103

Subramanian, N. and M. Abdulrahman, 2017. An examination of drivers and barriers to reducing carbon emissions in China's manufacturing sector. The International Journal of Logistics Management 28(4): 1168-1195. http://doi.org/10.1108/IJLM-07-2016-0171

Wang, H., et al., 2019, An integrated MCDM approach considering demands-matching for reverse logistics. Journal of cleaner production 208: 199-210. http://doi.org/10.1016/j.jclepro.2018.10.131

Waqas, M., et al., 2018, Critical Barriers to Implementation of Reverse Logistics in the Manufacturing Industry: A Case Study of a Developing Country. Sustainability 10(11): 4202. http://doi.org/10.3390/su10114202

Waqas, M., et al., 2020, Modeling Reverse Logistics Barriers in Manufacturing Industry of Pakistan: An ISM and MICMAC Approach. 19(02): 309-341. http://doi.org/10.1142/S021968672050016X

Wong, C. W., et al., 2012, Green operations and the moderating role of environmental management capability of suppliers on manufacturing firm performance. International journal of production economics 140(1): 283-294. http://doi.org/10.1142/S021968672050016X

Ye, F., et al., 2013, The impact of institutional pressures, top managers' posture and reverse logistics on performance—Evidence from China. International journal of production economics 143(1): 132-143. http://doi.org/10.1142/S021968672050016X

WPŁYW OGRANICZEŃ LOGISTYKI ZWROTNEJ NA ROZWÓJ ZRÓWNOWAŻONY PRZEDSIĘBIORSTWA

STRESZCZENIE. **Wstęp:** Wskutek wzrastającego rozwoju przemysłowego i intensyfikacji produkcji, zużywa się coraz więcej surowców, co z kolei wpływa na stan środowiska. Logistyki zwrotna (RL) to koncepcja dobrze rozwinięta w krajach rozwiniętych w stosunku do krajów rozwijających się. Wdrożenie logistyki zwrotnej jest w swojej początkowej fazie ze względu na wiele czynników ograniczających i utrudniających jej wprowadzenie. Celem pracy jest identyfikacji barier wpływających na logistykę zwrotną poprzez przegląd literatury oraz sprawdzenie wpływu tych czynników na wdrażanie praktyk logistyki zwrotnej jak również sprawdzenie czy mają one wpływ na działalność przedsiębiorstwa czy nie.

Metody: Dane do badania zostały zebrane od pracowników przedsiębiorstw produkcyjnych oraz odpowiednich instytucji rządowych i poddane analizie przy zastosowaniu metody modelowania równania strukturalnego. Nowatorski model strukturalny uwzględnia w sobie wszystkie analizowane zmienne w celu oceny wpływu barier logistyki zwrotnej na rozwój zrównoważony przedsiębiorstwa.

Wyniki: Badanie wykazuje, że czynniki: Infrastruktura i technologia, Finanse i ekonomia, Wiedza i doświadczenie, są czynnikami krytycznymi i mają negatywny wpływ na zaadoptowanie praktyk logistyki zwrotnej. Wdrożenie praktyk logistyki zwrotnej ma pozytywny efekt na działalność ekonomiczną i środowiskową przedsiębiorstwa.

Wnioski: Osiągnięte rezultaty pozwalają na poszerzenie dostępnej literatury, pokazując, że modernizacja ekologiczna oraz nowe prawodawstwa związane z ochroną środowiska powinno być zintegrowane w przedsiębiorstwie w celu zniwelowania barier związanych z czynnikami z grup Infrastruktura i technologia, Finanse i ekonomia, Wiedza i doświadczenie poprzez odpowiednio szkolenia oraz przez promowanie rozwoju zrównoważonego wśród szczebla najwyższego kierownictwa przedsiębiorstw.

Słowa kluczowe: rozwój zrównoważony, wdrożenie logistyki zwrotnej, ograniczenia, przedsiębiorstwa produkcyjne, Pakistan

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ORIGINAL PAPER

USING UTAUT2 MODEL TO EXAMINE THE DETERMINANTS OF OMNICHANNEL TECHNOLOGY ACCEPTANCE BY CONSUMERS

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ABSTRACT. **Background:** The paper presents the problem of omnichanneling technology acceptance by consumers in the purchasing process. The omnichanneling technology is an innovative solution used by retailers operating both brick&mortar and online retail formats, consisting in the integration of sales channels which aims to deliver a seamless customer experience regardless of the channel. It is an expensive and operationally complex solution, hence the need to test customer willingness to accept it. The objective of the article is to examine the determinants of both the intentions of acceptance the omnichannel technology by consumers and its use in purchasing behavior in accordance with the adopted UTAUT2 model.

Methods: The work uses a hypothetical-deductive scientific method. Based on the UTAUT2 model, hypotheses were formulated regarding the type and strength of the latent variables impact on intention to accept technology and technology acceptance.

Results: Data were collected from 280 respondents using CAWI method. Then, the factors were verified by exploratory factor analysis. Confirmatory factor analysis was used to examine the determinants (and the strength of their impact) of the intention to accept the technology and its use in the purchasing process.

Conclusions: The research identified personal innovatinveness as the strongest predictor of omnichannel purchase intention, accompanied by social impact and expected performance. It was also found that perceived risk and hedonic motivation were not relevant in this study. The habit was proved to be a reliable indicator of both the intention to accept omnichanneling technology in the purchasing process and the behaviour associated with using the technology, while the facilitating conditions turned out to be related only to the use of omnichanneling technology.

Key words: omnichanneling, UTAUT2 model, technology acceptance, customer intentions, use behaviour.

INTRODUCTION

Considered the future of the retail environment, the phenomenon of omnichanneling has gained the attention of researchers and practitioners. It enables customers to attain a very high level of convenience when buying a product, as it lets them switch between channels anytime and anywhere. This research aims to identify the factors that influence omnichannel consumer behaviour through their acceptance, intention and continuous behaviour in using new technologies in the shopping process. To achieve this, a customised conceptual research model derived from the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2), including two other factors (personal innovativeness and perceived risk), was designed.

Previous studies have revealed that omnichannel consumers are a growing phenomenon worldwide [Schlager, Maas, 2013], and they anticipate having many opportunities to interact with the brand during the shopping journey and expect an excellent shopping experience [Cook, 2014]. Omnishoppers tend to use several channels at once, and are likely to use the devices they own to search for information, compare

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between products, ask for guidance and comments, or seek for competitive alternatives throughout the shopping journey to view the offer on each channel [Yurova, et al. 2017]. Moreover, omnishoppers have a belief that they know more about shopping and have control over the sales encounter [Rippé, et al., 2015]. Also, the online environment offers a complete shopping experience that purchasers might pass by in the store. As a result, a new source of disruption has come to retail as the Internet era has arrived strongly, and retailing is transformed from multi-channel to omnichannel retailing [Rigby, 2011]. While multi-channel retail separates the physical and online; the concept of omnichannel provides the customer with more than just a way of shopping, as they can shift freely among channels [Piotrowicz, Cuthbertson, 2014]. As the phenomenon is growing, it is necessary to continue the examination into the area of omnichannel user behaviour [Verhoef, Kannan, Inman, 2015] to discover consumers' attitudes toward the influence of technology in purchasing decision and their use behaviour in the new context [Escobar-Rodríguez, Carvajal-Trujillo, 2014].

Technology is a requirement for omnichannel; with consumer recognition and acceptance of the technology being at the centre of it [Bloomberg, 2014] where an understanding of the variables that affect customer behaviour would be beneficial. The technology applied in an omnichannel environment is the technology consumers' associate within each touchpoint during the purchasing process [Juaneda-Ayensa, Mosquera and Murillo, 2016]. Several theories have been presented to demonstrate technology use behaviour, such as Technology Acceptance Model (TAM) by Davis [1989], , Innovation Diffusion Theory (IDT) by Moore and Benbasat [1991], Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh, et al. [2003], and UTAUT2 by Venkatesh et al. [2012]. The last one, the Unified Theory of Acceptance and Use of Technology 2, will be used in the current study as the main theoretical framework. UTAUT2 is seen as an extension of the previous version of UTAUT by adding three new variables – these being hedonic motivation (HM), price value (PV) and habit (H) [Venkatesh et al., 2012], in addition to the four main variables which are performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC) and social influence (SI) – to examine the factors influencing the acceptance and usage of technology from the consumers' perspective. This adjustment was made to have a better model of the consumer context [2012]. Although UTAUT2 was initially developed for American consumers, it has been suggested it could apply to other geographical contexts. Therefore, investigating UTAUT2 in the context of omnishopping acceptance in Poland provides both theoretical as well as practical contributions [Trojanowski, Kułak, 2017].

However, only limited studies have measured user acceptance and the use of the omnichannel system within the UTAUT2 model. Research by Juaneda-Ayensa, Mosquera and Murillo [2016] reviewed omnichannel strategy in the apparel sector, but not only in terms of the UTAUT2 model as they also included two other variables: personal innovativeness and perceived security. Until now, the number of studies measuring how omnichannel shopping is accepted and utilised by consumers in Poland is very limited, mainly due to the fact that the omnichannel shopping experience is a new concept for Polish consumers.

This study suggests a construct of the framework based on the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) as illustrated by Venkatesh et al. [2012]. Purchase intention and use behaviour of omnichannel shopping are placed as the endogenous constructs, representing consumer acceptance and use. Purchase intention of omnichannel shopping is driven by exogenous variables such as performance and effort expectancy, social influence, facilitating conditions, hedonic motivation, habit, personal innovativeness, and perceived risk which are set as main antecedents. The aim is to explain how the constructs of UTAUT2 and personal innovativeness (PIN) leverage purchase intention (PI) and use behaviour (UB) towards the adoption of omnichannel shopping.

Performance expectancy (PE) in information technology signifies that users view the omnichannel to be useful because it lets them fulfil their target-driven duties [Venkatesh et al., 2003]. PE has so far been shown to be the dominant component in user decision purchase intention [Pascual-Miguel, Agudo-Peregrina, Chaparro-Peláez, 2015] and behavioural intention [Venkatesh et al., 2003; Escobar-Rodríguez and Carvajal-Trujillo, 2014] in UTAUT2 model. Due to this the following hypothesis was formulated:

H1: Performance expectancy positively influences omnichannel purchase intention.

Effort expectancy (EE) is defined as how comfortable shoppers feel in using different touchpoints during the shopping journey and it reflects the perceived usage difficulty of accepting the various touchpoints from retailers. Based on previous research EE positively influences purchase intention [Venkatesh, Thong, Xu, 2012], so the following hypothesis was proposed for this construct:

H2: Effort expectancy positively influences omnichannel purchase intention.

Social influence (SI) is the construct which is based on the assumption that an individual's behaviour is affected by the way people believe others will see them as a result of their technology experience [Venkatesh et al. 2003] and positively affect purchase intention [Venkatesh, Thong, Xu, 2012]. Accordingly, the following hypothesis was suggested:

H3: Social influence positively influences omnichannel purchase intention.

Facilitating conditions (FC) relate to customers' perceptions of the availability of resources and support tools to produce behaviour [Brown, Venkatesh, 2005; Venkatesh et al., 2003]. Previous research illustrated that a set of FC could lead to higher intentions of using multiple channels [Hew, Lee, Ooi, 2015]. In order to use different platforms, users need to have certain resources and skills such as knowing how to use a computer, mobile phone or tablet; how to connect to the Internet; install applications, etc. These lead to the hypotheses that when the user has a good understanding of the FC, it will result in accepting different channels in two purchase stages:

H4a: Facilitating conditions positively influence omnichannel purchase intention.

H4b: Facilitating conditions positively influence omnichannel use behaviour.

Hedonic motivation (HM) explains either the pleasure or enjoyment received from adopting a technology [Brown, Venkatesh, 2005; Venkatesh, Thong, Xu, 2012]. HM has been proved to perform an essential role in defining technology acceptance and usage [Brown, Venkatesh, 2005]. But it was also proven that HM is not a factor that influences purchase intention in the omnichannel context [Juaneda-Ayensa, Mosquera, Murillo, 2016]. In order to check it, we set out the following hypothesis:

H5: Hedonic motivation positively influences omnichannel purchase intention.

Habit (H) is described as the extent that an individual has the propensity to perform certain behaviours automatically [Limayem, Hirt, Cheung, 2007], which influences purchase intention and use behaviour [Escobar-Rodríguez and Carvajal-Trujillo, 2014]. Hew, Lee and Ooi [2015] found that habit was the strongest predictor of behavioural intention to use mobile applications. However, Juaneda-Ayensa, Mosquera and Murillo [2016] found that H did not influence purchase intention in an omnichannel context. Considering the different results shown in the literature, the following hypotheses were formulated:

H6a: Habit positively influences omnichannel purchase intention.

H6b: Habit positively influences omnichannel use behaviour.

Personal innovativeness (PIN) is described as the degree to which one person decides to try different and new goods or channels, or search for new experiences which require more extensive research [Midgley, Dowling, 1978]. Juaneda-Ayensa, Mosquera and Murillo [2016] consider that PIN also includes consumers' profiles or preferences in trying new channels and experiences. In an omnichannel context, PIN has been utilised as a predictor which influences purchase intention [San Martín and Herrero, 2012; Escobar-Rodríguez and Carvajal-Trujillo, 2014; Juaneda-Ayensa, Mosquera, Murillo, 2016]. The next study hypotheses were thus formulated:

H7a: Personal Innovativeness positively influences omnichannel purchase intention.

H7b: Personal Innovativeness positively influences omnichannel use behaviour.

Herhausen, Binder, Schoegel and Herrmann [2015] founded that perceived risk (PR) impacts the shopping channel preferences of customers. PR is classified into six dimensions: financial risk, performance risk, psychological risk, social risk, privacy risk and time risk [Cunningham, 1967]. Kazancoglu and Aydin [2018] discovered that participants perceived omnichannel shopping as unsafe, considering it as a new kind of market organisation. PR connected to online transactions could decrease perception of behavioural and environmental control; hence, negatively influence transaction intentions [Kim, Forsythe, 2007; Chang, Chen, 2009]. Consequently, the following hypotheses are proposed:

H8a: Perceived risk negatively influences omnichannel purchase intention.

H8b: Perceived risk negatively influences omnichannel use behaviour.

It is anticipated that the eight independent variables of PE, EE, SI, FC, HM, H, PIN, and PR will have a noticeable impact on purchase intention (PI), being able to influence the attitude of possible omnishoppers via technology and show how they influence user behaviour in the shopping-process context. The following hypothesis is suggested:

H9: Purchase intention positively influences omnichannel use behaviour.

RESEARCH METHODOLOGY

The data were gathered in May 2019 using the CAWI method, i.e. access to the questionnaire was distributed via a link on social media (Facebook, Instagram) as well as sent by email. As previous research revealed that younger people between 18-34 years old are likely to regularly spend more time on mobile phone applications [Pedotto, Chen, 2016] than other users, young people were used as the main focus group. The research items are presented in Appendix 1. Respondents were asked to evaluate their response to each item on a seven-point Likert scale. During the three weeks of the survey 280 full questionnaires were collected.

The demographic characteristics of the sample is presented in the table 1.

Table 1. Demographic characteristics of the sample (in %)

Gender	Male	25.7
	Female	74.3
Age	15-18	1.8
	19-24	73.6
	25-30	16.1
	over 30	8.6

Source: Authors' own

RESULTS

Cronbach's alpha was used to measure reliability as well as consistency between construct variables [Morgan, Leech, Gloeckner and Barrett, 2013]. Then, exploratory factor analysis was employed to measure the accuracy of the research model. Finally, confirmation factors analysis (CFA) was applied to confirm the hypotheses. Both SPSS (version 24) and AMOS (version 20) were used to analyse the data. Descriptive statistic measures were applied to examine the principal characteristic of the data in order to verify the normal distribution. For all statements except one (PE2 kurtosis: 3.314) skewness and kurtosis remained in the normal distribution range. All Cronbach's alphas for independent constructs in this study are above the minimum standard at 0.6 [George and Mallery, 2010].

Purchase intention determinants

Twenty-six attributes were submitted to run Exploratory Factor Analysis (EFA) with the Maximum Likelihood method and the Oblimin rotation method including the factor loadings and was equivalent to the factor matrix that was rendered for the rotation [Field, 2009]. As a consequence, EFA produced a six-factor model. The KMO test reflected a value of 0.766, indicating that the sample was good enough so factor analysis could proceed to the next step; and Sigma was .000, meaning the figure was significant. The initial factor analysis indicated factors to explain for 70.2% of purchase intention out of total variance. Table 2 presents the pattern matrix of 6 factor loadings for purchase intention.

Table 2. Pattern Matrix for EFA

Pattern Matrix[a]						
	Factor loadings					
	1	2	3	4	5	6
PR2	.990					
PR1	.679					
PR3	.651					
EE2		.947				
EE1		.939				
EE3		.437				
SI1			.935			
SI2			.868			
SI4			.759			
SI3			.744			
PE3				-.924		
PE2				-.915		
PE1				-.660		
H2					.943	
H3					.851	
H1					.724	
PIN4						.855
PIN1						.834
PIN2						.752
Extraction Method: Maximum Likelihood. Rotation Method: Oblimin with Kaiser Normalization.						
a. Rotation converged in 11 iterations.						

Source: Authors' own

All items in the hedonic motivation (HM) and facilitating condition (FC) constructs were removed due to poor factor loading. Therefore, two hypotheses failed to be confirmed – H4a and H5. EE3 is slightly above 0.4 but still low (0.437) so will also be eliminated in the next step.

Use behaviour determinants

The process to analyse use behaviour is similar to purchase intention; however, use behaviour only includes attributes from FC, PIN, PR, and H. Therefore, a five-factor matrix was rendered in this case. The output of the KMO test was 0.793, a good value to continue with factor analysis. Sigma was .000, which met the requirements. Regarding use behaviour, initial factor analysis indicated factors to explain 61.1% of total variance. Similarly, the pattern matrix for user behaviour was also obtained by extracting from the Maximum Likelihood and Oblimin rotation methods [Field, 2009]. Table 3 represents the output for user behaviour.

Table 3. Pattern Matrix for EFA

Pattern Matrix[a]					
	Factor loadings				
	1	2	3	4	5
PR2	1.018				
PR1	.659				
PR3	.657				
PI2		.972			
PI3		.762			
PI1		.587			
H2			-.925		
H3			-.841		
H1			-.711		
PIN1				.826	
PIN4				.824	
PIN2				.772	
FC2					.795
FC1					.741
Extraction Method: Maximum Likelihood. Rotation Method: Oblimin with Kaiser Normalization.					
a. Rotation converged in 7 iterations.					

Source: Authors' own

PIN3 and FC3 were eliminated in the next step due to their poor factor loadings (below 0.4). In summary, the EFA extracted five factors, which explained 61.1% of the total variance.

Measurement model validation

Confirmation Factor Analysis (CFA) was applied to validate the measurement model. The CFA in this study was executed by adopting the maximum likelihood method in AMOS 20.0. CFA results does not indicate compliance with the values recommended by Januszewski (2011): $\chi 2$ = 653.926; CFI = 0.918; TLI = 0.908; GFI = 0.849; $\chi 2$/df = 2.255; p < 0.00, and RMSEA = 0.067. Therefore, the initial model was rejected. To obtain acceptable validity and reliability and to achieve a good model fit, critical ratio (C.R.) values were analysed. In table 4, all C.R.

values are higher than 1.96, which indicates the estimations are different from zero in this model [Byrne, 1998]. Consequently, the null hypotheses were rejected. Every p-value below a level of 0.001 stands for a significant relationship; for this reason it is essential that they are subjected to further analysis.

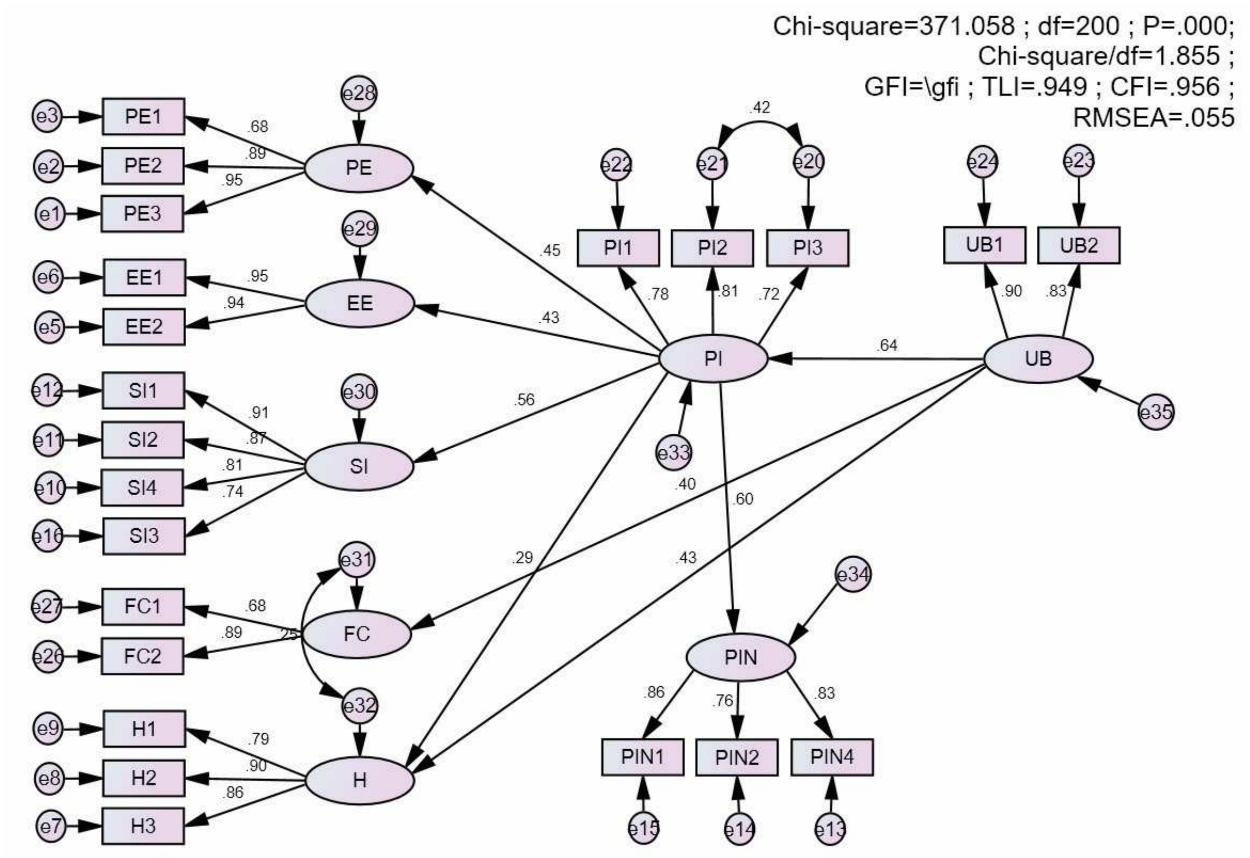
Table 4. 1st CFA model

			Estimate	S.E.	C.R.	p-value
PI	→	UB	0.408	0.051	8.079	***
PE	→	PI	0.494	0.085	5.788	***
EE	→	PI	0.324	0.06	5.431	***
SI	→	PI	0.76	0.096	7.958	***
H	→	PI	0.496	0.114	4,353	***
PIN	→	PI	0.725	0.123	5.88	***
FC	→	UB	0.213	0.054	3.939	***
PR	→	PI	0.272	0.155	1.759	0.079
PR	→	UB	-0.181	0.110	-1.646	0.100
H	→	UB	0.485	0.082	5.896	***
PIN	→	UB	0.125	0.081	1.539	0.124

Source: Authors' own

As shown in Table 4, the p-values of PR towards PI and UB are 0.079 and 0.1 respectively (>0.05). This result illustrates that there is no significant relationship between perceived risk and purchase intention or use behaviour regarding intention to adopt technology in the omnichannel shopping journey. Data revealed also that there is no significant relationship between PIN and UB (p-value = 0.124). Consequently, the hypotheses H7b, H8a and H8b failed to be supported:

The revised CFA model (Table 5 and Figure 1) were produced by eliminating standard regression weights one by one as mentioned above, and applying modification indices to enhance the model. The Chi-square index was 371.058 with a p-value of 0.000, and with Chi-square/df = 1.855, it represents a parsimonious fit. All results showed that this model achieved a good fit with the data and was accepted for further analysis.



Source: Authors' own

Fig. 1. Modified CFA model

Table 5. Output of model fit indicators

Model	RMSEA	GFI	TLI	CFI	CMIN/D
Default model	0.055	0.892	0.949	0.956	1.855
Saturated model		1		1	
Independence model	0.246	0.292	0	0	17.907

Source: Authors' own

The Figure 1 shows the outcomes of the adjusted model, which includes the structural relationships, the standardised estimates of the path coefficients, plus the index factor of model fit.

Table 6 presents a structural representation of unstandardized regression coefficients and correlated statistics results that generated positive impacts between predictor latent variables and purchase intention, plus use behaviour. All the factor loadings are significant at $p < .001$. The results show that the most important effects were those generated by personal innovativeness on purchase intention ($\beta = 0.835$; $p<0.01$), which indicates that personal innovativeness explains 83.5 percent of the variance in purchase intention. The social influences construct was found to have the second most positive influence toward purchase intention ($\beta = 0.740$; $p < 0.01$). Moreover, positive and significant influences were found between PE and PI ($\beta = 0.511$, $p < 0.01$); positive EE on PI ($\beta = 0.561$, $p < 0.01$); H on PI and UB respectively ($\beta = 0.425$ and $\beta = 0.476$, $p < 0.01$); and FC on UB but less importantly with $\beta = 0.231$, $p < 0.01$. Lastly, the structural coefficients estimate between UB and PI is 0.478, $p< 0.01$, which indicates purchase intention and explains 48 percent of the variation in the use behaviour of customers.

Table 6. Regression weight of modified model

			Estimate	S.E.	C.R.	p-value
PI	→	UB	0.478	0.054	8.923	***
PE	→	PI	0.511	0.084	6.090	***
EE	→	PI	0.561	0.087	6.426	***
SI	→	PI	0.740	0.093	7.921	***
PIN	→	PI	0.835	0.098	8.552	***
FC	→	UB	0.231	0.048	4.817	***
H	→	UB	0.476	0.092	5.186	***
H	→	PI	0.425	0.121	3.513	***

Source: Authors' own

This means the hypotheses H1, H2, H3, H4b, H6a, H6b, H7a, H9 were supported, whereas H4a, H5, H7b, H8a, H8b were rejected.

DISCUSSION

The main object of this research was to recognise the drivers of technology acceptance amongst omnichannel consumers, as well as to examine how they influence purchase intention and use behaviour in an omnichannel environment. Personal innovativeness turned out to be the most important influential predictor of purchase intention in an omnichannel setting ($\beta=.603$, $p<.05$). This factor fulfils the role of being a fundamental driver of omnichannel purchase intention. Innovativeness has so far gained massive recognition in previous studies on consumer behaviour [Rogers, 2010]. In recent studies especially, PIN is considered as a critical driver in an online environment [San Martin and Herrero, 2012], as well as significantly influencing purchase intention in an omnichannel context [Juaneda-Ayensa, Mosquera, Murillo, 2016]. However, personal innovativeness fails to have a significant effect on actual usage behaviour ($\beta=.12$; $p=0.124$).

Social influence turned out to be the second most crucial factor that predicts purchase intention to use omnichannel ($\beta=.564$, $p<.05$). In a previous studies social influence was proven not to influence purchase intention in an omnichannel context [Juaneda-Ayensa, Mosquera and Murillo, 2016]. However, the result of the current study are in line with some previous research [Kim and Forsythe, 2007; Venkatesh, Thong and Xu, 2012; Escobar-Rodríguez and Carvajal-Trujillo, 2014]. This reflects that technology use is conditioned by other people's opinions; it suggests that people recognise omnichannel shopping and social influence affect purchase intentions.

Performance expectancy was the third construct that was discovered to have a positive relationship with purchase intention within an omnichannel environment ($\beta=.447$;

p<.05). This result is compatible with previous research done by Davis, Bagozzi and Warshaw [1989], as they aimed to uncover the most critical factors that influence people's intentions to use technology. Venkatesh et al. [2003] also agreed that there was a positive relationship between performance expectancy and behavioural intention to use. Juaneda-Ayensa, Mosquera and Murillo [2016] also concluded that performance expectancy was a significant factor in driving the behaviour of buyers in an omnichannel context.

CONCLUSIONS

The results of the current study indicate that there is a positive correlation between effort expectancy and behavioural intention (β=.430, p<.05). This suggested that people believe that if a given omnichannel technology is clear, understandable and easy to use; it will enhance their behavioural intentions to use it. This finding is in line with Giesing [2003] who posits that effort expectancy is a factor that influences behavioural intention to use.

Habit also has a positive influence regarding both user purchase intention (β=.289; p<.05) and use behaviour (β=.432; p<.05) in omnichannel shopping. Habit has a more positive impact on use behaviour than purchase intention. Such a result is reasonable, as if buyers have used different channels previously and found them to be useful, they will continue and built an emerging habit towards utilising these channels. When a shopper frequent interacts with omnichannels, habit develops and heightens the desires that build the behavioural intention to continue using them [Hew, Lee, Ooi, 2015].

The findings verified personal innovativeness as the most potent predictor of purchase intention, accompanied by social influence and performance expectancy. Meanwhile, perceived risk and hedonic motivation were observed to be insignificant in this study. Habit was discovered as a reliable indicator for both purchase intention and usage behaviour, while facilitating conditions were found to only have a relation to use behaviour.

RESEARCH LIMITATIONS

There are always some limitations needing to be addressed in the research structure and method. Firstly, memories recalled from participants comprise a mixture of real experiences, what they have assumed, and what they received later. Therefore, it may be challenging for people to differentiate between situations, whether their opinions were obtained directly through their own experience, or of someone else, or some other aspects [Memory, 1999]. Any experience has a specific influence on individual perspectives for utilising omnichannels and the technology. Secondly, there is a lack of theoretical aspects involved in this study, where most of the omnichannel studies were carried out only on the intention to purchase, not continuous usage behaviour. This obstacle has undoubtedly limited the field of this analysis. Thirdly, the test and data were collected in the Voivodship of Greater Poland. Research in any other city with more significant or lower amount of omnichannel use and penetration could lead to contradictory results. Furthermore, with the limitation of sample size, as well as its coarse respondent scale, could have given rise to the fact why certain hypotheses were supported, as argued by Kang and Waller [2005].

This study also contributes possibilities for future study. For example, it can be about the role of technology in the physical store in an omnichannel environment. Retailers can use this study as it relates to their strategies, because as it identifies personal innovativeness as the main element of omnishopper behaviour, the retailer could build a system that personalise customer shopping experience, which can influence customer loyalty and maintain their reputation..

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REFERENCES

Bloomberg J., 2014,. Retrieved 5 10, 2019, from Forbes: https://www.forbes.com/sites/jasonbloomberg/2014/09/30/omnichannel-more-than-a-digital-transformation-buzzword/

Brown S.A., Venkatesh V., 2005. Model of adoption and technology in households: a baseline model test and extension incurporating household life cycle. MIS Q. , 29, 399-436. http://doi.org/10.2307/25148690

Byrne B., 1998. Structural Equation Modeling with LISREL, PRELIS and SIMPLIS: Basic Concepts, Applications and Programming. Mahwah. New Jersey: Lawrence Erlbaum Associates.

Chang H., Chen S., 2009. Consumer perception of interface quality, security and loyalty in electronic com- merce. Information & Management, 46(7), 411-417. http://doi.org/10.1016/j.im.2009.08.002

Childers T.L., Carr C.L., Peck J., Carson S., 2001. Hedonic and utilitarian motivations for online retail shopping behavior. Journal of Retailing, 77(4), 511-535. http://doi.org/10.1016/s0022-4359(01)00056-2

Cook G., 2014. Customer experience in the omni-channel world and the challenges and opportunities this presents. Journal of Direct, Data and Digital Marketing Practice, 15(4), 262-266. http://doi.org/10.1057/dddmp.2014.16

Cunningham S.M., 1967. The major dimensions of perceived risk, in Cox, D.F. (Ed). Risk taking and information handling in consumer behavior, 82-108.

Davis F.D., 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly, 13(3), 319-340. http://doi.org/10.2307/249008

Davis F.D., Bagozzi R.P., Warshaw P.R., 1989. User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. Management Science, 35(8), 982-1003. http://doi.org/10.1287/mnsc.35.8.982

Escobar-Rodríguez T., Carvajal-Trujillo E., 2014. Online purchasing tickets for low cost carriers: An application of the unified theory of acceptance and use of technology (UTAUT) model. Tourism Management, 43, 70-88. http://doi.org/10.1016/j.tourman.2014.01.017

Field A., 2009. Discovering statistics using SPSS. London: SAGE.

Forsythe S., Liu C., Shannon D., Gardner L.C., 2006. Development of a scale to measure the perceived benefits and risks of online shopping. Journal of Interactive Marketing, 20(2), 55-75. http://doi.org/10.1002/dir.20061

George D., Mallery P., 2010. SPSS for Windows Step by Step: A Simple Guide and Reference 17.0 (10th ed.). Boston: Pearson.

Giesing I., 2003. User Perceptions Related To Identification Through Biometrics Within Electronic Business. South Africa: University of Pretoria.

Herhausen D., Binder J., Schoegel M., Herrmann A., 2015. Integrating Bricks with Clicks: Retailer-Level and Channel-Level Outcomes of Online–Offline Channel Integration. Journal of Retailing, 91(2), 309-325. http://doi.org/10.1016/j.jretai.2014.12.009

Hew J., Lee V., Ooi K.W., 2015. What catalyses mobile apps usage intention: an empirical analysis. Industrial Management & Data Systems, 115(7), 1269–1291. http://doi.org/10.1108/imds-01-2015-0028

Januszewski A., 2011. Modele równań strukturalnych w metodologii badań psychologicznych. Problematyka przyczynowości w modelach strukturalnych i dopuszczalność modeli. [Models of structural equantions in methodology of psychological researches and acceptance of models]. Studia z Psychologii w KUL, 17, 213-245.

Juaneda-Ayensa E., Mosquera A., Murillo Y., 2016. Omni-channel customer behavior: key drivers of technology acceptance and use and their effects on purchase intention.

Frontiers in Psychology, 7(1117), 1-11. http://doi.org/10.3389/fpsyg.2016.01117

Kang S.M., Waller N.G., 2005. Moderated multiple regression, spurious interaction effects, and IRT. Applied Psychological Measurement, 29(2), 87-105. http://doi.org/10.1177/0146621604272737

Kazancoglu I., Aydin H., 2018. An investigation of consumers' purchase intentions towards omni-channel shopping. International Journal of Retail & Distribution Management, 46(10), 959-976. http://doi.org/10.1108/ijrdm-04-2018-0074

Kim J., Forsythe S., 2007. Hedonic usage of product virtualization technologies in online apparel shopping. Int. J. Retail Distrib. Manage, 35, 502-514. http://doi.org/10.1108/09590550710750368

Lai J.Y., Debbarma S., Ulhas K.R., 2012. An empirical study of consumer switching behaviour towards mobile shopping: a Push-Pull-Mooring model. International Journal of Mobile Communications, 10(4), 386-404. http://doi.org/10.1504/ijmc.2012.048137

Limayem M., Hirt S.G., Cheung C.M., 2007. How habit limits the predictive power of intention: the case of information systems continuance. MIS Q, 31, 705-737. http://doi.org/10.2307/25148817

Lu J., Yao J.E., Yu C., 2005. Personal innovativeness, social influences and adoption of wireless Internet services via mobile technology. The Journal of Strategic Information Systems, 14(3), 245-268. http://doi.org/10.1016/j.jsis.2005.07.003

Memory A., 1999. Remembering what happened: Memory errors and survey reports. The science of self- report: Implications for research and practice.

Midgley D., Dowling G., 1978. Innovativeness: The Concept and Its Measurement. Journal of Consumer Research, 4, 229-242. http://doi.org/10.1086/208701

Moore G.C., Benbasat I., 1991. Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation. Information Systems Research, 2(3), 192-222. http://doi.org/10.1287/isre.2.3.192

Morgan G., Leech N., Gloeckner G., Barrett K., 2013. IBM SPSS for Introductory Statistics: Use and Interpretation (5th ed.). NewYork: Routledge.

Pantano E., Viassone M., 2015. Engaging consumers on new integrated multichannel retail settings: Challenges for retailers. Journal of Retailing and Consumer Services, 25, 106-114. http://doi.org/10.1016/j.jretconser.2015.04.003

Pascual-Miguel F.J., Agudo-Peregrina Á.F., Chaparro-Peláez J., 2015. Influences of gender and product type on online purchasing. Journal of Business Research, 68(7), 1550-1556. http://doi.org/10.1016/j.jbusres.2015.01.050

Pedotto K., Chen V., 2016. 2016 US Mobile App Report. Comscore.

Piotrowicz W., Cuthbertson R., 2014. Introduction to the Special Issue Information Technology in Retail: Toward Omnichannel Retailing. International Journal of Electronic Commerce, 18(4), 5-16. http://doi.org/10.2753/jec1086-4415180400

Rigby D.K., 2011. The Future of Shopping. Harvard Business Review, 89, 65-76.

Rippé C.B., Weisfeld-Spolter S., Yurova Y., Sussan F., 2015. Is there a global multichannel consumer? International Marketing Review, 32(3/4), 329-349. http://doi.org/10.1108/IMR-10-2013-0225

Rogers E.M., 2010. Diffusion of Innovations (4th ed.). NY: Simon and Schuster.

San Martín H., Herrero A., 2012. Influence of the user's psychological factors on the online purchase intention in rural tourism: integrating innovativeness to the UTAUT framework. Tourism Management, 33, 341–350. http://doi.org/10.1016/j.tourman.2011.04.003

Schlager T., Maas P., 2013. Fitting International Segmentation for Emerging Markets: Conceptual Development and Empirical Illustration. Journal of International Marketing, 21(2), 39-61. http://doi.org/10.1509/jim.12.0066

Trojanowski M., Kułak J., 2017. The Impact of Moderators and Trust on Consumer's Intention to Use a Mobile Phone for Purchases. Journal of Management and Business Administration, 25(2), 91–116. http://doi.org/10.7206/jmba.ce.2450-7814.197

Venkatesh V., Morris M.G., Davis G.B., Davis F.D., 2003. User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly, 27(3), 425-478. http://doi.org/10.2307/30036540

Venkatesh V., Thong J.Y., Xu X., 2012. Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. MIS Quarterly, 36(1), 157-178. http://doi.org/10.2307/41410412

Verhoef P.C., Kannan P., Inman J.J., 2015. From Multi-Channel Retailing to Omni-Channel Retailing. Journal of Retailing, 91(2), 174-181. http://doi.org/10.1016/j.jretai.2015.02.005

Yurova Y., Rippé C.B., Weisfeld-Spolter S., Sussan F., Arndt A., 2017. Not all adaptive selling to omni-consumers is influential: The moderating effect of product type. Journal of Retailing and Consumer Services, 34, 271-277. http://doi.org/10.1016/j.jretconser.2016.01.009

BADANIE DETERMINANT AKCEPTACJI TECHNOLOGII OMNICHANNELINGU PRZEZ KONSUMENTÓW Z WYKORZYSTANIEM MODELU UTAUT2

STRESZCZENIE. Wstęp: W pracy przedstawiono problem akceptacji technologii omnichannelingu przez konsumentów w procesie dokonywania zakupów. Technologia omnichannelingu jest innowacyjnym rozwiązaniem stosowanym przez detalistów wykorzystujących zarówno stacjonarne, jak i internetowe formaty handlu, polegającym na integracji kanałów sprzedaży. Jest to rozwiązanie kosztowne oraz złożone operacyjnie, stąd konieczność zbadania skłonności nabywców do jej akceptacji. Celem artykułu jest zbadanie uwarunkowań zarówno intencji przyjęcia technologii omnichannel przez konsumentów, jak i jej wykorzystania w zachowaniach zakupowych zgodnie z przyjętym modelem UTAUT2.

Metody: W pracy zastosowano hipotetyczno-dedukcyjną metodę naukową. Na podstawie modelu UTAUT2 zostały sformułowane hipotezy dotyczące rodzaju i siły oddziaływania zmiennych latentnych, do weryfikacji których zastosowano konfirmacyjną analizę czynnikową. Pozwoliła ona wskazać determinanty i określić siłę ich wpływu zarówno na intencję akceptacji technologii omnichannelingu w procesie zakupu, jak i jej użycie.

Wyniki: Dane do analizy pozyskano od 280 respondentów metodą CAWI. Następnie zweryfikowano czynniki przy pomocy eksploracyjnej analizy czynnikowej. Do zbadania determinant (i siły ich wpływu) intencji akceptacji technologii oraz jej zastosowania w procesie zakupu zastosowano konfirmacyjną analizę czynnikową.

Wnioski: Przeprowadzone badanie wskazało osobistą innowacyjność jako najsilniejszy predyktor zamiaru zakupu, któremu towarzyszy wpływ społeczny i oczekiwana wydajność. Zaobserwowano także, że postrzegane ryzyko i motywacja hedoniczna były nieistotne w tym badaniu. Odkryto, że nawyk jest wiarygodnym wskaźnikiem zarówno intencji akceptacji technologii omnichannelingu w procesie zakupu, jak i zachowań związanych z wykorzystywaniem tej technologii, podczas gdy warunki ułatwiające okazały się mieć związek tylko z wykorzystywaniem technologii omnichannelingu.

Słowa kluczowe: omnichanneling, model UTAUT2, akceptacja technologii, intencja akceptacji

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ORIGINAL PAPER

MIXED-INTEGER PROGRAMMING FORMULATIONS FOR THE TRUCK SCHEDULING PROBLEM WITH FIXED OUTBOUND DEPARTURES

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ABSTRACT. **Background:** Truck scheduling at cross-docking terminals has received much academic attention over the last three decades. A vast number of mixed-integer programming models have been proposed to assign trucks to dock-doors and time slots. Surprisingly, only a few models assume fixed outbound truck departures that are often applied in the less-than-truckload or small parcel and express delivery industry. To the best of our knowledge, none of these papers explore whether a discrete-time or continuous-time model formulation has a better computational performance. This paper attempts to close this research gap and tries to shed light on which type of formulation is advantageous. Therefore, a variant of the truck scheduling problem with fixed outbound departures is considered. This problem's objective is to find a feasible truck schedule that minimizes the number of delayed freight units.
Methods: We propose two model formulations for the described variant of the truck scheduling problem with fixed outbound departures. Specifically, the problem is formulated as a discrete-time and a continuous-time mixed-integer programming model.
Results: A computational experiment is conducted in order to assess the computational performance of the presented model formulations. We compare the discrete-time and continuous-time formulation in terms of both the solution quality and computational time.
Conclusions: The computational results show that the proposed discrete-time model formulation can solve problem instances of medium size to proven optimality within less than one minute. The continuous-time model formulation, on the other hand, can solve small instances to optimality. However, it requires longer solution times than the discrete-time formulation. Furthermore, it is unable to solve medium-sized instances within a 5-minute time limit. Thus, it can be summarized that the proposed discrete-time model formulation is clearly superior to the continuous-time model formulation.

Key words: cross-docking; truck scheduling; mixed-integer programming; logistics; optimization.

INTRODUCTION

Cross-docking is a warehousing concept where incoming shipments are unloaded, sorted, and (directly) transferred to outgoing trucks. It aims to synchronize inbound and outbound shipments to avoid lengthy storage times and reduce the order picking effort. By consolidating less-than-truckload (LTL) shipments, cross-docking can also yield transportation cost savings compared to traditional point-to-point deliveries. Cross-docking terminals can be found in many of today's retailing (e.g., Wal-Mart [Stalk et al. 1992]), parcel delivery (e.g., UPS [Forger 1995] or DHL [Boysen et al. 2013]), automotive (e.g., Toyota [Witt 1998] or Renault [Serrano et al. 2017]), and logistics service provider [Gue 1999] supply chains.

A vast number of strategic (e.g., location and layout of cross-docking terminals), tactical (e.g., transportation flow optimization), and operational (e.g., truck assignment or truck scheduling) cross-docking decision problems

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have been studied in academic publications. Recent literature reviews are provided by Van Belle et al. [2012] and Buijs et al. [2014]. Especially truck scheduling, an operational decision problem in cross-docking terminals that deals with both assigning trucks to dock-doors and time slots, received much academic attention. Boysen and Fliedner [2010] and Ladier and Alpan [2016] provide an in-depth overview of the literature.

Many truck scheduling studies assume constraint-free outbound departures [e.g., Chmielewski et al. 2009, Serrano et al. 2017, Shakeri et al. 2012]. Under this assumption, outgoing trucks may only leave the cross-docking terminal after all freight units were loaded. However, this assumption could not be applicable in industries such as the LTL logistics industry or parcel delivery industry, which rely on fixed outbound departures in order to realize a smooth material flow in the transportation network [Ladier and Alpan 2016, Boysen et al. 2013]. Surprisingly, only a few studies consider a truck scheduling problem with fixed outbound departures. Minimizing the number of delayed product units is among the most frequently used performance indicators in truck scheduling models that consider fixed outbound departures. Existing truck scheduling models with fixed outbound departures can be classified into continuous-time [e.g., Boysen et al. 2013, Molavi et al. 2018] and discrete-time [e.g., Rahmandzadeh Tootkaleh et al. 2016, Tadumadze et al. 2019, Wolff et al. 2021] mixed-integer programs. Continuous-time models (CT) use a set of continuous decision variables to specify when trucks are processed. In these models, truck processing can start at any time within a truck's time window. Furthermore, the models often rely upon disjunctive (precedence) constraints in combination with precedence-based (binary) decision variables to express the processing sequence between pairs of trucks assigned to the same dock-door. Continuous-time model formulations are often characterized by a weak relaxation and large search trees as they often include many big-M formulations [Lamorgese and Mannino 2019]. Discrete-time model formulations (DT) were introduced to overcome this significant drawback. They discretize the planning horizon and use time-indexed (binary) decision variables that simultaneously indicate the truck-to-door assignment and the time a truck is processed. Discrete-time model formulations are usually characterized by stronger relaxations and lower bounds, and a larger number of decision variables than their continuous-time counterparts.

To the best of our knowledge, no paper that studies a variant of the truck scheduling problem with fixed outbound departures compared discrete-time and continuous-time model formulations regarding their computational performance. This paper attempts to close this research gap, as it may shed light on which type of formulation is advantageous. We propose both a discrete-time and a continuous-time mixed-integer programming formulation for a variant of the truck scheduling problem with fixed outbound departures. The model formulations are then compared in a computational experiment regarding their solution quality and computational time.

TRUCK SCHEDULING PROBLEM WITH FIXED OUTBOUND DEPARTURES

Model assumptions

This paper studies a variant of the truck scheduling problem with fixed outbound departures (TSFD). The general model assumptions can be summarized as follows:

- Inbound trucks and outbound trucks must be processed at inbound doors and outbound doors, respectively (exclusive service mode).
- The outbound truck departure times (and the truck-to-door assignments for outbound trucks) are given and known in advance (fixed outbound departures).
- Each inbound truck has a time window, defined through the truck release time and due date, in which truck processing must start.
- Only standardized freight units (e.g., pallets) are handled at the cross-docking terminal, and a sort-at-receiving protocol is applied [Bartholdi et al. 2008].

- An inbound truck's processing time includes the time for unloading all cargo from the inbound truck and transporting it to the associated outbound dock-doors. Thus, an inbound truck's processing time depends on the number of product units and the travel distance between inbound and outbound dock-doors [Van Belle et al. 2013, Wolff et al. 2021].
- A truck cannot leave the dock-door it is assigned to before it has been processed completely (no preemption).
- Cargo that arrives in the outbound area after loading operations of an associated outbound truck started is regarded as delayed cargo and postponed until the next departure to the same destination [Van Belle et al. 2012, Wolff et al. 2021].

In this setting, the objective is to find a feasible schedule for inbound trucks that leads to a minimum number of delayed products. Such a setting and goal is relevant in unit-load cross-docking platforms of logistics service providers or retailing companies. In the following, we present different mixed-integer programming (MIP) formulations for the TSFD.

Model formulations

The discrete-time formulation, denoted as TSFD-DT, uses the set of binary variables x_{idt} where $i \in I, d \in D, t \in T$. We set $x_{idt} = 1$ if inbound truck $i \in I$ is processed at dock-door $d \in D$ and processing starts in time interval $t \in T$. Moreover, a set of binaries y_{io} is used in order to signal if inbound truck i's cargo reaches the outbound area before loading of outbound truck o starts. When applying the notation summarized in Table 1, the TSFD-DT can be formulated as shown in Table 2.

Table 1. Notations for the discrete-time model formulation of the TSFD

Sets:	
I	Set of inbound trucks.
O	Set of outbound trucks.
D	Set of inbound doors.
T	Set of time intervals.
Parameters:	
r_i	Release time of inbound truck $i \in I$.
d_i	Due date of inbound truck $i \in I$.
d_o	Time when the processing of outbound truck $o \in O$ starts.
p_{id}	Processing time of inbound truck $i \in I$ at inbound dock-door $d \in D$.
f_{io}	Material flow between inbound truck $i \in I$ and outbound truck $o \in O$.
M	Big number.
Decision variables:	
x_{idt}	Binary decision variable: 1, if inbound truck $i \in I$ is assigned to door $d \in D$ and processing starts in time interval $t \in T$; 0, otherwise.
y_{io}	Binary decision variable: 1, if the processing of inbound truck $i \in I$ is finished after processing of outbound truck $o \in O$ starts; 0, otherwise.

Source: own table

Table 2. Discrete-time model for the TSFD

Objective function:		
$Minimize \sum_{i \in I} \sum_{o \in O} f_{io} \cdot y_{io}$		(1)
Constraints:		
$\sum_{d \in D} \sum_{t=r_i}^{d_i} x_{idt} = 1$	$\forall i \in I$	(2)
$\sum_{i \in I} \sum_{t'=\max\{0;t-p_{id}+1\}}^{t} x_{idt'} \leq 1$	$\forall t \in T, d \in D$	(3)
$\sum_{d \in D} \sum_{t \in T} (t + p_{id} - 1) \cdot x_{idt} - d_o \leq M \cdot y_{io}$	$\forall i \in I, o \in O$	(4)
$x_{idt} \in \{0,1\}$	$\forall i \in I, d \in D, t \in T$	(5)
$y_{io} \in \{0,1\}$	$\forall i \in I, o \in O$	(6)

Source: own table

The TSFD-DT aims to minimize the total number of delayed product units (1). Constraints (2) compel that each inbound truck is processed once and that truck processing starts within a truck's time window. Inequalities (3) assure that at most one inbound truck can be processed at a dock-door at a time. Moreover, constraints (4) determine whether inbound truck i's cargo arrives in the outbound area before the loading operations of outbound truck o start (i.e., $y_{io} = 0$) or not (i.e., $y_{io} = 1$). Lastly, the decision variables are defined in (5) and (6).

A significant drawback of the presented discrete-time model formulation is the time-indexation, which inevitably results in a huge number of decision variables for large problem instances, especially when long planning horizons with many time intervals must be considered. In order to overcome this disadvantage, a continuous-time model formulation is proposed below. Since time is not modeled explicitly in the formulation, it reduces the number of decision variables significantly.

The continuous-time formulation, denoted as TSFD-CT, applies a set of binary decision variables x_{id} for assigning inbound trucks $i \in I$ to dock-doors $d \in D$ and a set of continuous variables s_i to indicate the associated start times of the inbound trucks. An additional set of binary decision variables ϕ_{ij}, defined for every truck pair $(i,j) \in I^2$, is introduced for the sake of determining the truck sequence at a dock-door. ϕ_{ij} signals whether truck i starts before truck j (i.e., $s_i \leq s_j \Rightarrow \phi_{ij} = 1$) or truck j starts before truck i (i.e., $s_j < s_i \Rightarrow \phi_{ij} = 0$). When applying the notation summarized in Table 3, the TSFD-CT can be formulated as shown in Table 4.

Table 3. Additional and altered notations for the continuous-time model formulation of the TSFD

Decision variables:	
x_{id}	Binary decision variable: 1, if inbound truck $i \in I$ is assigned to door $d \in D$; 0, otherwise.
s_i	Continuous decision variable: Start time of inbound truck $i \in I$.
ϕ_{ij}	Binary decision variable: 1, if processing of inbound truck $i \in I$ starts before processing of inbound truck $j \in I$ starts; 0, otherwise.

Source: own table

Table 4. Continuous-time model for the TSFD

Objective function:		
$Minimize \sum_{i \in I} \sum_{o \in O} f_{io} \cdot y_{io}$		(7)
Constraints:		
$\sum_{d \in D} x_{id} = 1$	$\forall i \in I$	(8)
$r_i \leq s_i \leq d_i$	$\forall i \in I$	(9)
$s_i + p_{id} \cdot x_{id} + M \cdot (x_{id} + x_{jd} + \phi_{ij} - 3) \leq s_j$	$\forall i, j \in I: i \neq j, d \in D$	(10)
$\phi_{ij} + \phi_{ji} = 1$	$\forall i, j \in I: i \neq j$	(11)
$\left(s_i + \sum_{d \in D} p_{id} \cdot x_{id}\right) - d_o \leq M \cdot y_{io}$	$\forall i \in I, o \in O$	(12)
$x_{id} \in \{0,1\}$	$\forall i \in I, d \in D$	(13)
$s_i \geq 0$	$\forall i \in I$	(14)
$\phi_{ij} \in \{0,1\}$	$\forall i, j \in I$	(15)
$y_{io} \in \{0,1\}$	$\forall i \in I, o \in O$	(16)

Source: own table

The objective is to minimize the total number of delayed product units (7). Through constraints (8), every inbound truck is assigned to a dock-door, whereas constraints (9) guarantee that truck processing starts within a truck's time window. Inequalities (10) prevent multiple trucks from being processed simultaneously at the same dock-door. Constraints (11) are introduced to compel a well-defined precedence relation for truck pairs. Moreover, inequalities (12) determine whether an inbound truck i's cargo reaches the outbound area before outbound truck o's deadline. Lastly, the decision variables are defined in (13) to (16).

Model comparison

While the TSFD-DT involves $|I| \cdot (|D| \cdot |T| + |O|)$ decision variables and $|I| \cdot (|O| + 1) + |D| \cdot |T|$ constraints, the TSFD-CT contains $|I| \cdot (|I| + |D| + |O| + 1)$ decision variables and $|I| \cdot (|I| - 1) \cdot (|D| + 1) + |I| \cdot (|O| + 3)$ constraints. Table 5 presents exemplary model dimensions for both model formulations of the TSFD.

Table 5. Exemplary model dimensions for different model formulations of the TSFD

Instance dimensions				TSFD-DT		TSFD-CT	
$\|I\|$	$\|D\|$	$\|T\|$	$\|O\|$	# Decision variables	# Constraints	# Decision variables	# Constraints
50	8	20	48	20,200	1,434	3,950	23,200
50	8	20	96	39,400	1,818	3,950	23,200
50	8	20	240	97,000	2,970	3,950	23,200
100	15	40	48	76,000	4,820	15,600	162,700
100	15	40	96	148,000	5,540	15,600	162,700
100	15	40	240	364,000	7,700	15,600	162,700
200	30	60	48	300,000	13,640	58,200	1,246,400
200	30	60	96	588,000	15,080	58,200	1,246,400
200	30	60	240	1,452,000	19,400	58,200	1,246,400
300	50	80	48	744,000	26,700	129,300	4,599,600
300	50	80	96	1,464,000	29,100	129,300	4,599,600
300	50	80	240	3,624,000	36,300	129,300	4,599,600

Source: own table

The examples show that the TSFD-CT deals with a considerably lower number of decision variables than the TSFD-DT. If a fine time granularity is compulsory, the continuous-time model involves up to 96% fewer decision variables than the discrete-time model. However, this reduction comes at the cost of a higher number of constraints. It can be seen from the examples in the table that the TSFD-CT handles up to ca. 170 times more constraints than the TSFD-DT. However, it is uncertain which MIP formulation has a better computational performance when solving problem instances with an off-the-shelf solver such as CPLEX or Gurobi. Therefore, the computational experiment in the following section aims to identify the best performing MIP formulation.

COMPUTATIONAL EXPERIMENTS

This section sets out to analyze the computational performance of the proposed MIP formulations. For this purpose, test instances that consider the time from 8:00 – 16:00 as the planning horizon are generated. Furthermore, inbound truck arrival times are randomly distributed between 08:00 and 14:30, while outbound truck deadlines are randomly chosen between 13:00 and 16:00. By doing so, the outbound truck deadlines likely affect the scheduling of inbound trucks. Similar to Rijal et al. [2019], we assume that every inbound truck supplies between five and seven outbound trucks. Processing times p_{id} are randomly chosen between 30 and 70 minutes. Table 6 shows the additional parameters that are used to generate the test instances.

Table 6. Parameters for the test instance generation

Parameter	Parameter values
$\|I\|$	30, 50, 80
$\|D\|$	5, 7, 9
Time interval length	10 minutes, 5 minutes, 2 minutes
Inbound truck time windows	30-50 minutes, 60-80 minutes

Source: own work

A total of 180 test instances are randomly generated for the experiment. The experiment is conducted on a notebook with an Intel i7-8550 CPU and 16GB RAM. IBM's ILOG CPLEX Optimizer V12.10.0 is used to solve the MIP formulations. The solution time for all runs is limited to 5 minutes per test instance.

Table 7 reports the summarized computational results of the computational experiment. The TSFD-DT finds the optimal solution for all 180 problem instances in less than one minute. Moreover, the results indicate that the time interval length has a strong effect on the problem complexity of the discrete-time model. The solution time grows disproportionally when the time interval length is decreased. It can also be observed that the instances with wider truck time windows are more challenging to solve than instances with shorter time windows. Wider truck time windows increase the size of the discrete-time MIP model and the size of the solution space, which, in turn, results in longer computational times.

The TSFD-CT, on the other hand, solves 116 out of 120 test instances with 30 or 50 inbound trucks within the time limit. However, the continuous-time formulation requires a much longer solution time than the discrete-time formulation. Moreover, it has difficulties with the larger instances that include 80 inbound trucks. It only solves 8 out of 60 test instances with 80 inbound trucks to optimality. Surprisingly, the TSFD-CT cannot even identify a feasible integer solution in 49 out of 60 large test instances.

It can be summarized that the TSFD-DT clearly outperforms the TSFD-CT when seeking optimal solutions with an off-the-shelf solver such as CPLEX or Gurobi.

Table 7. Numerical results for the different MIP formulations of the TSFD

Instances				**TSFD-DT**			**TSFD-CT**			
$\lvert I \rvert$	$\lvert D \rvert$	Time interval length [min]	Time window length [min]	Avg. CPU time [s]	Optimal solution found	Avg. optimality gap	Avg. CPU time [s]	Feasible solution found	Optimal solution found	Avg. optimality gap
30	5	10	30-50	0.09	10/10	0.0%	0.35	10/10	10/10	0.0%
30	5	10	60-80	0.17	10/10	0.0%	1.44	10/10	10/10	0.0%
30	5	5	30-50	0.27	10/10	0.0%	0.66	10/10	10/10	0.0%
30	5	5	60-80	0.45	10/10	0.0%	4.36	10/10	10/10	0.0%
30	5	2	30-50	1.07	10/10	0.0%	1.21	10/10	10/10	0.0%
30	5	2	60-80	1.84	10/10	0.0%	5.65	10/10	10/10	0.0%
50	7	10	30-50	0.34	10/10	0.0%	34.98	10/10	10/10	0.0%
50	7	10	60-80	0.56	10/10	0.0%	58.52	10/10	9/10	0.2%
50	7	5	30-50	0.81	10/10	0.0%	31.20	10/10	10/10	0.0%
50	7	5	60-80	1.27	10/10	0.0%	101.27	10/10	9/10	2.2%
50	7	2	30-50	3.18	10/10	0.0%	69.10	10/10	9/10	0.4%
50	7	2	60-80	4.95	10/10	0.0%	58.85	10/10	9/10	0.2%
80	9	10	30-50	0.92	10/10	0.0%	239.63	4/10	4/10	60.0%
80	9	10	60-80	1.40	10/10	0.0%	300.00	0/10	0/10	100.0%
80	9	5	30-50	2.36	10/10	0.0%	281.72	4/10	2/10	65.4%
80	9	5	60-80	3.89	10/10	0.0%	300.00	0/10	0/10	100.0%
80	9	2	30-50	13.83	10/10	0.0%	298.96	3/10	2/10	70.1%
80	9	2	60-80	19.96	10/10	0.0%	300.00	0/10	0/10	100.0%

Note: For each parameter combination, ten different test instances are solved.
Source: own table

CONCLUSIONS

In this paper, we proposed both a discrete-time and a continuous-time mixed-integer programming formulation for a variant of the truck scheduling problem with fixed outbound departures. While the discrete-time formulation comes with a large number of decision variables, the continuous-time formulation requires a large number of constraints. Both formulation's computational performance was compared in a computational experiment with 180 test instances.

The experiment revealed that the discrete-time model clearly outperforms the continuous-time model in terms of solution time and solution quality. The discrete-time model can be solved to optimality in a reasonable time with a default solver, even for problem instances with 80 inbound trucks and a fine time granularity.

The tests showed that the solution time grows when increasing the number of trucks and decreasing the time interval length. Thus, the proposed discrete-time formulation may struggle to solve large-sized instances with several hundreds of trucks. Future research could develop solution procedures that can solve large instances of the truck scheduling variant.

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REFERENCES

Bartholdi J.J., Gue K.R., Kang K., 2008. Staging protocols for unit-load crossdocking, in Lahmar, M. (Ed.), Facility logistics. Approaches and solutions to next generation challenges, Auerbach Publications, Boca Raton, FL, 153-171, http://doi.org/10.1201/9781420013719.

Boysen N. Fliedne, M., 2010. Cross dock scheduling: Classification, literature review and research agenda, Omega, 38(6):413-422, http://doi.org/10.1016/j.omega.2009.10.008

Boysen N., Briskorn D., Tschöke M., 2013. Truck scheduling in cross-docking terminals with fixed outbound departures, OR Spectrum, 35(2):479-504, http://doi.org/10.1007/s00291-012-0311-6.

Buijs P., Vis I.F., Carlo H.J., 2014, Synchronization in cross-docking networks: A research classification and framework, European Journal of Operational Research, 239(3):593-608, http://doi.org/10.1016/j.ejor.2014.03.012.

Chmielewski A., Naujoks B., Janas M., Clausen U., 2009. Optimizing the door assignment in LTL-terminals, Transportation Science, 43(2):198–210, http://doi.org/10.1287/trsc.1090.0271.

Forger G., 1995. UPS starts world's premiere cross-docking operation, Modern Material Handling, 36-38.

Gue K.R., 1999. The effects of trailer scheduling on the layout of freight terminals, Transportation Science, 33(4):419-428, http://doi.org/10.1287/trsc.33.4.419.

Ladier A.L. Alpan G. 2016. Cross-docking operations: Current research versus industry practice, Omega, 62:145-162, http://doi.org/10.1016/j.omega.2015.09.006

Lamorgese L., Mannino C., 2019, A non-compact formulation for job-shop scheduling problems in traffic management, Operations Research, 67(6):1586–1609, http://doi.org/10.1287/opre.2018.1837.

Molavi D., Shahmardan A., Sajadieh M.S, 2018. Truck scheduling in a cross docking systems with fixed due dates and shipment sorting, Computers and Industrial Engineering, 117:29-40, http://doi.org/10.1016/j.cie.2018.01.009.

Rahmanzadeh Tootkaleh S., Fatemi Ghomi S.M., Sheikh Sajadieh M, 2016. Cross dock scheduling with fixed outbound trucks departure times under substitution condition, Computers and Industrial Engineering, 92:50-56, http://doi.org/10.1016/j.cie.2015.12.005.

Rijal A., Bijvank M., de Koster R, 2019. Integrated scheduling and assignment of trucks at unit-load cross-dock terminals with mixed service mode dock doors, European Journal of Operational Research, 278(3):752-771, http://doi.org/10.1016/j.ejor.2019.04.028.

Serrano C., Delorme X., Dolgui A, 2017. Scheduling of truck arrivals, truck departures and shop-floor operation in a cross-dock platform, based on trucks loading plans, International Journal of

Production Economics, 194:102-112, http://doi.org/10.1016/j.ijpe.2017.09.008.

Shakeri M., Low M.Y.H., Turner S.J., Lee E.W., 2012. A robust two-phase heuristic algorithm for the truck scheduling problem in a resource-constrained crossdock, Computers and Operations Research, 39(11):2564-2577, http://doi.org/10.1016/j.cor.2012.01.002.

Stalk G., Evans P., Shulman L.E., 1992. Competing on capabilities: The new rules of corporate strategy, Harvard Business Review, 70(2):57-68.

Tadumadze G., Boysen N., Emde S., Weidinger F., 2019. Integrated truck and workforce scheduling to accelerate the unloading of trucks, European Journal of Operational Research, 278(1):343-362, http://doi.org/10.1016/j.ejor.2019.04.024.

Van Belle J., Valckenaers P., Cattrysse D., 2012. Cross-docking: State of the art, Omega, 40(6):827-846, http://doi.org/10.1016/j.omega.2012.01.005

Van Belle J., Valckenaers P., Vanden Berghe G., Cattrysse D., 2013. A tabu search approach to the truck scheduling problem with multiple docks and time windows, Computers and Industrial Engineering, 66(4):818-826, http://doi.org/10.1016/j.cie.2013.09.024.

Witt C.E., 1998, Crossdocking: Concepts demand choice, Material Handling Engineering, 53(7):44-49.

ROZWIĄZYWANIE PROBLEMU HARMONOGRAMOWANIA PRZEWOZÓW PRZY USTALONYCH ZAŁADUNKACH

STRESZCZENIE. **Wstęp:** Harmonogramowanie przewozów oraz cross-dockingu leży w zasięgu zainteresowania uczonych już od ponad 30 lat. W tym okresie zaproponowało wiele różnych modeli programistycznych tablic awizacyjnych. Jednak zaledwie kilka modeli bierze pod uwagę stałe załadunki, które często są stosowane w przewozach niepełno samochodowych oraz kurierskich. Według naszego rozeznania, żaden z dostępnych modeli nie stosuje modelowania czasem w sposób dyskretny lub ciągły dla uzyskania lepszego wyniku. Celem pracy jest uzupełnienie tej luki w badaniach. Dlatego też rozważono wariant problemu harmonogramowania przewozów ze stałymi załadunkami z celem nadrzędnym znalezienia takiego sposobu harmonogramowania aby minimalizował on liczbę opóźnionych przewozów.

Metody: Zaproponowano dwa modele, opisujące harmonogramowanie przewozów ze stałymi załadunkami. Problem ten został sformułowany poprzez model programistyczny ze zmienną czasu w ujęciu dyskretnym i ciągłym.

Wyniki: Przeprowadzono symulację komputerową w celu określenie działania opracowanych modeli. Porównano wyniki pod względem jakości uzyskanego wyniku oraz niezbędnego czasu dla obliczeń.

Wnioski: Na podstawie uzyskanych wyników można stwierdzić, że proponowany model dyskretny może rozwiązywać problem średniej wielkości w czasie niższej niż minuta. Model oparty na czasie ciągłym uzyskał z kolei optymalizację przy małych przypadkach. Wymagało to jednak dłuższego czasu obliczeniowego. Dodatkowo nie uzyskano dla rozwiązań średniej wielkości czasu niższego od 5 minut. Dlatego też wysunięto wniosek, że model dyskretny jest lepszym w porównaniu z modelem ciągłym.

Słowa kluczowe: cross-docking, harmonogramowanie przewozów, programowanie różnych zmiennych, logistyka, optymalizacja

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FACTORS AFFECTING THE LEVEL OF SUPPLY CHAIN PERFORMANCE AND ITS DIMENSIONS IN THE CONTEXT OF SUPPLY CHAIN ADAPTABILITY

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ABSTRACT. **Background:** A vital determinant of supply chain performance is its adaptability. It is one of essential features that affect the results of the functioning of a supply chain. Many researchers indicate adaptability as a significant source of acquiring and maintaining a long-term competitive advantage, one of major factors that guarantee the success of a supply chain, or a major development megatrend of supply chains. The main objective of the article is to analyse the impact of such factors as industry and applied competitive strategy (cost leadership, differentiation, or focus) on the level of supply chain performance and results achieved by the supply chain with regard to the key aspects of performance in the context of adaptability.
Methods: In the article the author analyses results of studies conducted with CATI method at a sample of 200 enterprises representing four industries: automotive, food, furniture as well as consumer electronics and household appliances, which are among most advanced sectors in the Polish economy (leaders of Polish export). The analysis of data gathered was carried out at a few stages. Firstly, a hierarchical confirmatory factor analysis was applied. The developed model was used for measuring and assessing the performance of supply chains and its dimensions by means of designating factor scores. The last stage involved studying the impact of such factors as type of industry or applied competitive strategy on the level of performance and its four dimensions: visibility, velocity, versatility, and responsiveness. At this stage the non-parametric Kruskal-Wallis test was used.
Results: The results of the conducted studies provided evidence that the level of supply chain performance as well as its four dimensions is not affected by the type of industry, but vary in accordance to the applied competitive strategy.
Conclusions: The model, developed and positively verified in terms of quality, may constitute a useful tool for management practitioners to measure and assesses the performance of specific supply chains, as well as make comparisons between them. Thanks to determining factors that affect the level of performance and its four dimensions, managers may as well consciously indicate directions in improving supply chains.

Key words: supply chain performance, supply chain adaptability, 3V formula, hierarchical confirmatory factor analysis.

INTRODUCTION

According to the paradigm of the supply chain management, enterprises no longer compete as individual units but as a part of a larger, complex network. Growing market competition makes it possible that tightened cooperation within supply chains gives a better opportunity for achieving success [Espinoza, Bond, Kline 2010].

Supply chain management requires interpreting the supply chain as a whole, accounting for all links that must coordinate and synchronise their operations. R. Kaplan and D. Norton [1996] highlight that "it is not possible to effectively manage things that cannot be measured". Hence, the measurement and evaluation the functioning of supply chains has particular significance in the context of their management [Carvalho, Azevedo, Cruz-Machado 2012]. As D. Estampe claims [2014],

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there is no single, commonly accepted mechanism of identifying whether the supply chain functions properly. Literature describes many methods and models of measuring and evaluating the functioning of supply chains that account for many measures ascribed to various categories.

The selection of proper measurer and indicator categories used in measuring and evaluating supply chain performance depends on many factors, e.g. industry, organisational structure, conditions for the functioning of supply chains, output effects (product/service) [Cho et al. 2012; Elrod, Murray, Bande 2013]. Many authors (D. Chimhamhiwa, P. van der Molen, O. Mutanga & D. Rugege [2009], P. Folan & J. Browne [2005]) highlight the need for a multidimensional, balanced approach that incorporates the measurement context (objective and destination). Moreover, researchers emphasise the need to take into account the demanding number of dimensions [Chimhamhiwa et al. 2009; Espinoza at al. 2010]. The proper structure of the system of performance measurement also differs with regard to the desired features of the supply chain (e.g. agility, adaptability etc.) [Gopal, Thakkar 2012].

Literature, apart from the methods and models characterised by universality (e.g. Balanced Scorecard, SCOR model, GSCF model, APQC model, performance prism etc.), also offers solutions that account for the context of measurement and are dedicated to the evaluation of: green supply chains [Shaw, Grant, Mangan 2010], sustainable supply chains [Piotrowicz, Cuthbertson 2015; Zailani et al. 2012], lean supply chains [Arif-Uz-Zaman, Ahsan 2014] etc. While reviewing scientific publications, the author did not identify papers that deal with the subject of the measurement and evaluation of supply chain performance in the context of adaptability as one of the most significant features of the supply chain that affect the results of its functioning. Many researchers associate adaptability as an important source of acquiring and maintaining long-term competitive advantage and one of the major features that guarantee the success of the supply chain [Ahimbisibwe et al., 2016]. Adaptive capacity is also called the major developmental megatrend of supply chains [Szymczak 2015a].

With reference to the identified research gap, the article undertakes the issue of measuring and assessing the performance of a supply chain in the context of its adaptability. The basic objective of the paper is analysing major dimensions of performance as well as a studying the impact of such factors as industry and the applied competitive strategy on the performance of a supply chain and results achieved by this supply chain within key aspects of performance.

The article is organized as follows. In the first part of the article the author outlines a review of literature in the scope of assessing supply chain performance, supply chain adaptability and dimensions of supply chain performance with regard to the adaptability feature. The analysis of literary sources leads to the formulation of hypotheses, being the subject of theoretical and empirical verification. The article continues to describe the methodology of conducted research and next – the results of analyses. The author as well elaborates on the achieved findings and summarises the article, indicating basic limitations of the presented approach as well as future directions of studies.

THEORY AND HYPOTHESES

Supply chain performance measurement

As P. Brewer and T. Speh [2000] emphasise, a successful supply chain involves, apart from effective coordination of processes, concentration of measures on providing customers values and elimination of unnecessary costs in key areas of functioning, the implementation of a measurement system that provides information whether the supply chain properly satisfies basic expectations. H. Carvalho, S. Azevedo and V. Cruz-Machado [2012] also point out that the measurement and assessment of the functioning of a supply chain are of particular significance in the context of its effective management.

The notion of performance is most frequently understood as a process of quantifying the efficiency and effectiveness of actions. Efficiency measures the application of resources aimed at satisfying a specific level of customer satisfaction in an economic aspect. Effectiveness, in turn, measures the level of satisfying customer expectations [Neely, Gregory, Platts 1995].

What distinguishes the measurement of supply chain performance is the fact that it should primarily account for measurers that entail the entire supply chain, allowing for an analysis of interdependencies that go beyond the limits of an organization [Ganga, Carpinetti 2011; Schmidt, Foerstl, Schaltenbrand 2017]. Among basic elements of cooperation between entities in a supply chain, S. Min et al. [2005] enumerate a common assessment of achievements apart from information sharing, joint planning and problem solving and an ability to exert effective impact on partners. The assessment of effects that are the result of collaboration allows for drawing conclusions for further cooperation. Therefore, it is vital that the measurement and assessment are both of a horizontal character, which concentrates on the entire supply chain, and vertical – dedicated to analysing organisational processes in specific enterprises [Lin, Li 2010]. J. Ying and Z. Li-jun [2011] as well claim that the scope of measurement that refers to a supply chain should cover not only operational performance of enterprises, but also their impact on the entire supply chain, cooperation between these enterprises and their partners. The second aspect should even be the subject of greater attention. As D. Estampe et al. [2013] emphasise, the assessment of supply chain performance is a complex undertaking, being a transversal process that engages many actors cooperating one with another in order to achieve assumed logistics and strategic objectives.

Supply chain adaptability

Adaptiveness is one of the most significant features of the supply chain that affects the results of its functioning. Supply chain adaptability can be defined as its capacity for changes that lead to preventing from the occurrence of undesired events, improving the functioning or acquiring new skills in order to achieve the objective of the supply chain in specific environmental conditions (that are changeable) and in the light of incomplete information on their dynamics [Ivanov, Sokolov 2010]. Participants in the adaptive supply chain get the ability to recognise the changing operational conditions in a period that allows them to evaluate alternative corrective measures as well as react in order to alleviate their impact on the company's operation. This is particularly significant in the light of uncertainty currently faced by the enterprises (associated with such events as terrorist attacks, employee protests, force majeure etc.) [Davidrajuh 2006]. Adaptability allows partners in the supply chain to work in a dynamic environment so as to foster the achievement of greater effectiveness of operations [Whitten, Green, Zelbst 2012].

D. Ivanov, B. Sokolov and J. Kaeschel [2010] claim that a supply chain can be called adaptive if it is capable of adapting to:

- changes in the market environment and the functioning in conditions of uncertainty,
- changes in the executive environment of specific measures,
- internal changes in the supply chain itself

by means of using structural and functional reserves as well as better coordination that results from the application of information and computer technologies, in particular the Internet. Under the influence of long-term and strong changes in the environment, this type of supply chain is able to reduce, suppress or eliminate disruptions and maintain, or even improve the operational efficiency through reconfiguring its elements (transition to a new state). Adaptability is crucial in the context of adjusting to global markets as a response to changes in the life cycle of a product and technology as well as in reaction to the customer's needs.

Performance dimensions

Adaptability capacity is an effect of developing a certain set of features in the supply chain. The most significant ones are: visibility, velocity and versatility. R. Kalakota,

M. Robinson and P. Gundepudi [2003] consider inventory visibility, fulfillment velocity and coordination versatility as three fundamental pillars of adaptive supply chains, also termed as 3V in the literature [Ruhi, Turel 2005; Szymczak 2015b]. Moreover, analyses conducted by D. Leończuk, U. Ryciuk, M. Szymczak & J. Nazarko [2019] reveal that 3V formula need to be supplemented by yet another factor called responsiveness that relates to reaction to customer needs (expanded to 3V + R formula).

Visibility is associated with ensuring access to information to all participants in the supply chain, including customers [Barrat, Oke 2007; Johansson, Melin 2008; Jűttner, Maklan 2011; Swaminathan, Tayur 2003]. Its scope may also include the application of innovative technologies that support cooperation in the supply chain, coordination of material and non-material resources [Caridi et al., 2014; Holcomb, Ponomarov, Manrodt 2011; Johansson, Melin 2008; Kalakota, Robinson, Gundepudi 2003; Ross, Holcomb, Fugate 2004], as well as substitution of resources with information share [Clark 2007; Hines 2013]. A supply chain reaching high values in the framework of this dimension is characterised by transparency necessary for early detection and proper reaction to all sorts of disruptions, in particular associated with order execution [Scholten, Schilder 2015]. Ensuring visibility of all processes provides necessary information in order to make decisions and corrections in plans. This allows partners in the supply chain to identify bottlenecks, which in turn fosters immediate reaction in order to eliminate them [Iyer, Seshadri, Vasher 2009]. Supply chain visibility is also connected with the ability to track the flow of resources, in particular inventories, as well as the current update of the order fulfillment status [Szymczak 2015b].

Velocity, in turn, is associated with the capacity of the supply chain to execute various processes and measures aimed at achieving the desired goals in a fast manner [Tsironis, Matthopoulos 2015]. On the one hand, such velocity refers to implementing changes: the development of the currently offered products and launching new products [Hines 2013], on the other – it is associated with the ability to react to diverse events and changes on the market [Jűttner, Maklan 2011].

The third element that joins the described approaches is a widely understood versatility of operation. It primarily concerns balancing the operational efficiency of the supply chain with market needs, in particular providing proper products and services at the required quality and in the right volume. It is also crucial to adjust the offer to the individual needs of customers. [Momeni et al., 2014; Olugu, Wong 2009]. Versatility involves as well undertaking cooperation with suppliers and recipients in the light of various conditions of order processing, which is connected with the need to ensure high flexibility of the operation within the supply chain so that it can handle changeability [Szymczak 2015b]. Many authors also perceive variety as an important feature, which, however, can be treated as one of the elements of supply chain versatility [Kohlberger, Gerschberger, Engelhardt-Nowitzki 2011; Nielsen & Holmström 1995]. The supply chain reaching high values in the scope of this dimension is characterised by a high level of flexibility and changeability of the undertaken arrangements [Nutt 2004].

Responsiveness refers to the aspects of the supply chain responsiveness connected with getting familiarized with customer needs as well as reaction to them (delivering products fast and in a timely manner). H. Lee [2004] and G. Whitten, K. Green and P. Zelbst [2012] wrote about creating adaptive supply chains by means of analysing the needs of both direct and final customers. This dimension also referred to the time of order execution as well as their timely delivery, as e.g. R. Basu and J. Wright argued [2008].

Research hypotheses

C Bozarth and R. Handfield [2007] claim that "on a competitive market no enterprise can indefinitely maintain advantage in all dimensions of performance. Perfection in certain dimensions may contradict the perfection in other aspects; therefore there is no single company that can be best at everything. In such cases one has to make difficult choices and decisions as a result of which the significance of certain dimensions increases at the cost of other ones". Understanding the importance of specific measurers of supply chain performance and its dimensions translates into achieving a high level of measurement in areas perceived as essential.

In a competitive environment, the results of the functioning of an enterprise are closely related to its ability to manage complex relations with business partners. The so-called focal enterprise, namely the one that is seen by customers as being responsible for a product or service as well as coordinating material and information flow, plays a particularly significant role. By means of taking specific (e.g. improved visibility), such a company may influence the performance of the entire supply chain [Caridi et al. 2014; Elking et al., 2017; Kot, Onyusheva, Grondys 2018].

The significance of specific dimensions as well as specific measurers and indicators of assessing supply chain performance may as well differ, depending on the industry in which a given enterprise operates. Research on the significance of measurers of performance was conducted e.g. by F. Chan [2003], who suggested using the AHP method in indicating priorities of performance measures, as exemplified by various branches of industry. C. Elrod et al. [2013], in turn, analysed the issue of applying various measurers of supply chain performance in selected industries. On the basis of interviews conducted with representatives of enterprises from three industries (arms industry, chemical industry as well as food and beverage production and distribution industry), the authors state that the significance of measurers of supply chain performance depends on the type of industry, organisational structure and conditions of the functioning of an enterprise. In case of a company operating in food and beverage production and distribution, the most significant measurers are time (in particular time spent by the stocks in a warehouse in order to avoid being expired), elimination of delays and quality (assessed as per value perceived by a customer). Conducting business activity in the chemical industry requires focusing on ensuring flexibility of actions taken, using production capacity, adjusting plurality of production to current needs and limiting costs. In the arms sector, in turn, priority was given to: costs (also with regard to information processing), quality (expressed in the value perceived by the customer), time of order processing and flexibility within launching new products and services as a reaction to the development of technologies.

Thus, it can be assumed that the level of supply chain performance as well as the results achieved within specific dimensions of performance distinguished in the context of adaptability, will be diversified with respect to the industry in which a given supply chain functions, as well as the applied competitive strategy. Based on the above deliberations the following research hypotheses were formulated:

H1: The type of industry a given supply chain belongs to, affects the level of its performance and results achieved by the supply chain within performance dimensions assessed in the context of its adaptability.

H2: The competitive strategy applied in a supply chain (by a focal company) affects the level of supply chain performance and results achieved by the supply chain within performance dimensions assessed in the context of its adaptability.

METHODOLOGY

Survey development and measures

The construction of the measuring tool was initiated with drawing up a list of measures of supply chain performance that were cited in the literature and also applied in the business practice. Next, the author selected only those that were most frequently mentioned and that encompassed the perspective of the entire supply chain. The following step involved selecting potential indicators for each assumed dimensions of the supply chain performance, described with the use of the 3V formula, based on literature review. The list of indicators was limited on the basis of the principle "less is better" [Chae 2009;

Gunasekaran, Kobu 2007], according to which the system of performance measurement should be based on the minimal number of metrics and indicators.

In effect, the scale for measuring the performance of the adaptive supply chain included 23 indicators (Appendix A). The list of indicators has been prepared based on the definition of three assumed dimensions of the supply chain performance. Questions were listed without grouping into categories. Likert's seven-level scale was used in the questionnaire to evaluate each indicator: from "strongly disagree" to "strongly agree".

Data collection and sample

The research was conducted with the use of CATI technique. Interviews involved a sample of 200 enterprises operating in four industries: automotive, food, furniture as well as consumer electronics and household appliances (Table 1), which are among most advanced sectors in the Polish economy (leaders of Polish export). In case of all enumerated sectors, interviews were conducted with representatives of 50 randomly selected enterprises, mainly employing 50 or more employees. The research sample was selected in a quota random way. The percentage of denials or unsuccessful contact attempt is 81%.

Table 1. Sample characteristics

		N	%
Sector	Automotive	50	25
	Food	50	25
	Furniture	50	25
	Consumer electronics and household appliances	50	25
Employment	10-49 employees	6	3
	50-249 employees	118	59
	250 and more employees	70	35
	n/a	6	3
Source of the entity's capital	Entity with solely Polish capital	132	66
	Entity with solely foreign capital	23	11.5
	Entity with dominating Polish capital	16	8
	Entity with dominating foreign capital	17	8.5
	n/a	12	6

Research sample consisted of Polish companies (from all Polish voivodeships) mainly employing 50 or more employees of which 59% were medium-sized enterprises employing less than 250 employees and 35% of large enterprises employing more than 250 employees. The major part of the sample (74% in total) constituted enterprises with solely Polish capital or with dominating Polish capital.

Interviews involved persons experienced in logistics and supply chain management. Most respondents (72%) declared that they have more than five years of experience (in case of 62.5% of interviewees, their experience is more than ten years). The representatives of enterprises that took part in interviews knew the specifics of the companies under study, since 71.5% of them worked there for more than five years. Only 8.5% of respondents worked for less than two years in the analysed enterprise. A large percentage of interviewees (approximately 35.5%) constituted persons who worked in logistics departments. This group was comprised of managers and specialists in the following areas: logistics, transport, forwarding, storage as well as combining tasks related to purchasing and logistics, production planning and logistics, or transport and logistics. The same percentage of respondents constituted procurement specialists.

The interviews were conducted with the use of a structured questionnaire, which included statements comprising a developed scale for measuring supply chain performance, closed questions on the enterprise's strategy and characteristics of a supply chain, as well as open questions allowing for raising potential remarks and comments. The questionnaire was capped with demographics questions.

Analysis

The analysis of the gathered data was carried out at several stages. Firstly, the authors conducted an exploratory factor analysis of a set of indicator variables selected for measuring supply chain performance. The next stage involved a confirmatory factor analysis, where again, on the basis of obtained results, the authors modified a set of indicator variables by means of eliminating those which proved statistically insignificant or irrelevant (the signs of factor loadings did not meet expectations). The findings resulting from these two stages were published in a publication of Leończuk at al. [2019].

Another phase involved conducting a hierarchical confirmatory factor analysis, aimed at verifying the possible existence of a higher-order factor structure. The models of higher-order factors constitute an elaboration of a concept that characterises factor analysis, which assumes that a common variance of observable variables can be explained by means of underlying latent variable or variables (factors). In hierarchical models, the analysis of correlation-covariance existing between observable variables is replaced with a correlation between latent variables. The existence of correlations between latent variables means that there is a common between variance. In such a situation, similar to observable indicators, it is possible to distinguish one factor (or several factors) of higher order. Then correlations between primary factors (based on correlations between observable variables) become an input matrix for higher-order analyses [Brown, 2015].

The developed model was used for measuring and assessing supply chain performance as well as obtaining a detailed picture of their situation within major performance dimensions, crucial in the context of supply chain adaptability. On the basis of conducted factor analysis, according to the obtained factor structure, indicators of latent variables, the so-called factor scores, were created [O'Rourke, Hatcher 2013]. Factor scores are most frequently calculated with the use of the results of an exploratory factor analysis; however, they can also be designated on the basis of results of a confirmatory factor analysis. As Ch. DiStefano, M. Zhu and D. Mîndrilă [2009] indicate, factor scores created on the basis of CFA are of similar significance to those created with EFA results. Hence, they can also be used for determining the value of a latent variable and conducting further analyses.

Factor scores based on CFA outcomes are usually designated with the use of non-refined methods, e.g. sum (average) of variable values within a given factor, sums of standardized variable values, weighted sum of variable values. In ordinary indicator summing or averaging it is assumed that each statement is of the same significance for the measurement of a latent variable which is to be measured by the scale. Nonetheless, factor analysis proved the contrary since specific questions have different factor loadings. Many authors, e.g. M. Uluman and C. Doğan [2016], indicate that a more precise solution is creating indicators by means of averaging results of respondents in specific survey questions, after multiplying them by the values of standardized factor loadings. Thanks to this, statements of strong factor load make a greater contribution to the indicator and those with smaller factor load make a smaller contribution. Factor scores were determined for each enterprise under study within four constructs and a higher-order latent variable, based on confirmatory factor analysis. Factor scores for supply chain performance were designated on the basis of the results of a hierarchical factor analysis as a weighted average of factor scores for four performance dimensions: responsiveness, velocity, visibility and versatility, with weights in a form of factor loadings that define relations between a higher-order factor and specific performance dimensions.

The last stage of conducted analyses focused on the impact of such factors as type of industry and applied competitive strategy on the level of supply chain performance as well as results achieved by supply chains within indicated performance dimensions.

RESULTS

Conducting an exploratory, and subsequently confirmatory, factor analysis, the results of which were described in a publication of D. Leończuk et al. [2019], allowed for distinguishing four factors that create a scale for measuring supply chain performance: responsiveness (RES), versatility (VER), visibility (VIS) and velocity (VEL). Each of these factors portrays a different aspect of the performance of an adaptive supply chain, and variables connected with a given factor allow for measuring the level of a specific feature of a supply chain.

Table 2. Factor correlation matrix

Factor	RES	VER	VIS	VEL
RES	1.000	0.561	0.625	0.623
VER	0.561	1.000	0.518	0.580
VIS	0.625	0.518	1.000	0.597
VEL	0.623	0.580	0.597	1.000

All correlations significant at $p < 0.001$

With regard to the existence of correlations between distinguished factors (Table 2), a model of hierarchical factor analysis was constructed in order to capture a superior common factor, introducing an additional latent variable that represents the total outcome on a measurement scale of supply chain performance. Figure 1 presents the results of the conducted analysis.

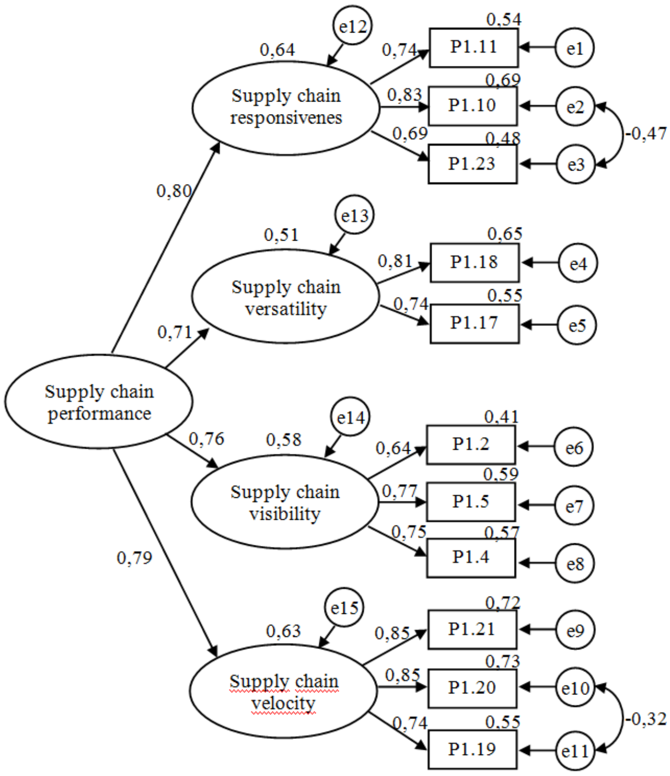

Fig. 1. Confirmatory factor analysis-hierarchical model

The quality assessment of the model engaged a series of goodness-of-fit. The author made an initial assessment of the model with the use of chi-squared statistics with reference to the number of degrees of freedom. It is often argued that the model is very good when this value is smaller than 2 [Fischer 2013]. In the assessed model the value $\chi 2/df$ equals 1.205. The good fit of the model is also confirmed by the RMSEA equals 0.032. It is assumed that the model is good if the approximation error does not exceed 0.05 [Fischer 2013]. Good model fit is also confirmed by such measures as GFI=0.958, AGFI=0.927, CFI=0,957, which exceed required value of 0.9 [Brown 2015]. Only the NFI=0.806 reached the value below 0.9. The main drawback of the NFI is its sensitivity to the sample size (it is frequently underestimated for samples below 200) and the model's complexity (higher values are obtained for more complex models). This problem was solved by the application of the TLI, which prefers simpler models [Hooper, Coughlan & Mullen 2008]. For the assessed model, the TLI exceeded the acceptance threshold and equals 0.938.

Analyses show that all questionnaire items obtain respectively high factor loadings (above 0.7 or slightly below this value) and are of statistically significant. It should be noted that a superior factor of supply chain performance is best represented by factor 1 – supply chain responsiveness (0.8) and factor 4 – supply chain velocity (0.79), and in lesser extent by factor 3 – supply chain visibility (0.76) and factor 2 – supply chain versatility (0.71).

The developed model was used for measuring and assessing the level of supply chain performance and its four distinguished dimensions in Polish enterprises, calculating indicators of latent variables, according to the obtained factor structure. The level of indicators may assume values from 1 to 7. In case of companies under analysis, an average level of supply chain performance was $\bar{x}$ =5.28 (with standard deviation SD=0.92). With its value of Me=5.33, the median as well obtained an approximate value. The values of the average and the median in case of three performance dimensions were also similar: responsiveness ($\bar{x}$ =5.41; SD=1.12; Me=5.61), visibility ($\bar{x}$ =5.48; SD=1.16; Me=5.7) and versatility ($\bar{x}$ =5.28; SD=1.3; Me=5.47). In measuring the fourth dimension – velocity, slightly lower values were obtained ($\bar{x}$ =4.95; SD=1.2; Me=5).

In order to compare the level of supply chain performance and its dimensions in enterprises operating in four analysed industries, the non-parametric Kruskal-Wallis test was used. The selection of the test was caused by the non-performance of assumptions required by parametric tests, primarily lack of compliance of the distribution of dependent variables with normal distribution. Table 3 illustrates outcomes of conducted tests.

Table 3. Results of the analysis of differences at the level of supply chain performance and performance dimensions in selected industries with the use of the Kruskal-Wallis test

	Food sector N=50	**Furniture sector N=50**	**Automotive sector N=50**	**Consumer electronics and household appliances sector N=50**	**Results of Kruskal-Wallis test**
Supply chain performance	M=5.29 SD=0.91	M=5.19 SD=1.07	M=5.26 SD=0.78	M=5.38 SD=0.91	chi=0.938, df=3, p=0.816
Supply chain responsiveness	M=5.47 SD=1.10	M=5.24 SD=1.23	M=5.42 SD=1.08	M=5.52 SD=1.09	chi=1.216, df=3, p=0.749
Supply chain velocity	M=5.02 SD=1.25	M=5.04 SD=1.19	M=4.72 SD=1.12	M=5.02 SD=1.24	chi=2.928, df=3, p=0.403
Supply chain visibility	M=5.57 SD=1.13	M=5.30 SD=1.29	M=5.50 SD=1.00	M=5.56 SD=1.24	chi=1.688, df=3, p=0.640
Supply chain versatility	M=5.08 SD=1.26	M=5.20 SD=1.52	M=5.42 SD=1.15	M=5.44 SD=1.25	chi=2.903, df=3, p=0.407

The results of the Kruskal-Wallis test (level of test probability for all dependable variables exceeding the value of 0.05) indicate that the level of supply chain performance as well as its four dimensions does not depend on the type of industry a given enterprise operates.

The level of variables was also compared among groups of enterprises with regard to the applied strategic approach (Table 4). For this reason, the author divided competitive strategies into three types, as proposed by M. Porter [1985]:

I. Cost leadership – involves obtaining a leading position in a given industry in terms of total costs; the leading motive of this strategy is a low manufacturing cost as compared to competitors, also with regard to quality, level of customer care etc.

II. Differentiation – involves differentiating the product or service offered by the enterprise, creating something which is considered unique in the entire sector.

III. Focus – involves concentrating on a specific group of purchasers, a specific range of product assortment or a geographical market.

Table 4. Results of the analysis of differences at the level of supply chain performance and performance dimensions with regard to a competitive strategy used by enterprises with the use of the Kruskal-Wallis test

	I. Cost leadership N=19	II. Differentiation N=67	III. Focus N=103	Results of Kruskal-Wallis test
Supply chain performance	M=4.48 SD=0.91	M=5.29 SD=0.85	M=5.39 SD=0.90	chi=14.8, df=3, p=0.002
Supply chain responsiveness	M=4.83 SD=1.22	M=5.32 SD=1.12	M=5.55 SD=1.06	chi=9.051, df=3, p=0.029
Supply chain velocity	M=4.31 SD=0.88	M=4.92 SD=1.23	M=5.06 SD=1.20	chi=8.526, df=3, p=0.036
Supply chain visibility	M=4.64 SD=1.23	M=5.59 SD=0.91	M=5.54 SD=1.23	chi=11.773, df=3, p=0.008
Supply chain versatility	M=4.08 SD=1.53	M=5.34 SD=1.22	M=5.43 SD=1.24	chi=13.787, df=3, p=0.003

The results of the conducted tests (the level of test probability for all dependable variables is below 0.05) indicate that the type of applied competitive strategy makes a significant statistical impact on the level of supply chain performance and its four dimensions. In order to identify which groups of enterprises vary among each other in terms of the level of supply chain performance, their responsiveness, velocity, visibility and versatility, the author conducted multiple comparisons tests for each analysed variable.

The test results showed that the level of supply chain performance, as well as their visibility and versatility, significantly vary for enterprises that apply a strategy of cost leadership and enterprises applying the other two strategies. However, there were no differences in the level of variables among enterprises that apply differentiation and focus strategies. It should also be noted that the application of the strategy of cost leadership entails a lower level of described variables.

Still, the multiple comparisons tests, conducted for responsiveness and velocity variables, point to the fact that the difference between the first and third strategy is significant. Other differences proved insignificant. Hence, it can be claimed that supply chains of enterprises applying the strategy of cost leadership are characterised by lower responsiveness and velocity than those that aim at concentration.

DISCUSSION

The conducted hierarchical factor analysis allowed for expanding the model described in a publication by D. Leończuk et al. [2019], which indicates visibility, velocity, versatility and responsiveness as four major factors in assessing supply chain performance in the context of its adaptability, by an additional, second-order factor. Introducing an additional, latent variable, defined as performance, allows for making a measurement and assessment of four major aspects of adaptability as well as assessing a general level of supply chain performance (Figure 2).

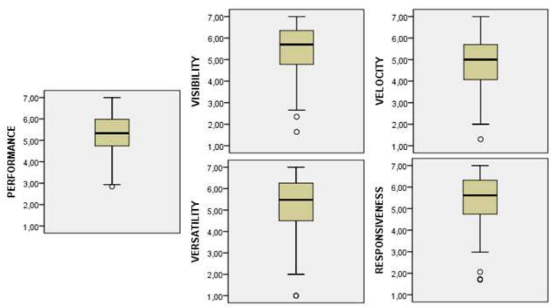

Fig. 2. The level of supply chain performance and its dimensions in Poland

The level of performance within the range <1.0-3.0> was considered as low, in the range <3.0-5.0> as medium, and within <5.0-7.0> as high [Ryciuk 2016]. According to the assumed assumptions, it can be stated that the level of supply chain performance in Poland is high (5.28). Also, the level of three dimensions of performance, i.e. responsiveness (5.41), visibility (5.48) and versatility (5.28) was high, whereas velocity ranks as medium (4.95).

A vital element of the research was also determining factors that affect the level of supply chain performance and its four dimensions. The results of the conducted statistical analysis suggest that the first hypothesis on the impact of the industry on the level of supply chain performance and the results achieved by the supply chain in its major dimensions: visibility, velocity, versatility, and responsiveness; should be rejected. Still, the conducted research provided evidence that the second hypothesis should be assumed. The factor which significantly affects the level of analysed variables is hence a competitive strategy applied in a supply chain by a focal enterprise. The most vital differences can be observed in case of applying the strategy of cost leadership and two other strategies. Supply chains in which this strategy is conducted, are characterised by a clearly lower level of performance as well as visibility, velocity, versatility and responsiveness. These results confirm that actions taken by an enterprise perceived by customers as the one that is in charge of a product or service, affects the results achieved by the supply chain [Caridi et al. 2014; Kot, Onyusheva & Grondys 2018].

Contribution and Implications

This article focuses on the issues of supply chain performance in terms of its adaptability. The author develops the model described by D. Leończuk et al. [2019]. The construction of an additional, hierarchical factor analysis model allowed for indicating an additional latent variable which represents a total outcome on the measurement scale of supply chain performance. Thanks to this, it is possible to make a measurement and assessment of the performance level of specific supply chains in the context of their adaptability, as well as a diagnosis of their situation within four major dimensions of performance: visibility, velocity, versatility, and responsiveness. The conducted statistical analyses also allowed for indicating factors that affect the level of analysed variables.

The model, developed and positively verified in terms of quality, may constitute a useful tool for management practitioners to measure and assesses the performance of specific supply chains, as well as make comparisons between them. Thanks to determining factors that affect the level of performance and its four dimensions, managers may as well consciously indicate directions in improving supply chains.

Limitations and future research

In addition to its contributions, this study has limitations. Firstly, limitations concern the selection of a research sample, in particular its volume. The research was conducted with a sample of 200 enterprises. Some researchers, e.g. J. Guilford [1954] claim that such a volume allows for conducting a factor analysis and generalizing results of the research. However, others suggest that the sample should be larger and entail 300, or even 500 respondents [MacCallum, Widaman, Zhang & Hong 1999]. The consequence of such a small research sample was an uneven number of groups of enterprises analysed with the Kruskal-Wallis test, as well as their small size (division according to the applied strategy into three groups with the size of 19-67-103). This dictates certain caution in interpreting results. Another limitation is connected with conducting research on a sample composed solely of Polish entrepreneurs (the major part of the sample constituted enterprises with solely Polish capital or with dominating Polish capital). Moreover, the research involved enterprises solely operating in four industries (automotive, food, furniture as well as consumer electronics and household appliances). It is recommended to analyse the existence of the observed dependencies also in other sectors.

The analyses and deliberations put forward in the article may constitute the basis and inspiration for further research in this field.

Due to the limitations resulting from the selection of such a research sample and the assumed research methodology, it is necessary to confirm the obtained results of studies in future research and expand them by other European countries. It is recommended to verify the model on a larger research samples. Further research directions may be also associated with the use of the developed model for measuring and evaluating supply chain performance from other than the sectors researched within the article, as well as in-depth analyses of dependencies between the distinguished performance dimensions. Moreover, the author identifies developing measurement tools that allow for improving the evaluation of the functioning of supply chains other than the adaptive ones (agile, lean etc.) as further research challenges.

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REFERENCES

Ahimbisibwe A., Ssebulime R., Tumuhairwe R., Tusiime, W., 2016. Supply chain visibility, supply chain velocity, supply chain alignment and humanitarian supply chain relief agility. European Journal of Logistics, Purchasing and Supply Chain Management, 4(2), 34-64.

Arif-Uz-Zaman K., Ahsan, A.M.M.N., 2014. Lean supply chain performance measurement. International Journal of Productivity and Performance Management, 63(5), 588-612, http://doi.org/10.1108/IJPPM-05-2013-0092

Barratt M., Oke A., 2007. Antecedents of supply chain visibility in retail supply chains: A resource-based theory perspective. Journal of Operations Management, 25(6), 1217-1233, http://doi.org/10.1016/j.jom.2007.01.003

Basu R., Wright J.N., 2008. Total supply chain management. Elsevier, United Kingdom.

Beamon B.M., 1999. Measuring supply chain performance. International Journal of Operations & Production Management, 19(3), 275-292, http://doi.org/10.1108/01443579910249714

Bozarth C., Handfield R.B., 2007. Wprowadzenie do zarządzania operacjami i łańcuchem dostaw [Introduction to operations and supply chain management]. Helion, Gliwice.

Brewer P.C., Speh T.W., 2000. Using the balanced scorecard to measure supply chain performance. Journal of Business Logistics, 21(1), 75-93.

Brown T.A., 2015. Confirmatory factor analysis for applied research. The Guilford Press, New York.

Caridi M., Moretto A., Perego A., Tumino A., 2014. The benefits of supply chain visibility: A value assessment model. International Journal of Production Economics, 151, 1-19, http://doi.org/10.1016/j.ijpe.2009.08.016

Carvalho H., Azevedo S.G., Cruz-Machado V., 2012. Agile and resilient approaches to supply chain management: Influence on performance and competitiveness. Logistics Research, 4(1), 49-62, http://doi.org/10.1007/s12159-012-0064-2

Chae B., 2009. Developing key performance indicators for supply chain: An industry perspective. Supply Chain Management: An International Journal, 14(6), 422-428, http://doi.org/10.1108/13598540910995192

Chan F.T.S., 2003. Performance measurement in a supply chain. International Journal of Advanced Manufacturing Technology, 21(7), 534-548, http://doi.org/10.1007/s001700300063

Chimhamhiwa D., van der Molen P., Mutanga O., Rugege D., 2009. Towards a framework for measuring end to end performance of land administration business process – a case study. Computers, Environment and Urban Systems, 33(4), 293-301, http://doi.org/10.1016/j.compenvurbsys.2009.04.001

Cho D.W., Lee Y.H., Ahn S.H., Hwang M.K., 2012. A framework for measuring the performance of service supply chain management. Computers & Industrial Engineering, 62(3), 801-818, http://doi.org/10.1016/j.cie.2011.11.014

Clark Ch., 2007. Getting back to basics: Top five tips for accelerating supply chain velocity. Supply & Demand Chain Executive, 8(4), 26.

Davidrajuh R, 2006. Structures for stepwise development of adaptive supply chains. Journal of Internet Commerce, 5(4), 55-72, http://doi.org/10.1300/J179v05n04_04

DiStefano Ch., Zhu M., Mîndrilă D., 2009. Understanding and using factor scores: Considerations for the applied researcher. Practical Assessment, Research & Evaluation, 14(20), 1-11.

Elking I., Paraskevas J-P., Grimm C., Corsi T., Steven A., 2017. Financial Dependence, Lean Inventory Strategy, and Firm Performance. Journal of Supply Chain Management, 53(2), 22-38, http://doi.org/10.1111/jscm.12136

Elrod C., Murray S., Bande S., 2013. A review of performance metrics for supply chain management. Engineering Management Journal, 25(3), 39-50, http://doi.org/10.1080/10429247.2013.11431981

Espinoza O.A., Bond B.H., Kline E., 2010. Quality measurement in the wood products supply chain. Forest Products Journal, 60(3), 249-257, http://doi.org/10.13073/0015-7473-60.3.249

Estampe D., 2014. Supply chain performance and evaluation models. ISTE, London.

Estampe D., Lamouri S., Paris J-L., Brahim-Djelloul S., 2013. A framework for analysing supply chain performance evaluation models. International Journal of Production Economics, 142(2), 247-258, http://doi.org/10.1016/j.ijpe.2010.11.024

Fischer C., 2013. Trust and communication in European agri-food chains. Supply Chain Management: An International Journal, 18(2), 208-218, http://doi.org/10.1108/13598541311318836

Folan P., Browne J., 2005. A review of performance measurement: towards performance management. Computers in Industry, 56(7), 663-680, http://doi.org/10.1016/j.compind.2005.03.001

Ganga G.M.D., Carpinetti L.C.R., 2011. A fuzzy logic approach to supply chain performance management. International Journal of Production Economics, 134(1), 177-187, http://doi.org/10.1016/j.ijpe.2011.06.011

Golrizgashti S., 2014. Supply chain value creation methodology under BSC approach. Journal of Industrial Engineering International, 10(67), 1-15, http://doi.org/10.1007/s40092-014-0067-5

Gopal P.R.C., Thakkar J., 2012. A review on supply chain performance measures and metrics: 2000-2011. International Journal of Productivity and Performance Management, 61(5), 518-547, http://doi.org/10.1108/17410401211232957

Guilford J. P., 1954. Psychometric methods. McGraw-Hill, New York.

Gunasekaran A.,Kobu B., 2007. Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995-2004) for research and applications. International Journal of Production Research, 45(12), 2819 2840, http://doi.org/10.1080/00207540600806513

Hines T., 2013. Supply chain strategies: Demand driven and customer focused. Routledge New York.

Holcomb M.C., Ponomarov S.Y., Manrodt K.B., 2011. The relationship of supply chain visibility to firm performance. Supply Chain Forum: An International Journal, 12(2), 32-45, http://doi.org/10.1080/16258312.2011.11517258

Hooper D., Coughlan J., Mullen M., 2008. Structural equation modelling: guidelines for determining model fit. Electronic Journal of Business Research Methods, 6(1), 53-60.

Ivanov D., Sokolov B., 2010. Adaptive supply chain management. Springer, London.

Ivanov D., Sokolov B., Kaeschel J., 2010. A multi-structural framework for adaptive supply chain planning and operations control with structure dynamics considerations. European Journal of Operational Research, 200(2), 409-420, http://doi.org/10.1016/j.ejor.2009.01.002

Iyer A., Seshadri S., Vasher R., 2009. Toyota supply chain management: A Strategic approach to Toyota's renowned system. McGraw-Hill Education, USA.

Johansson S., Melin J., 2008. Supply chain visibility. The value of information. A benchmark study of the Swedish industry. KTH Royal Institute of Technology, Stockholm.

Jűttner U.,Maklan S., 2011. Supply chain resilience in the global financial crisis: An empirical study. Supply Chain Management: An International Journal, 16(4), 246-259, http://doi.org/10.1108/13598541111139062

Kalakota R., Robinson M., Gundepudi P., 2003. Mobile applications for adaptive supply chain: A landscape analysis, in: E-P. Lim & K. Siau (Eds), Advances in mobile commerce technologies. Idea Group Inc, Hershey, USA, http://doi.org/10.4018/978-1-59140-052-3.ch013

Kaplan R.S., Norton D.P., 1996. The Balanced Scorecard: Translating Strategy into action. Harvard Business Press, Boston, Massachusetts.

Kohlberger R., Gerschberger M., Engelhardt-Nowitzki C., 2011. Variety in supply networks – definitions and influencing parameters, in: C.H. Fang (Ed.). Proceedings of the 6th International Congress on Logistics and SCM systems, 07-09.03.2011, Kaohsiung, Taiwan.

Kot S., Onyusheva I., Grondys K., 2018. Supply chain management in SMEs: evidence from Poland and Kazakhstan. Engineering Management in Production and Services, 10(3), 23-36.

Lee H.L., 2004. The triple-A supply chain. Harvard Business Review, 82(10), 102-112.

Leończuk D., Ryciuk U., Szymczak M., Nazarko J., 2019. Measuring performance of adaptive supply chains, in: A. Kawa, A. Maryniak (Eds), SMART Supply Network, EcoProduction (Environmental Issues in Logistics and Manufacturing). Springer, Cham, http://doi.org/10.1007/978-3-319-91668-2_5

Lin L-Ch., Li T-S., 2010. An integrated framework for supply chain performance measurement using Six-Sigma metrics. Software Quality Journal, 18(3), 387-406, http://doi.org/10.1007/s11219-010-9099-2

MacCallum R. C., Widaman K. F., Zhang S., Hong S., 1999. Sample size in factor analysis. Psychological Methods, 4(1), 84-99, http://doi.org/10.1037/1082-989x.4.1.84

Min S., Roath A.S., Daugherty P.J., Genchev S.E. Chen H., Arndt A.D., Richey R.G., 2005. Supply chain collaboration: what's happening? The International Journal of Logistics Management, 16(2), 237-256, http://doi.org/10.1108/09574090510634539

Momeni E., Tavana M., Mirzagoltabar H., Mirhedayatiane S.M., 2014. A new fuzzy network slacks-based DEA model for evaluating performance of supply chains with reverse logistics. Journal of Intelligent and Fuzzy Systems, 27(2), 793-804, http://doi.org/10.3233/IFS-131037

Neely A., Gregory M., Platts K., 1995. Performance measurement system design: A literature review and research agenda. International Journal of Operations & Production Management, 15(4), 80-116, http://doi.org/10.1108/01443579510083622

Nielsen N.P.H., Holmström, J., 1995. Design for speed: A supply chain perspective on design for manufacturability. Computer Integrated Manufacturing Systems, 8(3), 223-228, http://doi.org/10.1016/0951-5240(95)00016-M

Nutt B., 2004. Infrastructure resources: Forging alignments between supply and demand. Facilities, 22(13/14), 335-343, http://doi.org/10.1108/02632770410563031

O'Rourke N., Hatcher L., 2013. A step-by-step approach to using SAS for factor analysis and structural equation modelling. SAS Institute Inc, Cary, NC.

Olugu E.U., Wong K.Y., 2009. Supply chain performance evaluation: Trends and challenges. American Journal of Engineering and Applied Sciences, 2(1), 202-211, http://doi.org/10.3844/ajeassp.2009.202.211

Piotrowicz W., Cuthbertson R., 2015. Performance measurement and metrics in supply chains: An exploratory study. International Journal of Productivity and Performance Management, 64(8), 1-26, http://doi.org/10.1108/IJPPM-04-2014-0064

Porter M.E., 1985. Competitive advantage. The Free Press, New York.

Qrunfleh S., Tarafdar M., 2014. Supply chain information systems strategy: Impacts on supply chain performance and firm performance. International Journal of Production Economics, 147, 340-350, http://doi.org/10.1016/j.ijpe.2012.09.018

Ross T.J., Holcomb M.C., Fugate B.S., 2004. Connectivity. Enabling visibility in the adaptive supply chain. http://web.utk.edu/~mholcomb/Report2004.pdf, Accessed December 14, 2018.

Ruhi U., Turel O., 2005. Driving visibility, velocity and versatility: The role of mobile technologies in supply chain management. Journal of Internet Commerce, 4(3), 95-117, http://doi.org/10.1300/J179v04n03_06

Ryciuk U., 2016. Zaufanie międzyorganizacyjne w łańcuchach dostaw w budownictwie [Inter-organizational trust in construction supply chains]. Wydawnictwo Naukowe PWN, Warszawa.

Schmidt Ch.G., Foerstl K., Schaltenbrand B., 2017. The Supply Chain Position Paradox: Green Practices and Firm Performance. Journal of Supply Chain Management, 53(1), 3-25, http://doi.org/10.1111/jscm.12113

Scholten K., Schilder S., 2015. The role of collaboration in supply chain resilience. Supply Chain Management: An International Journal, 20(4), 471-484, http://doi.org/10.1108/SCM-11-2014-0386

Shaw S., Grant D.B., Mangan J., 2010. Developing environmental supply chain performance measures. Benchmarking: An International Journal, 17(3), 320-339, http://doi.org/10.1108/14635771011049326

Swaminathan J.M., Tayur S.R., 2003. Models for supply chains in e-business. Management Science, 49(10), 1387-1406, http://doi.org/10.1287/mnsc.49.10.1387.17309

Szymczak M., 2015a. Elastyczność, wrażliwość i odporność jako cechy adaptacyjnych łańcuchów dostaw [Flexibility, Responsibility and Resiliency as Features of Adaptive Supply Chains]. Studia Oeconomica Posnaniensia, 3(6), 39-54.

Szymczak M., 2015b. Ewolucja łańcuchów dostaw [The Evolution of Supply Chains]. Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, Poznań.

Tarasewicz R., 2014. Jak mierzyć efektywność łańcuchów dostaw? [How to measure the performance of supply chains?]. Szkoła Główna Handlowa – Oficyna Wydawnicza, Warszawa.

Tsironis L.K., Matthopoulos P.P., 2015. Towards the identification of important strategic priorities of the supply chain network. Business Process Management Journal, 21(6), 1279-1298, http://doi.org/10.1108/BPMJ-12-2014-0120

Uluman M., Doğan C.D., 2016. Comparison of factor score computation methods in factor analysis. Australian Journal of Basic and Applied Sciences, 10(18), 143-151.

Whitten G.D., Green K.W., Zelbst P.J., 2012. Triple-A supply chain performance. International Journal of Operations & Production Management, 32(1), 28-48, http://doi.org/10.1108/01443571211195727

Ying J., Li-jun Z., 2011. The quantitative research on the index system of supply chain performance measurement based on SCOR, in: J. Jiang (Ed.), Proceedings of the 2011 International conference on informatics, cybernetics, and computer engineering (ICCE2011) November 19–20, 2011. Melbourne, Australia. Advances in Intelligent and Soft Computing, 112, Springer, Berlin, Heidelberg.

Zailani S., Jeyaraman K., Vengadasan G., Premkumar R, 2012. Sustainable supply chain management (SSCM) in Malaysia: A survey. International Journal of Production Economics, 140(1), 330-340, http://doi.org/10.1016/j.ijpe.2012.02.008

Appendix 1. Questionnaire statements

Statement	Source
SCP1: The supply chain is able to limit stocks	Based on Whitten, Green & Zelbst 2012
SCP2: The supply chain is characterised by considerable planning accuracy	Based on Tarasewicz 2014
SCP3: The supply chain is capable of limiting wastefulness	Based on Whitten, Green & Zelbst 2012
SCP4: In the supply chain, it is possible to track and monitor order fulfillment and related resource flows	Own
SCP5: The supply chain can detect the appearing problem connected with order execution and deal with them	Based on Jűttner & Maklan 2011
SCP6: The demand forecasts developed in the supply chain are accurate	Based on Arif-Uz-Zaman & Ahsan 2014
SCP7: The supply chain is characterised by a large volume of mutual contacts with partners	Based on Qrunfleh & Tarafdar 2014
SCP8: The supply chain is able to foresee abrupt changes	Based on Szymczak 2015b
SCP9: The supply chain can minimise total costs of delivering the product to the final customer	Based on Beamon 1999
SCP10: The supply chain guarantees a short time from the moment of order placement to the execution of the delivery	Based on Jűttner & Maklan 2011
SCP11: The supply chain has the capacity to deliver products to the final customer exactly on time	Based on Beamon 1999
SCP12: The supply chain contains a mechanism for eliminating the execution of delayed, incomplete and damaged deliveries	Based on Whitten, Green & Zelbst 2012
SCP13: The supply chain is capable of quick reactions and solving problems raised by the final customer	Based on Tarasewicz 2014
SCP14: The supply chain is characterised by a high level of orders that can be executed immediately from the current stocks	Based on Chae 2009
SCP15: In the supply chain receivables are swiftly paid	Based on Chae 2009
SCP16: The supply chain ensures a short reaction time in terms of customer enquiry	Based on Beamon 1999
SCP17: The supply chain can handle non-standard orders and satisfy special customer requirements	Based on Qrunfleh & Tarafdar 2014
SCP18: The supply chain is capable of providing products in different variants	Based on Qrunfleh & Tarafdar 2014
SCP19: The supply chain can quickly adapt its production capacity so as to accelerate or slow down production in its reaction to decreasing demand	Based on Qrunfleh & Tarafdar 2014
SCP20: The supply chain can swiftly launch a new product on the market	Based on Qrunfleh & Tarafdar 2014
SCP21: The supply chain can swiftly implement product improvements	Based on Qrunfleh & Tarafdar 2014
SCP22: The supply chain offers a wide range of post-sales services	Based on Golrizgashti 2014
SCP23: In the supply chain the level of customer satisfaction is analysed	Based on Beamon 1999

CZYNNIKI WPŁYWAJĄCE NA POZIOM WYDAJNOŚCI ŁAŃCUCHA DOSTAW ORAZ JEJ WYMIARÓW W KONTEKŚCIE ADAPTACYJNOŚCI ŁAŃCUCHA DOSTAW

STRESZCZENIE. **Wstęp:** Ważną determinantą wydajności łańcucha dostaw jest jego adaptacyjność. Jest to jedna z istotnych cech, które przekładają się na wyniki funkcjonowania łańcucha dostaw. Adaptacyjność jest przez wielu badaczy wskazywana jako ważne źródło zdobycia i utrzymania długoterminowej przewagi konkurencyjnej, jeden z głównych czynników gwarantujących sukces łańcucha dostaw, czy też główny megatrend rozwojowy łańcuchów dostaw. Głównym celem artykułu jest zbadanie wpływu czynników, takich jak branża i stosowana strategia konkurencyjna na poziom wydajności łańcucha dostaw oraz wyniki osiągane przez łańcuch dostaw w ramach kluczowych aspektów wydajności z uwzględnieniem kontekstu adaptacyjności.

Metody: W artykule przeanalizowano wyniki badań przeprowadzonych techniką CATI na próbie 200 przedsiębiorstw z czterech branż: spożywczej, RTV/AGD i elektroniki, motoryzacyjnej oraz meblarskiej. Analiza zgromadzonych danych została przeprowadzona w kilku etapach. W pierwszej kolejności wykonano hierarchiczną konfirmacyjną analizę czynnikową. Opracowany model wykorzystano do pomiaru i oceny wydajności łańcuchów dostaw oraz jej wymiarów, poprzez wyznaczenie ocen czynnikowych. W ostatnim etapie zbadano wpływ takich czynników jak przynależność do branży oraz stosowana strategia konkurencyjna na poziom wydajności oraz jej czterech wymiarów. W tym etapie wykorzystano nieparametryczny test Kruskala-Wallisa.
Wyniki: Wyniki przeprowadzonych badań wykazały, że poziom wydajności łańcuchów dostaw, a także jej czterech wymiarów nie jest zależny od przynależności do branży, natomiast różni się w zależności od stosowanej strategii konkurencyjnej.
Wnioski: Opracowany oraz pozytywnie zweryfikowany pod względem jakości model może stanowić narzędzie użyteczne dla praktyków zarządzania do pomiaru i oceny wydajności poszczególnych łańcuchów dostaw, a także dokonywania ich porównań. Dzięki wskazaniu czynników wpływających na poziom wydajności oraz jej czterech wymiarów menedżerowie mogą także w świadomy sposób wskazywać kierunki doskonalenia łańcuchów dostaw.

Słowa kluczowe: dokonania łańcucha dostaw, adaptacyjność, formuła 3V, hierarchiczna konfirmacyjna analiza czynnikowa

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ORIGINAL PAPER

EXPLORING THE CIRCULAR SUPPLY CHAIN TO REDUCE PLASTIC WASTE IN SINGAPORE

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ABSTRACT. **Background:** The COVID-19 changes our lifestyle and triggers the rapid development of online shopping resulting in massive use of plastic for packaging for each parcel. Hence, plastic waste management has become a worrying concern in some countries. This research proposes that the circular supply chain could be a way to reduce plastic waste with regards to the triple bottom line: economy, social, and environment. It applies the life-cycle assessment (LCA) and target sampling method.
Methods: The data about plastic waste, including the production, consumption, and the end-of-life stage from target developed countries were collected and analyzed. By comparing practices applied in Germany and South Korea, this research investigates a framework for both the upstream and the downstream through the implementation of the 4R concept: reduce, reuse, recycle, and recovery.
Results and conclusions: This study provides new insights of the circular supply chain from the perspective of the government, producers, and consumers and call for more attention from the demand perspective (involving more efforts from authorities and consumers) of the plastic industry instead of only concentrating on the supply perspective.

Key words: circular supply chain, plastic waste management, life-cycle assessment, the 4R concept, triple bottom line, bioplastic.

INTRODUCTION

Over the last 50 years, plastic has become an integral part of modern life because it is lightweight but strong to carry and low cost in daily use [Van Eygen et al. 2017]. Plastic has infiltrated into every aspect of life, at the same time, it has been designed to meet the varying needs of customers such as plastic bags, plastic containers (Styrofoam), and PET bottles. Hence, in order to cater to the material needs of plastics, there is a growing development in the plastic industry. It is reported that the continuously growing trend is expected to double in the next 20 years [World Economic Forum 2016]. Given the characteristic that plastic packaging protects the distributing and the end-delivery stage, it contributes a critical role in supply chain management [Bovea et al. 2016]. Especially under the tremendous impacts of the COVID-19, individuals change their living habits to "online shopping style", such as online delivery service food and groceries. From the food catering industry's perspective, the plastic packaging and containers could preserve chemical and physical conditions of food during the purchasing, distributing, and delivering activities [Verghese and Lewis 2007]. Besides, the appropriate packaging could reduce the high levels of food waste; hence, it is necessary to implement packaging management within the food catering industry.

There is no doubt that the plastic packaging and food catering industry brings convenience and ease-of consumption during the COVID-19 situation. However, the "throw-away" society has posed threats to the planet's

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materials and resources because traditional plastic items cause irreversible environmental impacts. Plastic leakage into the environment, and single-use plastic packaging commonly found in oceans and coastal areas [Ocean Conservancy 2017], which bring around 5-13 million tons of plastic items, end up in the ocean. For enterprises, the awareness of environmental concerns, as well as the triple bottom line dimensions of sustainability, are increasingly vital for organizations. In this case, companies should integrate supply chain management with social, economic, and environmental sustainability to better maximize profits and minimize cost.

In this perspective, the implementation of the green supply chain not only aims to minimize the utilization rate of resources but also decrease waste generation through "closing the loop". The green supply chain and reverse logistic call for environment-friendly awareness to cater to the sustainability trend. However, the overview and board perspective about the green supply is missing in the current stage, while the circular supply chain could provide a more comprehensive management system. Besides, the circular supply chain requires innovations from the product design, delivery of the final product, and end-of-life treatments [Cascini et al. 2014], which targets long-term efficient operations and strategies. Hence, this paper will investigate how the circular supply chain mitigates plastic waste in the food catering industry.

This paper will provide a comprehensive view from the perspective of the triple bottom line (TPL): social, environment, and economy to explain the practical implementations of the circular supply chain. First of all, this study starts with the theoretical background and framework related to the plastic industry, the circular supply chain, and the 4R concept. Then, it reveals and defines the research gap for the green supply chain, which triggers the research question. The life-cycle assessment (LCA) methodologies and case studies will be applied in data collection and analysis in sections five and six. Moreover, section seven provides further discussion and recommendations for Singapore to manage plastic waste better. And finally, it comes to a conclusion with the limitations.

LITERATURE REVIEW

The definition of circular economy

In the stage of Industry 3.0 period, organizations and manufacturers implement take-make-dispose, which drives global environmental changes as well as environmental issues such as soil pollution and resource depletion [Northrop 2014]. Those environmental challenges lead to the increasingly critical decline in stocks of raw materials. Therefore, the shortage of raw materials and breakthroughs of high technologies trigger the fourth industrial revolution.

Considering the social impacts, more organizations aim to minimize waste, reduce raw materials, at the same time, close loops within the industrial system. Those potential values could be achieved by implementing a circular economy, which has gained more attention in the last few decades. The circular economy was proposed by several governments and several businesses around the world because it could effectively create economic gains. [Deselnicu et al. 2018]. In this case, the circular economy could be implemented in three levels: macro, meso, and micro-level from countries and regions to the product level. According to McDowall et al. [2017], identify the issues from the international perspective: China and Europe pay attention to different aspects of the circular economy. On the one hand, China's policies aim to mitigate pollution during rapid growth by identifying the challenges. These actions play as the hard action to drive and enforce the undertaking of CE. On the other hand, European countries focus on green product design and resource efficiencies that trigger business opportunities [Yuan, Bi, and Moriguichi 2008].

First of all, the circular economy could be defined as the ecosystem that transfers today's products into tomorrow's raw materials by closing the loop. Secondly, the "zero waste system" is introduced into the CE; therefore, no materials are wasted or underused. In this case, based on these characteristics, this study defines the circular economy as a regenerative system that maximizes the services produced from natural resources and materials input while minimizing the emission and energy leakage by narrowing and closing material and energy loops. Moreover, CE requires long-term planning and orienting towards economic and environmental impacts [Korhonen, Honkasalo, and Seppälä 2018; Geissdoerfer et al. 2017].

Packaging as a service

In this section will narrow down to the food catering industry, investigating the current packaging waste and the typical types of packaging. Due to the nature of food, the food catering industry could depend heavily on the packaging; hence, contributing to the entire environmental impacts. As this industry creates common value from providers to customers, the food catering industry is regarded as the dominant service logistics (SDL) in this paper [Yazdanparast, Manuj, and Swartz 2010]. During the process, food acts as a type of resource that delivers value to the service. Therefore, packaging could be considered a part of service, preserving the food quality it contains throughout the supply chain processes from production to consumption. In fact, the packaging revolution has integrated with the entirety of the food catering industry.

In fact, there are many types of packaging materials in general use, such as plastics, paper, metals, glass, and multi-material multilayers. Plastic plays a significant role since it takes up more than 40% of the demand. Consider the advantages of plastics: durable, light, and cheap, there are over 30 types of family-use plastics, which could be made in different kinds of plastics products for various purposes. With the expanding use of plastics, plastic production is becoming another challenging issue nowadays. Over the last 50 years, plastic production has surged from 15 million tons to 311 million tons [World Economic Forum, 2016]. Moreover, as predicted, global plastic production will continually double in the next 20 years.

The single-use food and drink plastic packaging could be seen as everyday items in the oceans and coastline from a global perspective. According to the report from the Ocean Conservancy [2017], the overwhelming majority of plastic waste ends up in landfills and finally floats into oceans each year. From the ecological perspective, the widespread use of plastic debris negatively impacts wildlife and the environment at every level, causing irreversible harm to oceans.

Meanwhile, with the increasing environmental protection awareness, 40% of consumers frequently store plastic shopping bags out of habit. However, only 8.5% of stored plastic bags were recycled because consumers could forget to bring them or run into unplanned shopping trips (Edgington 2019). To better understand the significant incentives of plastic usage habits, research has been conducted to investigate how initiatives impact the use, reuse, and disposal of plastics. Martinho, Balaia, and Pires [2017] point out that plastics' tax implementation could lead to a 74% reduction in plastics bag consumption. Meanwhile, the financial incentives and penalties are significant to enhance existing behaviors of plastics reuse. Therefore, the usage of plastic bags dropped more than 90% after the involvement of consumers.

Although consumers' involvement could significantly reduce plastic packaging, no one can deny the significant role of recycling from the manufacturing and retail perspective. First of all, the material flow under recycling refers to reprocessing the plastics into a secondary material for future plastics generation, reducing plastic waste [Geyer, Jambeck, and Law 2017]. At the regional level, more countries realized the importance of recycling plastics. For all Europe 28 states, the material recycling rate was around 42%. Some specific goals urge more recycling processes and innovative plastics products: all plastic packaging should be reusable or recyclable in a cost-effective way by 2030 in the EU market [Foschi and Bonoli 2019]. However, compared to the EU, Japan's material recycling rate is around 23%, becoming a significant concern [Yolin 2015]. Thus, authorities promote the development and usage of petroleum-based plastics substitutes, cumulating a 25% reduction of single-use plastic waste by 2030. Meanwhile, call for higher utilization of reusable and recyclable design for packaging products: 100% effective use of circular economy measures by 2035 [Japan Environment Quarterly 2019].

Research gap and research question

In all, the circular economy, together with the green supply chain and reverse logistics, is increasingly taking up the dominant stream within the supply chain management (SCM). Existing literature reviews have emphasized that the circular economy could be an effective method to reduce the negative impacts towards the triple bottom line (TPL) through implementing the 4R concept into operation management. Moreover, no one can deny the significance of plastic packaging's in the food catering industry: reducing food waste from physical and chemical damage. The 4R concept (Reduce, reuse, recycle, and recover) illustrates the benefits of applying the 4R concept and clarifies the challenges and issues towards different methods from both the macro-level and individual level.

Moreover, many academic papers evaluate waste management practice, including recycling and new types of bioplastics in developed countries. It is proven that those methods trigger the process of closing the loop and the green supply chain. While the recycling statistics of waste management are available in other developed countries, there are limited numbers of studies analyzing current plastic waste management challenges in Singapore [Van Eygen, Laner, and Fellner 2018]. Considering Singapore's geographical factor, most sorted recyclable plastics were discarded and exported after the first use. It is estimated that among 95% of discarded plastic value for around 157 billion SGD in 2018. Besides, the recycling rate dropped from 11% to 6% between 2013 to 2017, which holds excellent value without effective recycling [Singapore Environment Council 2018]. To sum up, plastics recycling management is relatively underdeveloped in Singapore. Given that the poor waste management towards plastics packaging could lead to a high social, economic, and environmental loss, plastic waste management could still benefit the food catering industry until a better plan of the 4R concept. In this case, the research question is defined as "How the circular economy helps mitigate the plastic waste in Singapore, considering the triple bottom line?"

RESEARCH METHODOLOGY

According to Yin [2014], there are three main types of case study: exploratory case study, descriptive case study, and explanatory case study. In order to better explain and explore plastics waste strategies, this paper combines these two types of case studies based on the explanatory and exploratory case study characteristics. Meanwhile, the explanatory case study aligns with the life-cycle assessment to investigate how and why the circular supply chain could help address the plastic waste's pressure on the environment. Life cycle assessment (LCA) can be used to quantify each component of plastics' environmental impacts from raw material extraction to end-of-life. This internationally acknowledged assessment specifies the impacts on climate change, human health, ecosystem quality, and nonrenewable resources.

In this sense, the exploratory case study's application promotes a theoretical circular supply chain system to address plastics waste based on practical strategies. Based on the case studies and target sampling, the study aims to make a horizontal comparison and observe the methodical view within the circular supply chain. Considering different degrees of economic development, this paper aims to collect data from developed countries: Germany and South Korea. The next section undertakes the target sampling method that implicitly represent the "developed" and "Asian country" characteristics of all the countries in the world. Therefore, it could imply the effective plastic management system and actions for the plastic waste management in Singapore.

First of all, it begins the data collection from European Union and Germany data because the EU was the first region to implement circular economy practices in 2015. Besides, the EU has obtained huge benefits and returns in terms of plastic waste management so far. Moreover, among the 27 member states, Germany has the highest demand for plastics while maintaining the EU's highest plastic recycling rate, which worth investigating into the circular supply chain system. After that, this study narrowed the scope to the target country: South Korea. Among Asian countries, South Korea ranks as one of the five best countries with the best plastic management, while others are all European countries. In this case, it makes sense to compare to Germany, South Korea, and Singapore because these countries are all developed countries with strong environmental awareness. In the end, the target sampling contributes to the findings because it analyzes the plastics waste management in other developed countries, which helps to generate a mature framework and system for plastics waste management.

DATA COLLECTION AND ANALYZE

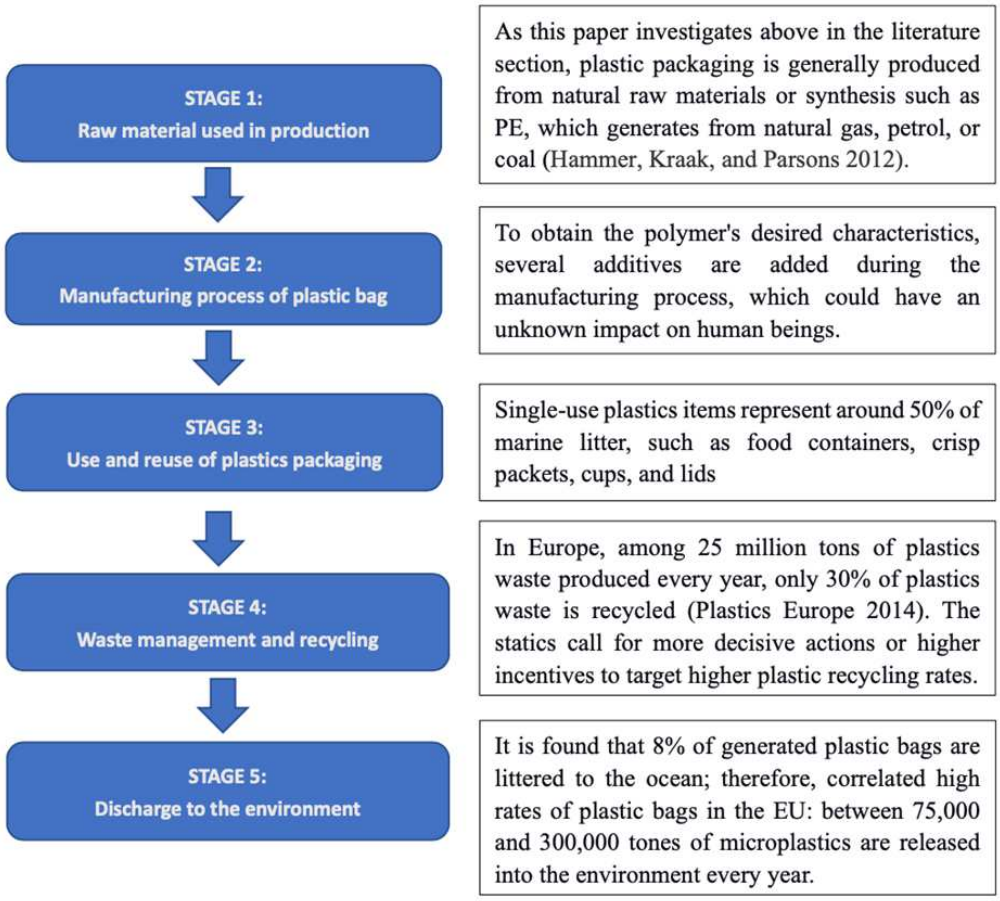
The plastic waste management in the EU

In 2017, plastics production worldwide reached 348 million tons compared to 2018; it increased to 359 million tons. While the global plastics production developed rapidly, the plastics production in Europe decreased from 64.4 million tons, representing almost 17% of the plastics production. It is a significant achievement that the EU has controlled plastics' demands and mitigated the negative impacts on the environment through the circular economy action that was enforced in 2015. In the EU, post-consumer plastic packaging waste is included in the mixed municipal solid waste (MSW) for compatibility among different countries. In this case, the MSW is defined by Eurostat as waste from the same or similar sources produced from the household (majority), commerce, office, and public institutions [Dahlbo et al. 2018]. In Europe, the packaging industry takes up the most sectors in plastics demand, around 39.9% share in 2018, and per capita, plastic consumption in Western Europe is approximately 100kg/year. Meanwhile, most plastic packaging is discarded after the first use, which leads to a short service life of plastics and ends up contaminating the environment [Commission of the European Communities 2020].

On the one hand, plastic waste could bring a tremendous irreversible impact on the environment and human beings because it could break into microplastic and leak into the ground. Therefore, it is significant to realize that the 3R concept could reduce plastic waste, especially "recycling". Although the average recycling rate (30%) is higher than other continents, the recycling rate varies differently between EU countries. For example, Germany has the highest demand and the highest recycling rate at 56.1%, while Romania's recycling rate is 5% [Zero Waste Europe 2018]. Meanwhile, the after-use activities related to recycling plays a significant role in reducing plastic waste in the EU. According to the report, only around 32.5% of collected plastic post-consumer waste is recycled for another use, while 42.6% is incinerated for energy recovery, and 24.9% ends up landfilling [European Commission 2020].

On the other hand, Europe's plastic industry creates more than 1.5 million jobs for citizens and brings around 350 billion turnovers annually. As [European Commission 2020] mentioned, innovation, digitization, and decarbonization are the three main factors leading the plastics industry to be stronger and more competitive worldwide.

In this case, plastic brings more benefits to human beings than damage to the environment if every part of society takes their responsibilities. In other words, the growing concern for resource-efficient and circular economy promotes sustainable and green product policy initiatives. The core of this policy aims to widen the eco-design beyond energy-related products: make it deliver on circularity. The next section will apply an incremental approach: life-cycle assessment (LCA) to assess a plastics bag's steps considering the European production, use, and particularly legislation. There are five stages to better identify the major activities during the lifecycle of a plastic bag: raw material for production, manufacturing phase, use and reuse, waste and recycling management and discharge to the environment.



Source: own work

Fig. 1. Five stages of life-cycle assessment in the EU

According to the plastic life-cycle assessment outline, it could be divided into two major processes: upstream (including production and transportation) and downstream (including use, reuse, recycle, and reproduce). Within the LAC analysis, the circular economy asks organizations and authorities to lay more attention to the downstream section; therefore, achieving sustainability and a circular supply chain. Here are the policies and strategies that the EU has applied in the last few years:

- Targeted policies: Circular economy package
- Apply the EU waste framework directive to clear the priority
- Set measurable targets for stakeholders

As the EU is in the leading position towards plastic waste management, it receives respect to its policies for achieving specific targets, including reducing, reuse, recycling, and recovery. Consequently, according to the circular economy package, at the end of this year, the target is set for 45% recycling (in 2020); at the same time, targets for MSW recycling and reuse rate is suggested to reach 65% by 2030 [Zero Waste Europe 2018]. According to the European Commission [2018], the crucial step to enhancing the alternatives is stimulating eco-design packaging. The mandatory goal is achieving 100% recyclable plastic packaging by 2030, encouraging consumers' behaviors to utilize better compostable and biodegradable plastics [Foschi and Bonoli 2019]. Also, there is a five-step framework that shows the "waste hierarchy" in the EU. According to the priorities, the waste framework directive shows the importance of (i) Prevention, (ii) Preparing for reuse, (iii) Recycling, then it considers (iv) other recovery and (v) Disposal. This waste framework aligns closely with the 4R concept and extends packaging waste, which helps guide the EU member states to achieve the circular economy [UNEP 2019]. With the instruction of the targeted policy, measurable and specific targets encourage the improvement of recycling infrastructure. It also regulates the product design, production, and transportation activates through the extended producers responsibility (EPR) system. Since the packaging levies are part of the EPR system, it could help reduce the production and disposal waste of plastics packaging; finally leads to greener plastic production.

Plastic waste management strategies in Germany

As the largest producer of plastic in the European countries, Germany has the leading plastic industry with sales of EUR 92 billion; thus, providing not only innovative plastic products but also job opportunities domestically. Instead, with the highest demand (25%) of plastic within the EU countries, the recycling rate in Germany is amazingly high at 56.1% (OECD 2018)

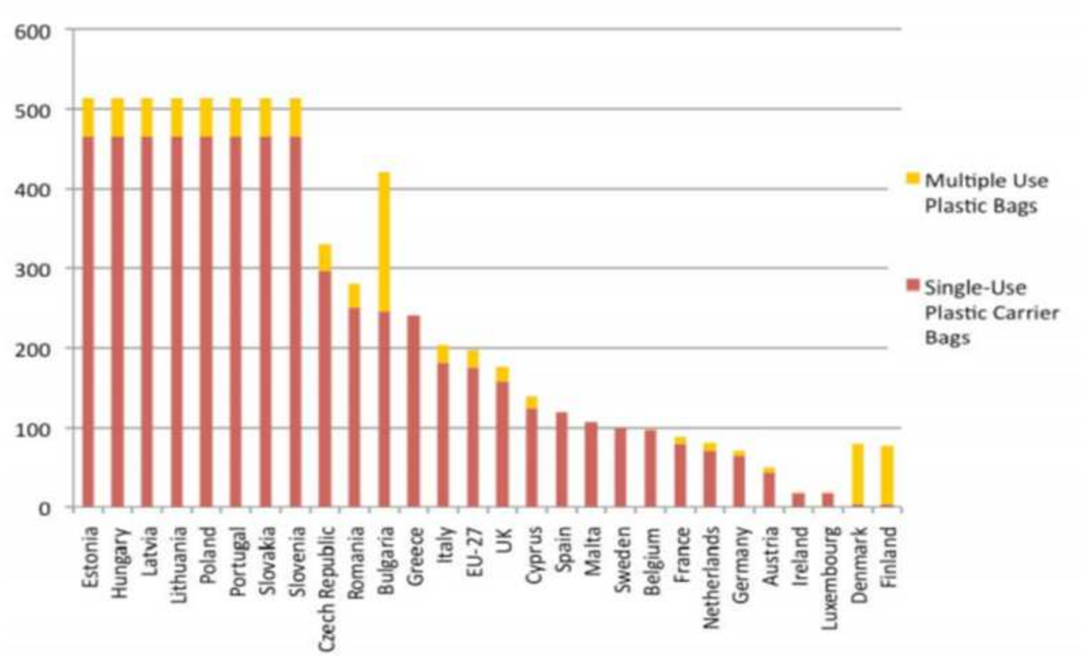
Becoming the world innovation leader: from raw material to R&D

In order to grant the high technological standard, the plastics value chain in Germany encourages universities, companies, and other institutes to contribute to the research and development of sustainable and green plastic items.

Plastic innovative cluster to attract more investors

There are different types of knowledge transfer in Germany to provide onsite services and utilities: innovative plastics industry networks, specialized chemical parks, and go-cluster. Those creative clusters trigger the world-class knowledge transfer and help to maintain the leading position of innovation leader. Moreover, the German government provides funds to support new production or R & D activities by reducing eligible investment costs.

Incentives for citizens to call for greener plastic usage habits



Source: Barbière [2015]

Fig. 2. Plastic bag consumption among the EU members

From the perspective of the EU countries, plastic using habits vary significantly within different EU member states. Some countries lead the consumption rate of more than 450 bags per person because citizens undertake single-use plastics more often, such as Estonia, Hungary, and Latvia [Barbière 2015]. Conversely, some countries such as France and Germany rely more on multiple-use plastics packaging leading to a lower consumption rate below 100 bags per person [European Parliamentary 2017].

In Germany, manufacturers created "the Green Dot" system (in 1991) to increase the recycling rate, which aims to collect waste from households and businesses. "The Green Dot" system is required by legislation and calls for valuable raw materials pick up from produced plastic products; hence, enhancing the circularity of plastic items and recycling rate [Baughan and Evale 2004]. Also, it is reported that citizens' awareness and various actions can significantly reduce plastic waste through reuse, reduce, and recycle practices. The self-motivation activities such as "say no to plastic products", "minimize the use of plastic items", and "use bioplastic products" could help to shift from antagonist to agonist behavior [Cecere, Mancinelli, and Mazzanti 2013].

The plastic waste management in Asia

In fact, no one can expect a world without plastic because plastic has become a significant part of today's society. Therefore, large-scale production has increased since 1970: from 35 million tons to 381 million tons in 2015; at the same time, half of the generated plastic was produced in recent 13 years. Compared to plastic material production in Europe, China alone accounts for more than 27% of the global resin. In this case, the Asia area, including Japan, South Korea, and other SEA countries, take up to 48.8% of all. In this case, the plastic waste in Southeast Asia is becoming the most concerning issue to the ocean environment: threatening wildlife.

The severe plastic pollution in Asia could be blamed for the high demand and inappropriate use habits during the consumption and end-of-life stage. Asia's majorities are developing countries without data technology and public awareness, so the data and statistics greatly vary between Asian countries. Moreover, considering the population and land area, some states could generate a tremendous amount of plastic in total. Still, when measuring the capita consumption per day, they could have lower numbers than other countries, such as China and Japan. According to the report, among the Asian countries, China, with the largest population in Asia, produces nearly 60 million tons of plastic annually, followed by Japan at 7.99 million tons in 2010 (Jambeck et al. 2015). However, the most effective way to measure plastic waste in different countries is the annual consumption per capita. Five states represent the typical cases, and Malaysia is highest among these five countries: 73 kilograms annually per capita, followed by Singapore at 69.35 kilograms, Japan at 62.05 kilograms. Meanwhile, the statistics in China and South Korea are relatively low compared to other countries: China generates 43.6 kilograms of plastic waste, and South Korea generates 40.15 kilograms per capita [Jambeck et al. 2015].

After the production and the consumption phase, the states about plastic end-of-life directly determine if it becomes waste or raw material; therefore, the recycling rate is the key point to measure. Compared to the European Union, the recycling rate in the Asia area is significantly lower: only 9% of plastic is recycled, which means around 79% of plastic (8.3 billion tons) leak into the environment. This phenomenon is blamed not only for the economy and the manufacturing industry of the developing countries but also for poor waste management policies and strategies. From the food catering industry's perspective, the majorities of plastic waste are Styrofoam and PET bottles. According to the news, it is said that the recycling rate of PET bottles in Asia only takes up to 54%, while Asia-pacific is the fastest growing market. Many reasons are resulting in the low PET recycling rate: poor packaging design, collection coverage, and accessibility [Green Queen 2019].

The plastic waste data and management in South Korea

Plastic packaging related to the food industry, such as beverage bottles and snack bags, accounts for 82% of total waste in South Korea, easily found on coastal lines [Jang et al. 2020]. With the development of the single-housing family trend, the food catering industry in South Korea is expected to increase, and it also results in higher demand for plastic packaging. Four essential elements significantly impact plastic waste in the food catering industry: consumption amounts, consumption frequency, the sales of products, and the number of fair deliveries in South Korea. This section will estimate plastic consumption that is commonly applied in plastic packaging, such as PET drinking bottles, single-use plastic cups and bags, single-use plastic containers, and cutlery for food delivery. The statistics released by the South Korean government report that based on these four items, the annual plastic demands reach around 637.7 units resulting in 602,900 tones of single-use plastic waste.

The demand for plastic material has been increasing during the last ten years of its outstanding physical properties in daily life. Throughout 2010-2018, the domestic market for plastic risen from 5.1 million tones to 6.5 million tones. As of 2018, the primary demand for plastic or synthetic resins in South Korea is PP, followed by PVC, LDPE, and HDPE. In South Korea, most manufactured plastic was used for packaging and containers: 2.7 million ton and represent 46.5% of the whole plastic production rate, while the second large section is building and construction (1.4 million ton, 24.7%). After the production and consumption stage, it is found that households could be the second-largest fraction source generating disposal bags and recyclables. Specific departments could separate recyclables from families such as food waste, plastic vinyl bags, and multi-layer films at South Korean authorities. However, the material flow analysis shows that the plastic recycling rate in the case of household waste was calculated by only 13%. Compared to the EU's plastic recycling rate (30%), it is considerably lower in South Korea. The deciding reasons underlying behind are that low economic benefits in sorting and recycling, low quality of mixed plastic waste, especially limited demands for recycled products from the upstream.

In order to enhance the efficiency of plastic material flow, South Korean authorities encourage both individuals and enterprises to take action. From the citizens' perspective, in the disposable stage, those non-recyclables are paid by households based on their weight, which is known as pay-as-you-throw (Miafodzyeva and Brandt 2013). It is proven that income and "pay-as-you-throw" has a positive impact on willingness to pay (WTP) regarding different types of housing (e.g., apartment) [Lee and Paik 2011]. Hence, those plastic products are collected at collection centers by the local government for better waste management. In general, those disposal bags were treated by shredding, sorting, and separation to recover material resources before incineration or landfilling. From the perspective of plastic producers, they are regulated by the extended producer responsibility (EPR) system, including manufacturing processes of PET bottles, foamed resins, and other synthetic resins [Jang et al. 2020; Kim and Mori 2015]. With the EPR system regulation, manufacturers must collect and recycle the specific quantities assigned to the long-term recycling target. Be members of the South Korea Packaging recycling Cooperative or producer responsibility organization (PRO); producers fulfill their obligations by collecting and recycling waste from plastic products or contributing fees to the PRO. In this case, the EPR system encourages manufacturers to increase the recycling rate and triggers the circular economy; otherwise, those who fail to achieve the recycling target have to pay a fine more than recycling.

The picture shows the recycling system for packaging waste regarding material, funding, and reporting flows in South Korea. Compared to the supply chain management: information flow, material flow, and cash flow, the reporting flow of the EPR system not only plays the role of information but also is regarded as the decisive political oversight to encourage the plastic recycling system.

At the current stage, the EPR system relies heavily on the manufacturers' contribution: intensive labor works towards sorting and separation methods. Although the development of the EPR system since 2003 has been nurtured, the poor working environment, low quality of recycling products, and fluctuations in the overseas recycling market still pose significant challenges to the recycling system in South Korea. Hence, it is urgent to develop and apply modern technologies to the plastics recycling industry. Moreover, expanding the investment of green plastic products such as bioplastic also triggers the current plastic waste management.

Current plastic demand in Singapore

Singapore is a developing country located in Southeast Asia, heavily relying on imported materials regarding food, daily consumer products, and an incredible number of plastic products. It is because plastic plays a vital role in everyday life, and there is a great demand for plastic: people in Singapore use about 1.76 billion plastic items annually. Since living and using habits drive plastic usage, plastic items' need includes 820 million plastic bags from supermarkets, 476 million PET bottles, and 473 million plastic takeaway containers [Singapore Environment Council 2018]. To be more specific, according to the fact that citizens take 2 to 4 plastic bags per trip to the supermarket, plastic bags' land areas equal 126 Gardens by the bay. Also, the consumption of PET bottles in Singapore is three times the landmass of Sentosa island. In fact, the generated waste in Singapore has substantially grown during the last few decades, from 1970 to 2017. There is a sevenfold increase in disposal waste: 1,260 tons per day to 8,443 tons per day (Singapore Environment Council 2018). Moreover, the majority of solid waste is plastic waste, including PET (bottled water), plastic bags, and Styrofoam. It is estimated that 95% of plastic waste consumption still holds a high economic value of SGD157 billion.

However, with only one landfill option in Singapore, most plastic wastes were incinerated at 4,320 tons per day, leading to a low recycling rate of plastic. The plastic waste recycling rate dropped from 11% to 6% between 2013 and 2017 (Singapore Environment Council 2018). It is not only to blame the poor waste management in Singapore, but it is also worth noticing that the ban on imported plastic in China also results in a low recycling rate. The poor waste management strategies such as incineration and landfill could cause irreversible damage to the environment as well as the loss of energy for next stage production. According to the report released by Singapore Environment Council (SEC), the usage of "single-use" plastic could be the biggest problem in Singapore because they provide a few minutes of convenience but pose significant threats to the environment after use.

Comparison between the EU, Asia; Germany, South Korea, and Singapore

It is obviously shown above in Table 1 that plastic consumption and recycling rates vary differently between the EU and Asia. First of all, the difference could be mainly explained through development: the majority of the EU members are developed countries with higher education levels. It is reported that the higher education level encourages more innovative technologies [Szopik-Depczyńska et al. 2020]; therefore, businesses can better recycle and recovery from plastic waste. In this case, the current plastic recycling rate is about three times higher than the recycling rate in Asia. Moreover, the EU has a common goal shared among members that could lead to a better waste management system, such as the Waste Framework Directive 2008/98/EC (WFD). However, compared to the EU, Asian countries focus more on their development; thus, the ASEAN region and Asia-Pacific have minimal reports about plastic waste management. Also, considering the different political structures and geographical factors, setting the shared targets for countries is meaningless. Finally, since the plastic industry is snowballing in the Asia market, no one can deny the importance of plastic waste management in Asia. Indeed, some countries, such as Japan and South Korea, are leading the position to manage plastic waste while taking advantage of plastic packaging.

Table 1. The comparison (plastic consumption and recycling management strategies) between the EU and Asia

	Plastic production	Plastic consumption	Recycling rate	Recycling	Plastic production
The European Union	359 million (t) 17 % of the world	100 kg/year/capita	30%	Reach 65% by 2030	Produce 350 billion tones each year
Union	381 million (t) 48.8% of the world	25 kg/year/capita	9%	Vary differently	The fastest growing market

Source: own work

Table 2. The comparison between Germany, South Korea, and Singapore

	Plastic industry	Recycling rate	Strategies
Germany	Sales: EUR 92 billion	56.1%	- Encourage innovation - Incentives for more investors - Incentives for greener usage habits
South Korea	Demands: 6.5 million tons	53.7%	- Enhance public awareness and WTP - Extended Producer Responsibility
Singapore	1.76 billion plastic items annually	6%	Refer to the recommendation section

Source: own work

In Table 2, the plastic industry brings not only financial gains but also environment-friendly benefits in both Germany and South Korea. These two developed countries were fully aware of the environmental damages that plastic waste could bring and call the joint efforts from authorities, enterprises, as well as citizens to take their social responsibilities.

Key challenges in plastics waste management for Singapore

First and foremost, the EU aims for 90% recovery of single-use plastic items by 2025, at the same time, switching the plastics usage habit to reusable plastic packaging by 2030 [European Commission 2018]. Besides, there are policies to stimulate producers for the eco-design in packaging, for example, using bioplastic. The eco-design not only adds social value to the plastic items but also encourages consumers to behave in a more responsible way [Filho et al. 2020]. Secondly, it can be observed from the strategies from South Korea that the high recycling rate was driven by the framework: "Comprehensive Measures for Plastic Waste Recycling Management". The South Korean governments set the recycling target to 70% by 2030 while expanding green manufacture by increasing the number of products from 43 to 63 in the EPR system. In this sense, it is found that under the supervision of the government, laws and regulations are a powerful driver for plastic waste management.

To sum up, analyzing the strategies from the EU and South Korea, both the upstream and the downstream play a crucial role for the success of plastics waste management. Policies and strategies implementation, as well as priorities settings, are the driving factors undertaking to reduce, recycle, and recover strategies. While the consumer's environmental awareness and plastic usage habits could bring practical impacts at the purchase and disposal phase; hence, triggering the reduce and reuse strategies. With the joint efforts from upstream and downstream, the implementation of better plastic waste management could speed up the transformation from a linear supply chain to a circular supply chain.

As Singapore targets the "Zero Waste Nation", the government designated the "zero waste" in 2019 to call for less consumption of materials through reuse, recycle, and recovery [Towards Zero Waste 2020]. Meanwhile, the circular supply chain, including the prevention of waste, recycling, and recovery of plastic items, is complex to undertake because it involves the whole lifecycle of plastic. All in all, there are challenges and opportunities under three main stages: production, consumption, and distribution that require profound changes. As compared to the European countries as well as some developed countries in Asia, the low recycling rate (7%) and the throwaway culture of plastic could be the biggest barrier to "zero waste". First of all, the low recycling rate could be blamed for consumer habits and overpackaging. The weak environment-protecting awareness results that people are used to over-packaging food in the hawker center and delivering food with many plastics layers. Although those single-use plastic items could bring great convenience and physically protect the food during the distribution and transportation stage, untreated waste plastics could damage the Earth. Secondly, Singapore's low recycling rates could be attributed to the lack of awareness about the types of plastic that can be recycled. For example, about 70% of respondents are not aware of different recyclable plastic types, while only 45% of respondents could assess useful information about different types of recyclable plastic in Singapore. Thirdly, the improper recycling technologies and infrastructure result in municipal landfills and dumps. Hence, the lack of recycling technologies makes only 2 percent of recycled plastic products maintain the same quality, causing potential health concerns when recycled plastic is in contact with food [Packaging Europe 2017]. To sum up, the limited environmental awareness for recycling results in the low plastic recycling rate in Singapore.

Moreover, the lack of market demand is a hidden problem in the current situation. Since human beings take advantage of the fossil fuel economy, although the oil price could impact plastic's price, the raw materials are cheap for manufacturing [The Ellen MacArthur Foundation 2017]. In particular, there is a typical scenery of mixed or dirty plastics, which leads to a low recycling rate because they cannot be recycled through current mechanical tools. In this case, the cost of recycled plastic products is higher than traditional plastic, which leads to low demand for recycled plastic. Finally, the most significant barriers that stop the development of plastic waste recycling are economic issues. The research and development cost of bioplastic takes up a generous share of investment; hence the higher economic factors make it difficult to be competitive as conventional plastic [Hopewell, Dvorak, and Kosior 2009].

RECOMMENDATIONS

Policy instruments towards an effective waste management system

Redesign the waste management system could be a strong and effective action to raise Singapore's plastic recycling rate from 7% to the EU's 30% standard. With the right information and knowledge about plastic waste management, effective governance could encourage manufacturers to create a conducive environment and call for responsibilities for the environment and society. Meanwhile, policies could regulate the behaviors by reducing disposable containers and packaging and improved the collective and recycling of used plastics. Singaporeans should introduce more stringent policies to contribute to the reduction of single-use plastic and increase the recycling rate. In fact, according to the NEA, the ministry did not implement the mandatory levy on plastic bags because plastic bags are used for responsible and hygienic bagging [Tan and Boh 2017]. However, it is observed that the policy "ban the banning" could be an effective solution to reduce the plastic in supermarkets to 60-80% after the Chinese government banned non-bioplastic [Walker and Xanthos 2018].

For example, the Japanese government adopted the "Resource Circulating Strategy for Plastic" in 2019 to clarify the specific goals: enhance the effective utilization to 100% of used plastic items by 2035. Moreover, South Korea also implemented a set of policies to regulate plastic using habits: increasing the recycling rate to 70% by 2030 [Korea times 2018]. However, only a few countries have laws to prevent packaging and packaging waste. Thus, from the board view, authorities should provide a specific framework, practical tools, technologies, information as well as obligations carried by general laws.

Enhance social awareness and public pressure

It is proven that education levels have positively correlated with the policy effects, and there are many leading countries adopting regulations and policies to control plastic waste. "Bag leakage: The effect of disposable carryout bag regulations on unregulated bags". Public awareness and education are essential to shape and trigger the shift from the traditional economy to the circular economy. Be aware of the throwaway culture of plastic usage in Singapore; authorities could also ask the corporation with the food industry and consumers through mandatory reports and legislations. Governments can apply strategies to persuade and educate the citizens in a wide range, such as public videos and school and youth events. By these practices, individuals are more aware of reuse and recycling plastic resources; at the same time, taking their responsibilities to minimize plastic waste. Also, in order to prevent the overuse of single-use plastic items, plastic products that are difficult to recycle should be banned or phased out in the food restaurant or food catering industry. Then, after the consumption stage, a sustainable approach to control the plastic recycling rate is tackling the excessive consumption of plastic disposables in Singapore. According to the NEA report, most of the respondents are willing to reuse and recycle plastic products if they have information about recyclable plastic. Hence, authorities should provide more details on recycling plastics and improving the accessibility to recycling facilities. The plastic waste could be easily collected through the well-designed recycling infrastructure within the circular supply chain, which makes "plastic logistics" more viable.

Promote the eco-friendly alternatives

In Singapore, the limited market for recycled products is the hidden issue under the high volume of plastic waste and low recycling rate, which results from the small market demand and high cost of eco-friendly alternatives. In order to shift from fossil-based to bioplastic and trigger the development of bio-based plastic, the government should limit fossil-based activities (Kakadellis and Harris 2020). Considering the limited recyclability and degradability of bioplastic, authorities should also encourage the necessary infrastructure to provide effective bioplastic waste management, at the same time, promote the use of bioplastic [Arikan and Ozsoy 2015]. Compared to the traditional plastics, the eco-friendly alternatives have many advantages: lower carbon footprint and non-renewable energy loss. Although the bioplastic cannot benefit the micro-enterprises because of the high financial cost, it could still be applicable in macro-businesses. By introducing economic incentives, MNC would take its responsibilities to use more recycled plastics items, for example, Coca-Cola and Unilever.

Lastly, the implementation of the circular supply chain in Singapore calls for joint efforts from the consumer level (downstream) and upstream. Findings from the recommendation part show that the circular supply chain could definitely benefit the environment because it triggers the non-reusable energy reduction recovery during both production, consumption, and collection stage. Secondly, from the manufacturers' perspective, the circular supply chain strategy for plastic production would positively impact enterprises because enterprises cater to the sustainability trend and contribute their efforts to make the living environment better. Finally, although the circular supply chain would bring a higher cost in the short run, it could benefit the company in the long run.

CONCLUSION AND LIMITATIONS

As this paper has shown, although plastic is a useful and valuable product in daily life, it generates wastage and cause environmental pollutions. Especially under the COVID-19 situation, the plastic industry's incredible growth due to online sales brings severe environmental impacts during the production and the disposal stage. Thus, it is important to implement the circular supply chain into plastic waste management by minimizing the natural environment's pressure and maximizing society's profit and reputation. In other words, this study's research objective is to investigate effective practices to avoid the negative impacts of plastic waste while taking advantage of plastic packaging to make daily life more convenient.

This paper applies the life-cycle assessment (LCA) and the case study to analyze the current situation and the strategies in the EU, Asia, Germany, and South Korea. From the case studies, it is found that regulation, policies, and extended producer responsibility (EPR) system in the upstream, together with the citizens using habits and environmental awareness, could help Singapore achieve the plastic waste management goal. Based on the examples of the waste management strategies in Germany and South Korea, the implications and recommendations of the study are threefold. First of all, regulation and policies could be an effective method to enhance public awareness and promote bioplastics development. Secondly, from the perspective of producers, although the cost of bioplastic and recycling management is higher than conventional plastic, the circular supply chain will benefit the organization in the long run. Hence, the EPR system is a vital but practical tool to regulate the product design's environmental impacts on the end-of-life stage. Finally, the downstream recycling efforts also promote Singapore's recycling rate through the end-of-life stage, such as the Bring Your Own (BYO) campaign.

Although this paper provides some useful solutions and tools for better plastic waste management practices in Singapore that are mere consideration of the triple bottom line (TPL), it still has some limitations. First of all, there is only little data that can be collected about the current plastics' situation in Asia. Because in Asia, regions or non-government organizations have not paid as much attention as compared with the EU, and most of the reports about the plastic waste are out-of-date. Secondly, this study refers to the strategies and policies undertaken in Germany and South Korea but more studies can be done with more countries for comparison.

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REFERENCES

Arikan Ezgi B., Havva Ozsoy D., 2015. A Review: Investigation of Bioplastics. Journal of Civil Engineering and Architecture 9, 2. http://doi.org/10.17265/1934-7359/2015.02.007.

Bovea M.D., Serrano J., Bruscas G.M., Gallardo A., 2006. Application of life cycle assessment to improve the environmental performance of a ceramic tile packaging system. Packaging Technology and Science 19, 2, 83-95. http://doi.org/10.1002/pts.711.

Deselnicu D.C., Militaru G., Deselnicu V., Zăinescu G., Albu L., 2018. Towards a Circular Economy – a Zero Waste Programme for Europe. http://doi.org/10.24264/icams-2018.xi.4.

Edgington T., 2019. Plastic or Paper: Which Bag is Greener? BBC News. https://www.bbc.com/news/business-47027792.

European Commission. 2018. Packaging Waste Directive. Brussels: European Commission. https://eurlex.europa.eu/legalcontent/EN/TXT/?qid=1551965345008&uri=CELEX:32018L0852.

Filho W.L., Salvia A.L., Bonoli A., Saari U.A., Voronova V., Klõga M., Kumbhar S.S., Olszewski K., De Quevedo D.M., Barbir J., 2020. An assessment of attitudes towards plastics and bioplastics in Europe. Science of The Total Environment, 142732. http://doi.org/10.1016/j.scitotenv.2020.142732.

Geissdoerfer M., Savaget P., Bocken N.M., Hultink E.J., 2017. The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production 143, 757-768. http://doi.org/10.1016/j.jclepro.2016.12.048

Green Queen. 2019. Landmark PET Report: Southeast Asia Plastic Crisis Result Of Government Inaction. Green Queen. https://www.greenqueen.com.hk/ga-circular-full-circle-pet-plastic-bottle-report-southeast-asia/.

Hopewell J., Dvorak R., Kosior E., 2009. Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences. http://doi.org/10.1098/rstb.2008.0311.

Hu J., Xiao Z., Zhou R., Deng W., Wang M., Ma S., 2011. Ecological utilization of leather tannery waste with circular economy model. Journal of Cleaner Production 19, 2-3, 221-228. http://doi.org/10.1016/j.jclepro.2010.09.018

Jambeck J.R., Geyer R., Wilcox C., Siegler, M. Perryman T.R., Andrady A., Narayan R., Law K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 6223, 768-771. http://doi.org/10.1126/science.1260352.

Japan Environment Quarterly. 2019. Establishing a sound material-cycle society and measures to address marine litter. Ministry of the Environment. https://www.env.go.jp/en/focus/jeq/issue/pdf/Volume20January2018.pdf.

Kakadellis S., Harris Z.M., 2020. Don't scrap the waste: The need for broader system boundaries in bioplastic food packaging life-cycle assessment – A critical review. Journal of Cleaner Production 274, 122831. http://doi.org/10.1016/j.jclepro.2020.122831.

Korea times. 2018. Gov't Aims to Reduce Plastic Waste 50% by 2030. https://www.koreatimes.co.kr/www/nation/2018/08/371_248796.html.

Korhonen J., Honkasalo A., Seppälä J.. 2018. Circular Economy: The Concept and its Limitations. Ecological Economics 143, 37-46. http://doi.org/10.1016/j.ecolecon.2017.06.041.

Martinho G., Balaia N., Pires A., 2017. The Portuguese plastic carrier bag tax: The effects on consumers' behavior." Waste Management 61, 3-12. http://doi.org/10.1016/j.wasman.2017.01.023.

McDowall W., Geng Y., Huang B., Barteková E., Bleischwitz R., Türkeli S., Kemp R., Doménech T., 2017. Circular Economy Policies in China and Europe. 2017. Journal of Industrial Ecology 21, 3, 651-661. http://doi.org/10.1111/jiec.12597.

Northrop E., 2014. Prosperity Without Growth: Economics for a Finite Planet. " Eastern Economic Journal 40, 3, 440-442. http://doi.org/10.1057/eej.2013.22.

Ocean Conservancy. 2017. Together for Our Ocean - International Coastal Cleanup 2017 Report. Washington, D.C: Ocean Conservancy. https://oceanconservancy.org/wp-content/uploads/2017/06/International-Coastal-Cleanup_2017-Report.pdf.

Packaging Europe. 2017. Functional Barriers for the Use of Recycled Plastics in Multilayer Food Packaging. Packaging Europe. https://packagingeurope.com/functional-barriers-for-the-use-of-recycled-plastics/.

Szopik-Depczyńska K., Cheba K., Bąk I., Kędzierska-Szczepaniak A., Szczepaniak K., Ioppolo G., 2020. Innovation level and local development of EU regions. A new assessment approach. Land Use Policy 99, 104837. http://doi.org/10.1016/j.landusepol.2020.104837.

Tan A., Boh S., 2017. Supermarkets in Talks to Charge for Plastic Bags. The Straits Times. https://www.straitstimes.com/singapore/environment/supermarkets-in-talks-to-charge-for-plastic-bags.

Towards Zero Waste. 2020. Chapter 7 - Towards A Zero Waste Nation, Together. Singapore: Towards Zero Waste. https://www.towardszerowaste.gov.sg/zero-waste-masterplan/chapter7/.

Van Eygen E., Laner D., Fellner J., 2018. Circular economy of plastic packaging: Current practice and perspectives in Austria. Waste Management 72, 55-64.

http://doi.org/10.1016/j.wasman.2017.11.040.

Verghese K., Lewis H. 2007. Environmental innovation in industrial packaging: a supply chain approach." International Journal of Production Research 45, 18-19, 4381-4401. http://doi.org/10.1080/00207540701450211

Walker T.R., Xanthos D., 2018. A call for Canada to move toward zero plastic waste by reducing and recycling single-use plastics." Resources, Conservation and Recycling 133, 99-100. http://doi.org/10.1016/j.resconrec.2018.02.014.

World Economic Forum. 2016. World Economic Forum Annual Meeting 2016. World Economic Forum. https://www.weforum.org/events/world-economic-forum-annual-meeting-2016.

Yazdanparast A., Manuj I., Swartz St.,M., 2010. Co-creating logistics value: a service-dominant logic perspective. The International Journal of Logistics Management 21, 3, 375-403. http://doi.org/10.1108/09574091011089808

Yin R.K. 2014. Case Study Research: Design and Methods. Thousand Oaks: SAGE Publications.

Yolin Ch., 2015. Waste Management and Recycling in Japan Opportunities for European Companies (SMEs focus). Tokyo: EU-Japan Centre for Industrial Cooperation. https://www.eu-japan.eu/sites/default/files/publications/docs/waste_management_recycling_japan.pdf.

Yuan Z., Bi J., Moriguichi Y., 2008. "The Circular Economy: A New Development Strategy in China." Journal of Industrial Ecology 10, 1-2, 4-8. http://doi.org/10.1162/108819806775545321.

ŁAŃCUCH SUROWCÓW WTÓRNYCH JAKO SPOSÓB NA OGRANICZENIE ODPADÓW PLASTIKOWYCH W SINGAPURZE

STRESZCZENIE. Wstęp: COVID-19 zmienił nasz styl życia i wpłynął na drastyczny wzrost zakupów dokonywanych on-line, co z kolei związane jest ze znacznym wzrostem użycia opakowań plastikowych. Z tego też powodu zagadnienia gospodarki odpadami plastikowymi zdaje się być coraz ważniejszym tematem w wielu krajach. W pracy proponowane jest rozwiązanie zamkniętego obiegu opakowaniami plastikowymi na trzech poziomach: ekonomicznym, społecznym i środowiskowym. Jest to powiązane z zarządzaniem cyklem życia (LCA).
Metody: Zebrano i poddano analizie dane dotyczące odpadów plastikowych, obejmujące produkcję, konsumpcję oraz cały cykl życia w krajach rozwiniętych. Poprzez porównanie stosowanych praktyk w Niemczech i Południowej Korei stworzono ramy wdrożenia koncepcji 4R: redukcja, ponowne użycie, recycling i odzyskiwanie surowców wtórnych.
Wyniki i wnioski: W pracy zaprezentowano nowe spojrzenia na zamknięty łańcuch dostaw z punktu widzenia rządu, producentów oraz konsumentów oraz zwrócono uwagę na istotność uwzględniania możliwości przemysłu wyrobów plastikowych (co wymaga zaangażowania zarówno ze strony rządu jak i konsumentów) a nie tylko oczekiwań konsumentów.

Słowa kluczowe: łańcuch dostaw surowców wtórnych, zarząnie plastikowymi odpadami, zarządzanie cyklem życia, koncepcja 4R, potrójna linia dolna, bioplastik

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ORIGINAL PAPER

EXPLORING THE PROCESS OF AQUA LOGISTICS IN THE MALAYSIAN AQUACULTURE INDUSTRY- A QUALITATIVE STUDY

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ABSTRACT. **Background:** The production of freshwater aquaculture fish has developed quickly and being important activity. An intensive logistics system is required to handle the shipment since the aquaculture products especially aquaculture fish are perishable. The process begins right after fish farming to final consumption. It involves a large number of stakeholders as the significant effort is required to build an efficient supply chain. However, little is known about process faced by the Malaysian aquaculture entrepreneurs during the aqua logistics activities. Therefore, this study aims to address this gap by exploring this phenomenon.
Methods: For methodology part, a series of 12 aquaculture companies through focus group discussion (FGD) with the entrepreneurs were done across aqua logistic business. This was done to explore the topic and refine the research questions.
Results: The present study discovers that there were linkages along the value chain of aqua logistics in aquaculture industry, which provides a specific recommendation to stakeholders in managing day-to-day logistics operations. Also, the findings show four main process emerging from the qualitative study, which led to the following themes, namely: [i] procurement; [ii] production; [iii] order fulfillment; and [iv] transport and distribution.
Conclusion: The adopted qualitative methodology provided rich information that will lead the future research. In brief, this study has contributed new knowledge to the existing literature in aqua logistics and will benefit the future studies.

Key words: aqua logistics, distribution, aquaculture, tilapia, transportation, agro-logistics.

INTRODUCTION

In today's competitive business environment, good management practice in logistics, particularly in aquaculture industry could provide better products, high quality of service, optimize resources and facilities, and minimize operational costs. This is because success or failure is closely related to logistics management [Glavee-Geo, Engelseth, 2018]. Logistics deal with the supply chain process that plans, implements, and controls the efficient and effective point-to-point flow and storage of goods, services and related information, throughout the production, distribution and delivery stages, from the initial suppliers of inputs to final customers of products. The process along the chain involves the manufacturer, suppliers, transporters, warehouses, retailers and consumers [Prasetyanti, Simatupang, 2015; Zhao, Droge, Stank, 2017].

The efficiency of product arrangement is related to logistics management in providing a flow of goods and services without any waste and interruption [Jasti, Kodali, 2015]. The difficulty in coordinating the aqua logistics activities (packaging, transportation, warehousing, inventory, and distribution) among aquaculture entrepreneurs is expected to increase in aquaculture industry. Aqua logistics covers the production (farmers),

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processing, and transportation & distribution. It handles the three products such as agricultural commodities, agricultural/ aquaculture products, and processed and customized products [Jensen, Nielsen, Larsen, Clausen, 2010]. Regarding aquaculture products, it should be handled and transported by highly efficient logistics and distribution channels to ensure the integrity of the production is maintained. The downstream process by the farmers is selling fresh fish at local markets. The popular dishes at the food premises in Malaysia are cooked aquaculture fish and some fresh fish are exported to the other countries.

Handling the aqua logistics system in the supply network will create new demands on logistics management, which means that new approaches and methods are needed for aquaculture entrepreneur in the aquaculture industry to understand and deal with logistics processes. In this context, stakeholders in logistics have to effectively play their respective role, so that aquaculture entrepreneur could enhance their performance. However, previous studies were focused on agro-logistics and supply chain in agriculture without concentrating to the aqua logistics system [Alfonso-Lizarazo, Montoya-Torres, Gutierrez-Franco, 2013; Gardas, Raut, Jagtap, Narkhede, 2019; Jonkman, Barbosa-Povoa, Bloemhof, 2019; Moazzam, Akhtar, Garnev-ska, Marr, 2018; Shankar, Gupta, Pathak, 2018; Zai, Hadiguna, Afrinaldi, 2018].

Therefore, the research in this field should be paid much attention in order to enhance knowledge. However, there is relatively little analytical work dealing specifically with the aqua logistics, particularly in Malaysia's tilapia industry. Numerous studies deal with logistics or supply chain practices in fishing industry, for example, a model of fishing supply chain management for enhancing production and distribution of fishes in Bangladesh was proposed by Islam and Habib [2013]. It was supported study by Seung and Kim [2020] developed the supply chain network model in the German fish industry.

As suggested by Guritno & Tanuputri [2017], there is a need for the current researchers to conduct further research on this issue based on aquaculture supply chain and logistics management in other industries and study settings. Seung and Kim [2020] also recommend exploring supply chain management for seafood industries in another context for more understanding. Therefore, there are needed to study this issue. The present study seeks to promote a greater understanding of aqua logistics in the Malaysian aquaculture industry connected to transportation and distribution of tilapia production. Logistics creates and enhances the value offered by businesses by increasing products and ensuring product availability. To provide more value, aqua logistic entrepreneurs strive to improve their own logistics activities or rely on professionals. Hence, this study is important to comprehend the steps faced by aquaculture companies during the aqua logistic activity. Based on these issues, the following research question is proposed: “What is the process of logistics management for the Malaysian aquaculture industry?”

LITERATURE REVIEW

The aquaculture sector in Malaysia has been developed since 1920’s and now becomes as an important activity [Food and Agriculture Organization of the United Nations [FAO], 2018]. It has been growing rapidly in Malaysia, especially in the production of freshwater aquaculture fish. Based on record, the production of aquaculture products were increased from 260,773 metric tons [MT] in 2013 to 427,015 MT in 2017 (Malaysia Department of Fisheries [DOF], 2013, 2017]. Based the data presented by DOF, it seems the consumers accept aquaculture fish in Malaysia. Apart of sea fish, the Malaysian now considers aquaculture fish as an alternative. It shows that the production of sea fish was depleted. The main aquaculture products in Malaysia are freshwater fish and brackish water fish to be a second choice. [Ibrahim, Khan, Norrakiah, Fazleen, 2014; DOF, 2018]. The most popular aquaculture fish produced by farmers are red and black tilapia, keli and patin. The farmers in Malaysia have cultured freshwater fish in earthen ponds, floating net cages in rivers and ex-mining pools for many years [Malaysia Department of Fisheries [DOF], 2018].

As the aquaculture industry continues growing, the logistics networking that links to farmers, marketing, transportation and distribution plays an important role to sustain the aquaculture business. It involves the processes of logistics activities such as procurement, handling, production, order processing and transportation as well as distribution [Borade, Bansod, 2007; Islam, Habib, 2013]. In addition, a proper management in managing the fish distribution is also required as the quality of fish is determined by temperature [Bhatnagar, Devi, 2013]. The main reason is that fresh fish is a perishable product that needs to be monitored during processing, storing, transport and distribution [Tingman, Jian, Xiaoshuan, 2010].

The Council of Logistics Management [CLM] defined the logistics management as 'Logistics is that part of the supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point-of-origin to the point-of-consumption in order to meet customers' requirements [Lambert, Cooper, 2000]. The main logistics activities consist of procurement, transportation, inventory management, order fulfillment, information processing, warehousing management, and dissemination from the supplier to the end consumer [Ballou, 2007]. The logistics activities are integrated with other firm functions such as marketing, sales manufacturing, finance, and information technology [Glavee-Geo, Engelseth, 2018]. As a key function of supply chain, logistics ensures raw material and goods and services in the firm are managed to improve the efficient of production to deliver better service to the customers [Baah, Jin, 2019].

METHODOLOGY

Qualitative Method

Qualitative methodology is defined as "any research that produces findings not arrived at employing statistical procedures or other means of quantification" [Strauss, Corbin 1990a] where it requires the researcher to seek, understand, illuminate, and extrapolate to a comparable situation. In qualitative methodology, researchers study things in their natural settings, endeavoring to make sense or understand phenomena in terms of the meanings brought to them [Denzin, Lincoln, 2011].

In qualitative methodology, researchers study things in their natural settings, endeavouring to make sense or understand phenomena in terms of the meanings brought to them [Denzin, Lincoln, 2011]. Qualitative research comprises an empirical materials-case study, introspective, life story and personal experience, historical, and observational and visual texts that describe the problematic moments, routines and meanings of individuals' lives [Denzin, Lincoln, 2011].

Qualitative research appropriately looks for answers to questions by examining various social settings and the individuals who inhabit these settings [Berg, 2008]. Qualitative techniques allow researchers to share the perceptions and understandings of others and explore how people construct and give meaning to their daily lives. Some researchers adopt qualitative methods to examine how people learn about and make common sense of themselves and others [Berg, 2004].

Constructivist Grounded Theory

The qualitative approach selection affects the theoretical foundation, data collection, and analysis methods that are suitable for a set of research objectives [Parry 2004; Patton 2002a, 2002b]. Nevertheless, the phenomenon of research in the present study is also influenced by the research design. Firstly, there was a lack of a framework that existed from which this study could be conceptualized. Secondly, only a small number of aquaculture entrepreneurs operate in the Malaysian domestic market. Thirdly, there have been limited discussions on aqua logistics within the broader logistics and supply chain literature, thus requiring a deeper understanding of the phenomenon's theoretical context. Next, an aquaculture entrepreneur in an organizational context and a logistics function are seemed to be more complicated than the present literature. Therefore, a more in-depth investigation is required.

The present study will adopt the constructivist approach of Charmaz [2005, 2006, 2014]. The constructivist version of the grounded theory suits the qualitative inquiry, and this is a contemporary version from the original version by Barney Glaser and Anselm Strauss in 1967 [Charmaz, 2016]. In comparing constructivist and objectivist grounded theory, this approach provides a heuristic device to understand debates and divisions in the grounded theory; thus, it specifies how to move the approach further into social constructionism [Charmaz 2000, 2002, 2006]. Besides that, the constructivist grounded theory presents the 'what' and 'how' questions. They highlighted the understanding of phenomena and emphasized that this understanding must be in specific conditions studied in the research process [Charmaz, 2008]. The constructivist approach by Charmaz emphasized theory development consequential from a co-construction process that is reliant upon a researcher's interactions with the participants of the study [Charmaz, 2014].

Data Collection and Analysis

This study used Focus Group Discussion [FGD] in collecting the research data. Regarding qualitative data collection in the social sciences, business and health research, FGD is one of the most common tools used by the researchers. [Dilshad, Latif, 2013; Merriam, 2009; Rabiee, 2004; Rodrigues et al., 2010]. By using the method of FGD, the researchers can obtain the relevant information and gain an in-depth understanding of Malaysian aqua logistics systems.

For this study, researchers organized the focus group discussion with selected twelve [12] participants. Participants' selections are based on knowledge and experiences in logistics, aquaculture systems, and tilapia production management. The data's main source is the rich and thick information to support data validity in the study. FGD was conducted at the research location, and it was planned several weeks before the actual session.

The researcher carried out focus group sessions via interview protocol of FGD, which Merriam [2009] designed as a guideline to conduct the FGD session in the study. There were several general criteria used in the study, but not limited to.
- Overview of tilapia farming practices. It includes raw materials, operational procedures, and products;
- Types of distribution channel system;
- Distribution methods in handling, transportation, storage, and resources deployment;
- Constraints of managing the tilapia product.

The interviewers ask key question, in the same way, each time and do not probing for further data. Nevertheless, this probing is more limited compared in unstructured in-depth interviews [Ritchie, Lewis, 2003; Ritchie et al., 2014]. The interview covers the answers on the process of logistics management confronted by the Malaysian aquaculture industry. The FGD was conducted approximately 3-4 hours. A Digital recorder was used to record the data from the participants. The major themes that emerged from the data grounded were discovered through analysis by NVivo 10.

FINDING AND DISCUSSIONS

For this study, the findings are segmented into four thematic categories that are revealed based on focus group analysis done on the issue discussed and focusing on the model process of aqua logistics management confronted by the Malaysian aquaculture industry shown in Figure 1.

Furthermore, four dominant themes were identified during the analysis which are: [i] procurement; [ii] production; [iii] order fulfillment; and [iv] transport and distribution. Each of the themes is explained as follows.

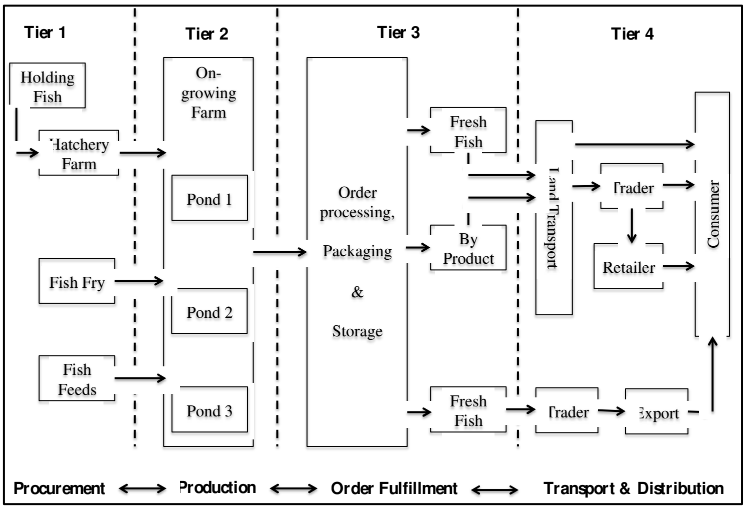

Fig. 1. Model Process of Aqua logistics of Malaysian Aquaculture Industry

Tier 1 – Procurement

The participants agreed that aquaculture entrepreneurs must be acquainted with the procurement process in dealing with the supplier in terms of purchasing material supplies such as fish fry and fish feeds. Based on the discussion, the first step in farming freshwater fish is to locate a quality holding fish and fish fry to produce a quality finish product. This is in line with how aquaculture entrepreneurs manage the procurement process. PK12 stated:

"Farmers are required to select a quality supplier. If possible, it comes from an accredited or registered supplier with Department of Fisheries. [……] This is to avoid a low quality of fish fry such as high mortality and maturity level. At the initial stage, the aquaculture entrepreneurs have to refer with Department of Fisheries or breeding center that able to produce a quality fish fry. Department of Fisheries are also providing fish fry with no cost"

"[………] next cycle, the aquaculture entrepreneurs have to find it but must be knowledgeable with the procurement process"

Above method is also applied to the purchasing the holding or main fish. PK11 explained that:

"[….] usually, the aquaculture entrepreneurs have imported holding or main fish instead of fish fry. Then, this product will transfer to the breeding farm to produce a quality fish fry. [……] but make sure the aquaculture entrepreneurs apply the import permit from Department of Fisheries"

Additionally, PK 1 stated:

"We feel around Kelantan and Terengganu .... very little in the Terengganu area .... Wholesalers will take it simultaneously. Usually, they will take freshwater fish, vegetables and fruits at the same time ... Only on the Terengganu coast. In Kuala Terengganu .... here their market distribution and procurement"

This is line with [Hong, Lee, Zhang, 2018] where they claimed that the procurement process is a part of the logistics and supply chain. This activity is also vital in the aquaculture business, as it will determine the entire logistics process and cost [Guritno, Tanuputri, 2017]. Proper management procurement activities are needed to expose with the uncertainties, including variable lead-time, uncertain demand, and volatile price [Manuj, Mentzer, 2008].

Tier 2 – Production

The second tier in aqua logistics is production. The sources of aquaculture fish production in Malaysia includes freshwater and brackish water culture system. In 2017, both culture systems produced 427, 015 tones, and the contribution from freshwater was 102,596 tones, valued at RM1.08 billion. Out of 102,596 tonnes of freshwater production, both tilapia products [black tilapia and red tilapia] contributed to 31% of production [Malaysia Department of Fisheries [DOF], 2017]. The participants agreed that most farmers were involved in many small-scale producers, whereby the fish production focused on one site. It was explained by PK8 that:

"Based on record, the fish production started with 2-3 small cages, and then when they have more capital, they will increase. Production is not so many, it about few tones only per cycle".

Therefore, it would create a constraint to farmers in implementing the good practices of fish production. Although there is no specific government regulation in fish farming, the aquaculture entrepreneurs are encouraged to comply with several national standards. PK12 stated that:

"We advised the aquaculture entrepreneur to practice Malaysian Good Agricultural Practices [MyGAP]. [……] because MyGAP covers good production handling. Fish grading accurate, fish storage, cage, fish feeding method, etc"

PK 10 also added that:

"So far not many aquaculture entrepreneurs awarded with the MyGAP, but we are in the midst of assist them to implement it. Department of Fisheries has provided full commitment to increase more MyGap practices in aquaculture industry"

PK4 stated that:

The aquaculture entrepreneurs are aware that the agencies encouraged them to increase the fish production, but it is not applied to all as the constraint of size of ponds, capital, lacking skill are facing by the them....

The above quotes clearly show that government agencies have worked hard to provide encouragement and assistance to aquaculture industry entrepreneurs. Various programs and initiatives have been implemented to boost the production of these fish farms. Past study by Little et al. [2016], the rise of unconventional and innovative foodstuffs, often joint with terrestrial livestock, with aquaculture itself the primary source of marine materials.

Additionally, Sampantamit et al. [2020] discover that Thailand's aquaculture production has increased significantly over the last few decades, and it makes a significant contribution to socio-economic development. Obviously, estimated total aquaculture production in Thailand is gradually growing from about 0.6 to 0.9 million tonnes over the last twenty years. Meanwhile, livestock shrimp is a major animal aquatic product, accounting for about 40% of total revenue aquaculture production, followed by fish (38%) and molluscs (22%). The budget exceeded decades ago; it showed that around 199470 hectares of land were used for aquaculture agriculture. Of the total area, 61% used for freshwater farms, and 39% were used for coastal agriculture.

Tier 3 – Order Fulfillment

Participants were agreed that the order fulfillment should be in the part of fish farming logistics and supply chain. The aquaculture entrepreneurs should manage order fulfillment from the customers properly to deliver the right products with accurate order processing and quality of packaging. In the situation of local fish farming, PK7 stated that:

"Department of Fisheries is always encouraged the aquaculture entrepreneurs to use a quality packaging for delivery final products. […..] In fact, the department has put the commitment in conducting the short course of packaging process"

In term of order processing, PK5 and PK2 explained that:

"Some of the aquaculture entrepreneurs have a contract with wholesaler to market their products. In this case, the order processing conducted by the aquaculture entrepreneurs is based on the contract between the parties. It is more regular practices but for those who market the product in retail form, order processing is normally based on the instant order"

The logistics system covers the flow of goods from the point of origin to the point of consumption. A part of that is the function of order fulfillment, including the activities of order processing, stock checking, and final product packaging and delivery [Li, 2014; Zhang, Jiao, & Ma, 2010]. The aquaculture entrepreneurs should have knowledge and competency in handling the order fulfillment. It includes managing the activities ranging from material supply to the farming site and delivering final fresh fish and by-products. It starts by receiving an order from the customers and end at the delivery point, the final products, and acceptable storage practices [Croxton, 2003].

Tier 4 – Transport and distribution

The aquaculture entrepreneurs must quickly get knowledge in transport operations and distribution in order to improve their services, particularly in the aquaculture business. Improved transport and distribution with lower transportation cost is one of the participants' main agenda. Lower transportation cost has given the opportunities to the aquaculture entrepreneurs to access a wider range of market. Improvement in logistics has also created economies of scale in handling aquaculture products where all levels in value chain can be managed efficiently. PK 6 mentioned:

"If it is FAMA, it is more about transportation. For example, if we take talapia fish, usually, we buy on the farm at an average price of about RM 7.50 ...... this is in Lancang. Maybe you can all refer back to the FAMA Lancang operation center ... ... he is active ...... with this talapia fish, freshwater fish ... catfish ... ... Sometimes 20 cents, 50 cents per 1 kilo ... ... depends on transportation and delivery cost...."

Input from the discussion, participants highlighted that the distribution channel in local fish farming consists of distribution to end consumers, intermediaries, and direct to the processor. The aquaculture entrepreneurs have to deal and do all marketing by themselves to market aquaculture products when the first type of distribution channel is selected. There are two transportation options involved either the aquaculture products transported direct to the consumers or the consumer picking up the aquaculture products using their transport. PK 9 revealed that:

"We have set up CC and DC..Collecting Center and Distribution Center ..... the largest is located in Bangi, and the second is in Kuantan ... also in Besut ... ... we will also create all over Malaysia. The purpose is to store sea fish, we will also make a collection for freshwater fish. So, we have also created several fishing markets, mostly in the area fishing markets ... for the purpose of marketing sea fish and including freshwater fish and want to absorb into LKIM for distribution ...."

In the Malaysia aquaculture industry, participants mentioned that Federal Agricultural Marketing Authority [FAMA] is the agency authorized to be an actor for marketing and distribution of aquaculture products. The agency purchased the tilapia from the aquaculture entrepreneurs with agreed price and distribution to the retailer to market the products. Other alternative provided by the agency was the Consolidation Centre and Distribution Centre, act as intermediaries. As at to date, only three [3] centers were established in Malaysia. The objective to establish these centers is to help the aquaculture entrepreneurs to reduce cost and time. This is because tilapia products will be gathered in one place and the processors or wholesaler or retailer may pick up and transport it by their own. PK3 stated that:

"[……] buyer may collect a tilapia product from one place. In this place, they would be able to get all type tilapia product [……] that our purpose to establish Consolidation Centre & Distribution Centre"

A part of the above method of transportation and distribution, participants highlighted that the aquaculture entrepreneurs were selling and distributing direct to processors. In this case, the aquaculture entrepreneurs have to ensure that the agreed schedule needs to comply during the distribution process. Thus, the aquaculture entrepreneurs have able to supply regularly. The processor will purchase in large volume in standard practice, which requires a proper transportation and distribution. This practice is due to ensure the production would not be affected and able to avoid unnecessary problems.

The other important is that aquaculture entrepreneurs can identify and access aquaculture products distribution at domestics and global level [Gani, 2017; Ottinger, Clauss, & Kuenzer, 2016)] This finding is supported by Obiero et al. [2014], most aquaculture products such as fish has sold directly to individual consumer.

CONCLUSIONS

The research helped in identifying the logistics process in aquaculture industry, which leads to develop the model process of aqua logistics. It consists of four main components along the process, starting from procurement until transport and distribution. The research findings point out to the presence of customer-supplier relationship throughout the logistics chain. The framework developed in the study helps to understand the levels of aqua logistics in aquaculture industry. It includes roles and importance every tier of the aqua logistics level along the process.

Since this study adopted qualitative methodology instead of statistical analysis, generalization may not be appealed [Finfgeld-Connett, 2010]. Next, the sample case for this study was small, and could dent the findings. Finally, due to the nature of the qualitative, generalizations cannot be made with the other industries unrelated to logistics. Therefore, other similar studies need to be carried out on other categories of aquaculture businesses by using other methods.

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REFERENCES

Alfonso-Lizarazo E.H., Montoya-Torres J.R., Gutierrez-Franco E., 2013. Modeling reverse logistics process in the agro-industrial sector: The case of the palm oil supply chain. Applied Mathematical Modelling, 37, 9652-9664. http://doi.org/10.1016/j.apm.2013.05.015

Baah C., Jin Z., 2019. Sustainable supply chain management and organizational performance: The intermediary role of competitive advantage. Journal of Management and Sustainability, 9[1], 119-131. http://doi.org/10.5539/jms.v9n1p119

Ballou R.H., 2007. The evolution and future of logistics and supply chain management. Economic and Business Review, 19[4], 332-348. http://doi.org/10.1108/09555340710760152

Berg B.L., 2008. Qualitative Research Methods, pp.. 7th Edisi . Boston: Allyn and Bacon: Pearson Education, Inc.

Bhatnagar A., Devi P., 2013. Water quality guidelines for the management of pond fish culture. International Journal of Environmental Sciences, 3[6], 1980-2009. http://doi.org/10.6088/ijes.2013030600019

Borade A.B., Bansod S.V., 2007. Domain of supply chain management – a state of art. Journal of Technology Management & Innovation, 2[4], 109-121. https://www.jotmi.org/index.php/GT/article/view/rev4

Bruce L. Berg., 2004. Qualitative Research Methods For Social The Sciences. [A. C. Jeff Lasser, Ed.], pp.. 5th Edisi . United State of America: Pearson Education, Inc.

Charmaz K., 2000. Constructivist and Objectivist Grounded Theory. Handbook of Qualitative Research, pp.. 2nd Edisi ., 509–535. Thousand Oaks: Sage Publication, Inc.

Charmaz K., 2002. Grounded Theory Analysis. Handbook of Interview Research, pp.. 675–694. Thousand Oaks: Sage Publication, Inc.

Charmaz K., 2005. Grounded Theory in the 21st Century: Applications for Advancing Social Justice Studies. The Sage handbook of qualitative research, pp.. N.K. Denzi., 507–536. Thousand Oaks, California: Sage Publication Ltd.

Charmaz K., 2006. Constructing Grounded Theory: A practical guide through qualitative analysis, 2nd Edisi. Los Angeles: Sage Publication Ltd.

Charmaz K., 2008. Constructionism and the Grounded Theory Method. Constructionism and the Grounded Theory, Holstein, 397–412. New York,London: The Guilford Press.

Charmaz, K. 2014. Constructing Grounded Theory. [J. Seaman, Ed.], pp.. 2nd Edisi . Thousand Oaks, California: Sage Publication Ltd.

Charmaz K., 2016. The Power of Constructivist Grounded Theory for Critical Inquiry. Qualitative Inquiry 23[1]: 34–45. http://doi.org/10.1177/1077800416657105

Croxton K.L., 2003. The order fulfillment process. The International Journal of Logistics Management, 14[1], 19-32. http://doi.org/10.1108/09574090310806512

Denzin N.K., Lincoln Y.S., 2011. The SAGE Handbook of Qualitative Research. [Vicki Knight, Ed.], 4th Edisi. Thousand Oaks: Sage Publication Inc.

Dilshad R.M., Latif M.I., 2013. Focus group interview as a tool for qualitative research: an analysis. Pakistan Journal of Social Sciences, 33[1], 191-198.

Finfgeld-Connett D., 2010. Generalizability and transferability of meta-synthesis research findings. Journal of Advanced Nursing, 66[2], 246–254.

Food and Agriculture Organization of the United Nations [FAO] 2018. National Aquaculture Sector Overview: Malaysia. Retrieved from http://www.fao.org/fishery/countrysector/naso_malaysia/en

Gagalyuk T., Hanf J., Herzlieb C., 2010. Managing supply chains successfully: an empirical testing of success of supply chain networks in the German fish sector. Acta Agriculturae Scandinavica, Section C - Food Economic, 7 [2-4], 139-150. http://doi.org/10.1080/16507541.2010.531922

Gani A., 2017. The logistics performance effect in international trade. The Asian Journal of Shipping and Logistics, 33[4], 279-288. http://doi.org/10.1016/j.ajsl.2017.12.012

Gardas B., Raut R., Jagtap A.H., Narkhede B., 2019. Exploring the key performance indicators of green supply chain management in agro-industry.

Journal of Modelling in Management, 14, 1, 260-283. http://doi.org/10.1108/JM2-12-2017-0139

Glavee-Geo R., Engelseth P., 2018. Seafood export as a relationship-oriented supply network: evidence from Norwegian seafood exporters. British Food Journal, 120[4], 914-929. http://doi.org/10.1108/BFJ-04-2017-0249

Guritno A.D., Tanuputri M.R., 2017. Comparison of fish supply chain from aquaculture and sea catchment areas. Journal of Service Science and Management, 10[04], 353-359. http://doi.org/10.4236/jssm.2017.104028

Hong Z., Lee C.K.M., Zhang L., 2018. Procurement risk management under uncertainty- a review. Industrial Management & Data Systems, 118[7], 1547-1574. http://doi.org/10.1108/IMDS-10-2017-0469

Ibrahim A.B., Khan M.A., Norrakiah A.S., Fazleen I.Z., 2014. Fresh water aquaculture fish consumption in Malaysia and heavy metals risk exposure to consumers. International Food Research Journal, 21[6], 2109-2113.

Islam S.B., Habib M.M., 2013. Supply chain management in fishing industry: a case study. International Journal of Supply Chain Management, 2 [2], 40-50.

Jasti N.V.K., Kodali R. 2015. A critical review of lean supply chain management frameworks: proposed framework. Production Planning & Control, 26 [13], 1051-1068. http://doi.org/10.1080/09537287.2015.1004563

Jensen T.K., Nielsen J., Larsen E.P., Clausen J., 2010. The fish industry-toward supply chain modeling. Journal of Aquatic Food Product Technology, 19 [3-4], 214-226. http://doi.org/10.1080/10498850.2010.508964

Jonkman J., Barbosa-Povoa A.P., Bloemhof J.M., 2019. Integrating harvesting decisions in the design of agro-food supply chains. European Journal of Operational Research, 276, 247-258. http://doi.org/10.1016/j.ejor.2018.12.024

Lambert D.M., Cooper M.C., 2000. Issues in supply chain management. Industrial Marketing Management, 29, 65-83.

Lambert D.M., García-Dastugue S.J., Croxton K.L., 2005. An evaluation of process-oriented supply chain management frameworks. Journal of Business Logistics, 26[1], 25-51. http://doi.org/10.1002/j.2158-1592.2005.tb00193.x

Li X., 2014. Operations management of logistics and supply chain: issues and directions. Discrete Dynamics in Nature and Society, 2014, 1-7.

Little D.C., Newton R.W., Beveridge M.C.M., 2016. Aquaculture: A rapidly growing and significant source of sustainable food? Status, transitions and potential. Proceedings of the Nutrition Society 75 [3]: 274–286.

Malaysia Department of Fisheries [DOF]. 2013. Perangkaan Perikanan Tahunan 2013.

Malaysia Department of Fisheries [DOF]. 2017. Perangkaan Perikanan Tahunan 2017. Retrieved from https://www.dof.gov.my/index.php/pages/view/3343

Malaysia Department of Fisheries [DOF]. [2018]. Skim Persijilan Ladang Akuakultur Malaysia. Retrieved from https://www.dof.gov.my/index.php/pages/view/2350

Manuj I., Mentzer J.T., 2008. Global supply chain risk management strategies. International Journal of Physical Distribution & Logistics Management, 38[3], 192-223. http://doi.org/10.1108/09600030810866986

Merriam S.M., 2009. Qualitative Research and Case Study Applications in Education. Revised and Expanded from Case Study Research in Education [3rd ed.]. San Francisco: Jossey-bass Publisher.

Moazzam M., Akhtar P., Garnevska E., Marr N.E., 2018. Measuring agri-food supply chain performance and risk through a new analytical framework: A case study of New Zealand dairy. Production Planning & Control, 29[15], 1258-1274. http://doi.org/10.1080/09537287.2018.1522847

Obiero K.O., Opiyo M.A., Munguti J.M., Orina P.S., Kyule D., Yongo E., Charo-Karina H., 2014. Consumer preference and marketing of farmed Nile Tilapia [Oreochromis niloticus] and African Catfish [Clarias gariepinus] in Kenya: case study of Kirinyaga and Vihiga Counties. International Journal of Fisheries Aquatic Studies, 1[5], 67-76.

Ottinger M., Clauss K., Kuenzer C., 2016. Aquaculture: relevance, distribution, impacts and spatial assessments: a review. Ocean & Coastal Management, 119, 244-266. http://doi.org/10.1016/j.ocecoaman.2015.10.015

Parry K., 2004. Grounded Theory. Great Barrington: Berkshire Publishing.

Patton M.Q., 2002a. Qualitative Research and Evaluation Methods, pp.. 3rd Edisi .

Thousand Oaks, California: Sage Publication, Inc.

Patton M.Q., 2002b. Two Decades of Developments in Qualitative Inquiry. Qualitative Social Work: Research and Practice 1[30]: 261–283.

Prasetyanti L.A., Simatupang T.M., 2015. A framework for service-based supply chain. Procedia Manufacturing, 4, 146-154. http://doi.org/10.1016/j.promfg.2015.11.025

Rabiee F., 2004. Focus-group interview and data analysis. Paper presented at the The Proceedings of Nutrition Society. http://doi.org/10.1079/PNS2004399

Rodrigues V.S., Piecyk M., Potter A., McKinnon A., Naim M., Edwards J., 2010. Assessing the application of focus groups as a method for collecting data in logistics. International Journal of Logistics Research and Applications, 13[1], 75-94. http://doi.org/10.1080/13675560903224970

Seung C.K., Kim D.-H., 2020. Examining supply chain for seafood industries using structural path analysis. Sustainability, 12 [5]: 1-20. http://doi.org/10.3390/su12052061

Sampantamit T., Ho L., Lachat C., Sutummawong N., Sorgeloos P. Goethals P., 2020. Aquaculture production and its environmental sustainability in Thailand: Challenges and potential solutions. Sustainability [Switzerland], 12 [5]: 1–17. http://doi.org/10.3390/su12052010

Shankar R., Gupta R., Pathak D.K., 2018. Modeling critical success factors of traceability for food logistics system. Transportation Research Part E: Logistics and Transportation Review, 119, 205-222. http://doi.org/10.1016/j.tre.2018.03.006

Stock G.N., Greis N.P., Kasanda J.D., 2000. Enterprise logistics and supply chain structure: the role of fit. Journal of Operations Management, 18, 531-547. http://doi.org/10.1016/S0272-6963(00)00035-8

Strauss A.L., Corbin J.M., 1990. Basics of Qualitative Research: Grounded Theory Procedures and Techniques. [A. L. Strauss, Ed.]. Thousand Oaks, California: Sage Publication, Inc.

Tingman W., Jian Z., Xiaoshuan Z., 2010. Fish product quality evaluation based on temperature monitoring in cold chain. African Journal of Biotechnology, 9[37], 6146-6151.

Yin R.K., 2009. Case Study Reserach: Design and Methods [4th ed.]: Thousand Oaks: SAGE Publications.

Zai Y.Y.M., Hadiguna R.A., Afrinaldi F, 2018. A review on success factors of logistic innovation in agro-industry International Journal of Engineering & Technology, 7[49], 236-240.

Zhang L.L., Jiao R.J., Ma Q., 2010. Accountability-based order fulfillment process reengineering towards supply chain management: a case study at a semi-conductor equipment manufacturer. Journal of Manufacturing Technology Management, 21[2], 287-305. http://doi.org/10.1108/17410381011014413

Zhao M., Droge C., Stank T.P., 2017. The effects of logistics capabilities on firm performance: customer-focused versus information-focused capabilities. Journal of Business Logistics, 22[2], 91-108. http://doi.org/10.1002/j.2158-1592.2001.tb00005.x

ANALIZA PROCESU LOGISTYKI PRZEDSIĘBIORSTW HODOWLANYCH WODNYCH JAKO CZĘŚCI AQUA-PRZEMYSŁU W MALEZJI – STUDIUM JAKOŚCIOWE

STRESZCZENIE. **Wstęp:** Produkcja ryb słodkowodnych rozwija się szybko i zyskuje coraz większe znaczenie. Intensywny system logistyczna wymaga dobrej obsługi dostaw ze względu na łatwą podatność na psucie się oferowanych produktów. Proces zaczyna się od momentu połowu aż do dostawy do końcowego konsumenta. Obejmuje swoim zasięgiem wielu uczestników, budujących wydajny łańcuch dostaw. Aczkolwiek nadal jest mało dostępnej wiedzy na temat procesu realizowanego przez malezyjskich przedsiębiorców tej branż podczas czynności w obrębie całego łańcucha logistycznego. Celem pracy jest pogłębienie i rozszerzenie wiedzy w tym obszarze.
Metody: Do badania wykorzystano grupy fokusowe 12 przedsiębiorstw związanych z badaną działalnością w celu analizy problemu.
Wyniki: Prezentowane badania wykazały powiązania wartościowe pomiędzy uczestnikami łańcucha dostaw w obrębie aqua-przemysłu, które dostarczają specyficznych rekomendacji uczestnikom łańcucha w codziennych operacjach logistycznych. Dodatkowo wyodrębniono cztery główne procesy związane z następującymi obszarami: zakupy, produkcja, realizacja zamówień oraz transport i dystrybucja.
Wnioski: Zastosowana metodologia jakościowa dostarczyła obfitej informacji, które będzie wykorzystana w kolejnych pracach. Rozszerza ona istniejący stan wiedzy na temat aqua-logistyki i stanowi bazę dla przyszłych badań.

Słowa kluczowe: aqua-logistyka, dystrybucja, hodowla ryb, tilapia, transport, agrologistyka

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ORIGINAL PAPER

DO THE FACTORS AFFECTING INCOTERMS® SELECTION DIFFER FOR EXPORTERS AND IMPORTERS? A FUZZY ANALYTICAL HIERARCHY PROCESS (FAHP) APPLICATION

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ABSTRACT. **Background:** There are a few studies that have findings regarding the factors affecting Incoterms® selection decisions, however, the importance weights of the factors weren't revealed prominently for importers and exporters separately. This study intends to overcome this gap by examining the factors that influence Incoterms® selections to find out whether there are any differences or not between exporters and importers. For this purpose, we analyzed the importance weights of each factor and ranked them for both two parties.

Methods: We constructed a conceptual model based on different approaches, previous studies and expert decisions. Data were collected from 19 experts, 9 of whom are importers and 10 are exporters, via e-mail. We conducted Fuzzy Analytical Hierarchy Process (FAHP) with the geometric mean method to find out the importance weights of each criterion.

Results: Findings of the study revealed that the most important factor influencing the selection of international commercial terms for both exporters and importers is "transportation costs" while the least important one is "firm size". Four factors which are "relations with forwarding agents, type of goods, complexity of transportation and distance" differ according to importers and exporters in their selections. Relations with forwarding agents and distance are found to be more influential for exporters while the type of goods and complexity of transportation are more effective for importers.

Conclusions: We conclude that cost related factors are the most influential ones and apart from a few factors, there is no significant divergence between the selection decisions of importers and exporters. The small sample size and the sample consisting of companies operating in different sectors in a particular region are among the limitations of the study. We suppose that the factors determined in this study will contribute to future studies with a larger sample using different analysis methods.

Key words: Incoterms®, FAHP, export, import, foreign trade.

INTRODUCTION

International Chamber of Commerce (ICC) which was founded in 1919 states that "Incoterms® is an acronym standing for international commercial terms and a trademark of International Chamber of Commerce, registered in several countries" [ICC, 2021a].

The Incoterms® rules which are the world's crucial terms of trade, indicate abbreviations for terms such as EXW (Ex Works), FOB (Free on Board), CIP (Carriage and Insurance Paid To), DAP (Delivered at Place) and guide the individuals participating in the foreign trade [ICC, 2021a].

ICC studied on the commercial trade terms and published the first version of the Incoterms® rules in 1936 and updated the rules in 1953, 1967, 1974, 1980, 1990, 2000, 2010, and finally 2020 [ICC, 2021b].

The studies in the literature are generally concerned with the Incoterms® rules revisions

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in terms of risks, costs and responsibilities of the buyers and sellers. They particularly focus on the Incoterms® 2000 and Incoterms® 2010 comparison to reveal the reasons of the revision [Baslangic 2015], inadequacies [Yilmaz et al. 2011] and amendments [Bergami 2012]. However, they have not sufficient considerations in selecting the right trade terms. We suppose that the process of the selection of international commercial terms and finding out its determinants are crucial since they have an important relationship between firm export performance [Hien et al. 2009; Yaakub et al. 2018]. There are a few studies in the literature on identifying the influential factors on international commercial terms selections [Hien et al. 2009, Yaakub et al. 2018, Suraraksa et al. 2020]. However, although previous studies have findings regarding the factors affecting terms selection decisions, importance weights of the factors weren't revealed prominently for importers and exporters separately. This study intends to overcome this gap by examining the factors with the aim of finding any differences concerning factor importance weights with respect to importers and exporters. As a result of the aforementioned reasons concerning international commercial terms selection, we address the following research questions (RQ):

RQ1: Which criteria are the most influential ones on exporters' Incoterms® selection decisions?
RQ2. Which criteria are the most influential ones on importers' Incoterms® selection decisions?
RQ3. Which criteria influencing the Incoterms® selection decisions differ for exporters and importers?

The contributions of this study to the existing literature are like the following: (1) this study proposes a new conceptual model including terms selection criteria and sub-criteria by synthesizing three different approaches, (2) to the best of our knowledge, this study is the first to discuss whether there are any differences in importance weights of factors influencing international commercial terms selection decisions with respect to importers and exporters by using FAHP with the geometric mean method, and (3) the results of the study make recommendations that could guide the experts in selecting the appropriate terms.

The remainder of the study is organized as follows. Section 2 introduces the theoretical foundations of the study and literature review. Section 3 is the methodology part which involves the research plan, data collection and empirical application. Section 4 gives the results and discussions. Finally, we concluded the findings by giving recommendations for future studies in section 5.

THEORETICAL FOUNDATIONS AND LITERATURE REVIEW

Trade terms between two companies are determined as a result of an agreement with which both parties will choose the best mode that will be the minimum cost for them, taking into account environmental risks. Since this is an agreement, the advantageous party will play a more significant role. Accordingly, we constructed the conceptual framework of this study based on three approaches: (1) Resource Based View (RBV) [Barney 1991], (2) Transaction Cost Approach (TCA) [Williamson 1981], and (3) Institutional Theory (IT) [DiMaggio and Powell 1983, Yiu and Makino 2002] since each approach covers the designing problems of international channels via specific theoretical views that underline the distribution activities and essential agent relationship [Bello and Briggs 2009: 399].

Resource-Advantage (R-A) criteria: From the point of RBV [Barney 1991], firm resources are the sources of sustained competitive advantage of a firm, which are valuable, rare, non-substitutable and imperfectly imitable. They can be divided into three groups: (1) physical capital resources (a firm's plant and equipment, location, technology, etc.), (2) human capital resources (training, experience, relationships, intelligence, etc.), and (3) organizational capital resources (formal and informal planning, controlling and coordinating systems, informal relations within a firm and in its environment) [Barney 1991]. We suppose that these resources are effective in the bargaining power of the parties in the selection of the terms. Firm size, for instance, as a firm's capital is found to be analyzed as a factor in the studies related to Incoterms® rules. In general, small size and amateur exporting firms prefer certain terms and the transportation process and the cost plan are executed by the buyer [Malfliet 2011]. Staff characteristics, as human capital resources, involve the knowledge, experience and attitudes of all personnel including employees and managers of a firm and could impact terms selections. Having greater knowledge of international commercial terms and considering them will lead a firm to a better export performance [Hien et al. 2009].

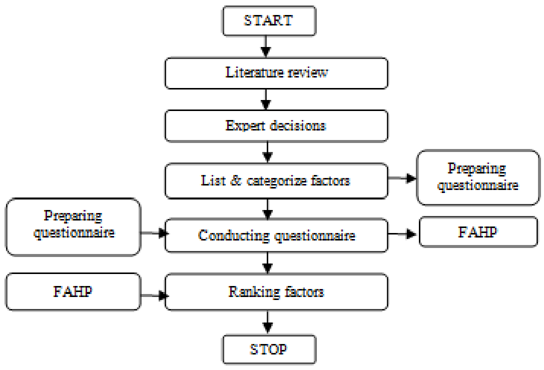
Efficiency-Cost (E-C) criteria: We use the TCA since the selection of the terms is a kind of firm behavior as a result of decisions concerning the cost and risk control activities of a company. TCA is based on "efficiency criteria" [Yiu and Makino 2002]. It proposes that economizing the transaction costs is central and the transactions are required to be dimensionalized as (1) uncertainty, (2) the frequency, and (3) asset specificity [Williamson 1981]. Trade terms rely on the affiliation between the exporter and importer and influence the costs of the trading process especially in global supply chains [Blanco, Ponce-Cueto 2015]. Suraraksa et al. [2020] argue that operating costs including shipment expenses, annual budget and value of products are the most effective factors while making decisions on international commercial terms selection. Another criterion affecting costs in the selection of terms is the mode of transport. Malfliet [2011] in his study, focuses on the impact of the transport mode on the selection of terms indicating that all the D-Terms can be used for any transport mode, even multimodal, while some terms such as FOB are used as maritime terms. Yaakub and Szu [2017] divided the factors influencing the selection of terms into two groups as external factors (freight, transport issue and tariff classification) and internal factors (mode of transportation, habit, experience and practices) of the firms and revealed that the mode of transportation is the most influential one.

Legitimacy – Environment (L-E) criteria: IT is based on "legitimacy criteria" [Yiu and Makino 2002]. Firm behaviors are a kind of response to institutional isomorphic changes through (1) political influence and the problem of legitimacy, (2) uncertainty and (3) professionalization in an environment [DiMaggio, Powell 1983]. Duncan [1972] defines the business environment as a total of physical and social factors considered in a decision-making of the individuals in a firm. The internal environment involves social and physical factors regarding organizational personnel, functional and staff units, and organizational level components inside of a firm while the external environment comprises the factors concerning customers, suppliers, competitors, technological and socio-political components outside the boundaries of the firm [Duncan 1972]. Erramilli [1992] states that the influential external factors on foreign market entry mode choice are host country restrictions, uncertainty-risk, market size and availability of acceptable partners and associates while indicating that the internal factors are firm's desire to get rapidly established, internal resources (capital and personnel) and corporate policy. Both exporters and importers have to realize the business environmental factors that affect the selection decisions of the most convenient international commercial terms [Hien et al. 2009]. International trade of goods is handled within varied international and domestic regulations and legislations that exporters and importers must pay attention to for conducting successful business activities [Bergami 2013]. The selection of delivery terms will be affected by a challenging risk distribution and transfer between importers and exporters [Shangina, 2007]. For instance, EXW and FCA are determined as the best terms for the buyer because of the visibility, control and command of shipping transactions [Stapleton et al. 2014]. Weight/value ratio of the products, income per capita and the distance between partner countries are also determined to be the factors influencing the choice of delivery terms [Rosal 2016].

METHODOLOGY

Research Plan

The research plan of the study consists of two main parts. In the first part, criteria were obtained and categorized as a consequence of the literature review and expert decisions to construct the questionnaire form.



Source: own work

Fig. 1. Research process

In the second part, questionnaire forms were filled out by the experts to analyze the criteria by using quantitative methods. Figure 1 demonstrates the steps of the research process in detail.

Sample and Data Collection

Data in this study were obtained by surveying foreign trade experts from the Aegean region of Turkey using judgement sampling method. Survey forms were distributed via e-mail to 25 companies and received 22 responses of which 19 are completed and appropriate to analyse. Since the FAHP used in the study allows to measure the decisions of a single expert, as well as analyze the decisions of a group of experts, it was determined that the sample size used in the study is sufficient to solve the research questions. The sample of the study consists of 10 exporters and 9 importers operating in several sectors. Around 60 % are small and medium sized enterprises (SME's) and have more than 15-year experience. Table 1 presents the descriptive statistics of the sample.

Table 1. Descriptive statistics of sample (%)

	Number	Position			Sector			
	Participants	*Owner*	*Manager*	*Specialist*	*Medical*	*Machine*	*Textile*	*Other*
Exporter	52.63%	10.00%	60.00%	30.00%	10.00%	20.00%	10.00%	60.00%
Importer	47.37%	55.56%	33.33%	11.11%	44.44%	11.11%	11.11%	33.33%
Total	100.00%	31.58%	47.37%	21.05%	26.32%	15.79%	10.53%	47.37%
	Firm size				**Firm Experience**			
	Big-size	*Medium-size*	*Small-size*	*Micro-size*	*1-5 years*	*11-15 years*	*16-20 years*	*> 20 years*
Exporter	20.00%	10.00%	60.00%	10.00%	20.00%	20.00%	20.00%	40.00%
Importer	-	11.11%	44.44%	44.44%	22.22%	22.22%	11.11%	44.44%
Total	10.53%	10.53%	52.63%	26.32%	21.05%	21.05%	15.79%	42.11%

FAHP with Geometric Mean Method

FAHP can be defined as a kind of synthesis of Analytical Hierarchy Process (AHP) and fuzzy logic approaches. AHP is one of the widely used multi-criteria decision making methods which depends on decisions of experts to reveal priorities on the factors through pairwise comparisons [Saaty 2008]. However, decision makers may remain uncertain while making comparisons. Fuzzy logic approach and factor weighting methods are considered to be effective in correcting the deficiencies concerning the uncertainty of data used in computations of exact values and relative weight of the occurrence factors [Sari 2020]. Zadeh [1965] identified a fuzzy set as "characterized by a membership function which assigns to each object a grade of membership ranging between zero and one". Fuzzy numbers are indicated by a symbol "~" placed above them. In this study, we prefer to use triangular fuzzy numbers commonly used in fuzzy calculations. Figure 2 shows the triangular fuzzy number Ã represented by three parameters (a, b, c), and the membership function is defined as equation (1) (Figure 2) [Lee et al. 2008]:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & otherwise \end{cases} \qquad (1)$$

Parameter b is the middle (m) value and the strongest grade of membership that equals to 1, while parameter a and c are the lower (l) and upper (u) values, respectively [Lee et al. 2008]. Another crucial concept is the linguistic variable that refers to linguistic labels of fuzzy sets having values are words not numbers [Zadeh 1983].

Linguistic variables and fuzzy numbers used in this study are demonstrated in Table 2, and membership functions of linguistic variables are shown in Figure 2.

Table 2. Fuzzy AHP Scale numbers

Linguistic variables	Triangular fuzzy numbers	Reciprocal triangular fuzzy numbers
Equally strong	(1, 1, 1)	(1, 1, 1)
Intermediate	(1, 2, 3)	(1/3, 1/2, 1)
Moderately strong	(2, 3, 4)	(1/4, 1/3, 1/2)
Intermediate	(3, 4, 5)	(1/5, 1/4, 1/3)
Strong	(4, 5, 6)	(1/6, 1/5, 1/4)
Intermediate	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strong	(6, 7, 8)	(1/8, 1/7, 1/6)
Intermediate	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely strong	(9, 9, 9)	(1/9, 1/9, 1/9)

Source: Lee et al. 2008

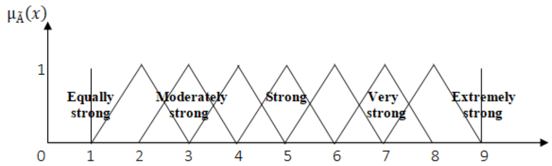


Fig. 2. Membership functions of linguistic variables

In this study, FAHP with geometric mean method proposed by Buckley [1985] is employed to determine primary factors according to expert decisions and to minimize uncertainties in the decision-making process. The process of application FAHP is explained by the following steps:

Step 1: Construct the decision hierarchy [Saaty 2008]

Step 2: Obtain one group decision

Saaty [2008] argued that the geometric mean is the unique way to construct a group judgment from individual judgments. Thus, geometric means of upper values, middle values and lower values obtained from expert decisions are calculated separately to build one group decision.

Step 3: Construct the pairwise comparison matrix (2).

$$\tilde{A} = \begin{array}{c} \\ c_1 \\ c_2 \\ \vdots \\ c_n \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{bmatrix} 111 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 111 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 111 \end{bmatrix} \end{array} \qquad (2)$$

where $\tilde{a}_{12}$ refers to the importance of criterion 1 relative to criterion 2 in a fuzzy pairwise comparison matrix.

Step 4: Calculate the geometric mean of fuzzy comparison value ($\tilde{r}_i$) and the fuzzy weights ($\widetilde{w}_i$) of each factor by using equations (3) and (4) respectively [Buckley 1985].

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots \otimes \tilde{a}_{in})^{1/n} \qquad (3)$$

$$\widetilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \oplus \tilde{r}_n)^{-1} \qquad (4)$$

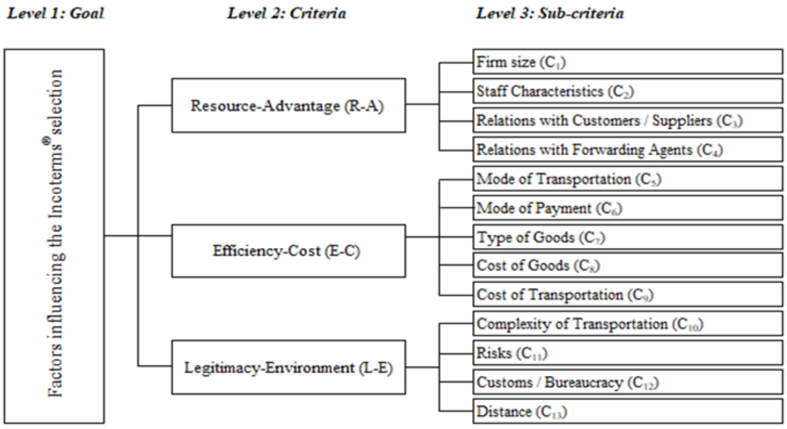
Step 5: To utilize the center of area (COA), a method of defuzzified fuzzy ranking, calculate Best Nonfuzzy Performance value (BNP) of each fuzzy number ($\tilde{R}_i$) by using the equation (5) [Hsieh et al. 2004].

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)] / 3 + LR_i \quad \forall i \qquad (5)$$

Application of FAHP

Step 1: We synthesized RBV, TCA, IT and literature review to list the influential criteria (factors) and sub-criteria (sub-factors) that should be evaluated while selecting international commercial terms. We grouped the sub-criteria under three main criteria. Each criterion has 4-5 sub-criteria for a total of 13 sub-criteria. These criteria and sub-criteria were validated by eleven foreign trade experts working in different industries to structure the conceptual model of the study. This model is provided as a "decision hierarchy" (Figure 3). Accordingly, (1) Resource-advantage criterion includes firm size, staff characteristics, relations with customers/suppliers, relations with forwarding agents; (2) Efficiency-cost criterion involves mode of transportation, mode of payment, type of goods, cost of goods, cost of transportation; (3) Legitimacy-environment criterion covers the complexity of transportation, risks, customs/bureaucracy and distance.

Step 2-3: We obtained one group decision and construct fuzzy pairwise comparison matrices. Two fuzzy pairwise comparison matrices were structured for the sub-criteria (13x13 matrix) compared by 10 export experts and 9 import experts separately. Table 3 demonstrates the pairwise comparisons of the criteria with respect to export experts while Table 4 shows comparisons with respect to import experts.



Source: own work

Fig. 3. Decision hierarchy of the study

Table 3. Pairwise comparisons of the sub-criteria with respect to exporters (ex)

	C_{1ex}			C_{2ex}			C_{3ex}			C_{4ex}			C_{5ex}			C_{6ex}		
C_{1ex}	1.00	1.00	1.00	0.13	0.14	0.16	0.20	0.22	0.25	0.17	0.18	0.21	0.48	0.57	0.67	0.25	0.28	0.31
C_{2ex}	6.45	7.19	7.88	1.00	1.00	1.00	1.50	1.74	2.08	1.14	1.31	1.49	0.93	1.07	1.21	0.15	0.17	0.18
C_{3ex}	4.00	4.54	5.07	0.48	0.57	0.67	1.00	1.00	1.00	1.78	2.07	2.35	1.39	1.65	1.90	0.51	0.55	0.59
C_{4ex}	4.74	5.42	6.05	0.67	0.76	0.88	0.43	0.48	0.56	1.00	1.00	1.00	1.04	1.15	1.27	0.20	0.23	0.26
C_{5ex}	1.50	1.75	2.10	0.82	0.94	1.08	0.53	0.60	0.72	0.79	0.87	0.96	1.00	1.00	1.00	0.18	0.21	0.23
C_{6ex}	3.27	3.60	3.96	5.45	6.05	6.86	1.71	1.82	1.96	3.88	4.34	4.99	4.41	4.84	5.43	1.00	1.00	1.00
C_{7ex}	0.96	1.15	1.36	1.41	1.57	1.78	0.77	0.83	0.90	1.35	1.53	1.73	1.03	1.25	1.47	0.18	0.20	0.21
C_{8ex}	2.66	2.96	3.22	7.14	7.63	8.05	3.60	3.95	4.27	3.91	4.28	4.65	6.84	7.46	8.00	0.95	1.10	1.24
C_{9ex}	6.03	6.38	6.69	5.14	5.40	5.64	6.38	7.20	7.97	6.79	7.45	8.05	7.70	8.19	8.64	4.95	5.94	6.78
C_{10ex}	2.44	2.92	3.37	0.82	0.93	1.06	0.53	0.62	0.72	0.35	0.39	0.44	1.05	1.19	1.39	0.31	0.37	0.45
C_{11ex}	1.44	1.67	1.96	0.77	0.84	0.92	0.56	0.62	0.69	0.87	1.02	1.17	1.46	1.59	1.73	0.99	1.09	1.21
C_{12ex}	2.31	2.73	3.25	1.10	1.31	1.53	0.61	0.70	0.84	1.04	1.17	1.33	1.86	2.09	2.38	0.48	0.61	0.79
C_{13ex}	0.81	0.88	0.93	1.30	1.43	1.68	0.39	0.45	0.52	0.55	0.59	0.64	0.95	1.14	1.33	0.32	0.37	0.43

	C_{7ex}			C_{8ex}			C_{9ex}			C_{10ex}			C_{11ex}			C_{12ex}			C_{13ex}		
C_{1ex}	0.73	0.87	1.04	0.31	0.34	0.38	0.15	0.16	0.17	0.30	0.34	0.41	0.51	0.60	0.69	0.31	0.37	0.43	1.07	1.13	1.23
C_{2ex}	0.56	0.64	0.71	0.12	0.13	0.14	0.18	0.19	0.19	0.94	1.08	1.22	1.08	1.19	1.30	0.65	0.76	0.91	0.59	0.70	0.77
C_{3ex}	1.11	1.20	1.30	0.23	0.25	0.28	0.13	0.14	0.16	1.39	1.62	1.88	1.45	1.61	1.78	1.20	1.42	1.65	1.94	2.24	2.58
C_{4ex}	0.58	0.65	0.74	0.22	0.23	0.26	0.12	0.13	0.15	2.26	2.54	2.89	0.86	0.98	1.15	0.75	0.85	0.96	1.57	1.70	1.82
C_{5ex}	0.68	0.80	0.98	0.13	0.13	0.15	0.12	0.12	0.13	0.72	0.84	0.95	0.58	0.63	0.68	0.42	0.48	0.54	0.75	0.88	1.06
C_{6ex}	4.80	5.08	5.41	0.80	0.91	1.05	0.15	0.17	0.20	2.24	2.73	3.19	0.82	0.92	1.01	1.26	1.63	2.08	2.31	2.67	3.10
C_{7ex}	1.00	1.00	1.00	0.29	0.32	0.36	0.18	0.19	0.20	0.40	0.46	0.54	0.44	0.51	0.61	0.33	0.40	0.51	0.67	0.72	0.80
C_{8ex}	2.80	3.15	3.43	1.00	1.00	1.00	0.44	0.48	0.54	1.96	2.38	2.84	1.19	1.27	1.34	1.45	1.65	1.90	1.93	2.22	2.55
C_{9ex}	5.00	5.36	5.69	1.86	2.09	2.29	1.00	1.00	1.00	5.23	5.81	6.36	4.07	4.51	4.87	4.16	4.53	4.93	3.27	3.45	3.61
C_{10ex}	1.87	2.17	2.51	0.35	0.42	0.51	0.16	0.17	0.19	1.00	1.00	1.00	0.42	0.46	0.52	0.59	0.70	0.82	1.02	1.17	1.34
C_{11ex}	1.63	1.95	2.27	0.74	0.79	0.84	0.21	0.22	0.25	1.93	2.17	2.41	1.00	1.00	1.00	2.04	2.33	2.67	1.85	2.16	2.51
C_{12ex}	1.98	2.49	3.04	0.53	0.61	0.69	0.20	0.22	0.24	1.22	1.44	1.68	0.37	0.43	0.49	1.00	1.00	1.00	1.73	2.02	2.39
C_{13ex}	1.25	1.38	1.49	0.39	0.45	0.52	0.28	0.29	0.31	0.75	0.86	0.98	0.40	0.46	0.54	0.42	0.49	0.58	1.00	1.00	1.00

Source: own work

Table 4. Pairwise comparisons of the sub-criteria with respect to importers (im)

	C_{1im}			C_{2im}			C_{3im}			C_{4im}			C_{5im}			C_{6im}		
C_{1im}	1.00	1.00	1.00	0.12	0.13	0.14	0.12	0.13	0.15	0.21	0.24	0.29	0.46	0.51	0.56	0.14	0.14	0.15
C_{2im}	7.09	7.82	8.53	1.00	1.00	1.00	1.23	1.34	1.47	1.71	1.87	2.03	0.81	0.94	1.13	0.15	0.16	0.18
C_{3im}	6.61	7.45	8.27	0.68	0.75	0.82	1.00	1.00	1.00	0.97	1.25	1.51	1.55	1.86	2.20	0.24	0.26	0.27
C_{4im}	3.49	4.12	4.73	0.49	0.53	0.58	0.66	0.80	1.03	1.00	1.00	1.00	1.05	1.20	1.37	0.14	0.15	0.16
C_{5im}	1.79	1.97	2.15	0.89	1.06	1.23	0.45	0.54	0.65	0.73	0.83	0.96	1.00	1.00	1.00	0.14	0.16	0.16
C_{6im}	6.86	6.96	7.05	5.55	6.09	6.87	3.65	3.89	4.19	6.24	6.53	7.05	6.07	6.44	7.05	1.00	1.00	1.00
C_{7im}	1.30	1.67	2.08	1.08	1.21	1.34	0.72	0.79	0.86	1.02	1.21	1.44	2.68	3.19	3.69	0.15	0.16	0.17
C_{8im}	6.74	7.28	7.70	6.37	6.68	6.96	4.54	4.91	5.25	6.24	6.44	6.60	7.20	7.76	8.22	1.28	1.47	1.65
C_{9im}	8.22	8.43	8.60	8.14	8.53	8.88	6.31	7.02	7.68	7.86	8.20	8.49	6.86	7.52	7.97	3.90	4.49	4.98
C_{10im}	2.40	2.87	3.32	0.61	0.73	0.88	1.09	1.29	1.51	0.24	0.30	0.36	3.51	4.09	4.55	0.17	0.20	0.23
C_{11im}	3.82	4.56	5.25	1.53	1.78	2.12	1.82	2.11	2.44	2.20	2.74	3.42	3.51	4.37	5.05	0.20	0.24	0.29
C_{12im}	1.06	1.41	1.84	1.40	1.73	2.12	0.98	1.14	1.34	2.64	3.32	3.99	3.28	4.46	5.43	0.19	0.22	0.26
C_{13im}	0.76	0.81	0.85	0.52	0.60	0.73	0.35	0.40	0.48	0.31	0.39	0.53	1.56	1.96	2.27	0.16	0.17	0.20

	C_{7im}			C_{8im}			C_{9im}			C_{10im}			C_{11im}			C_{12im}			C_{13im}		
C_{1im}	0.48	0.60	0.77	0.13	0.14	0.15	0.12	0.12	0.12	0.30	0.35	0.42	0.19	0.22	0.26	0.54	0.71	0.94	1.18	1.24	1.31
C_{2im}	0.75	0.83	0.93	0.14	0.15	0.16	0.11	0.12	0.12	1.13	1.37	1.64	0.47	0.56	0.65	0.47	0.58	0.72	1.36	1.66	1.91
C_{3im}	1.16	1.27	1.39	0.19	0.20	0.22	0.13	0.14	0.16	0.66	0.78	0.92	0.41	0.47	0.55	0.74	0.88	1.03	2.08	2.48	2.83
C_{4im}	0.69	0.83	0.98	0.15	0.16	0.16	0.12	0.12	0.13	2.76	3.37	4.13	0.29	0.37	0.45	0.25	0.30	0.38	1.87	2.57	3.19
C_{5im}	0.27	0.31	0.37	0.12	0.13	0.14	0.13	0.13	0.15	0.22	0.24	0.28	0.20	0.23	0.28	0.18	0.22	0.31	0.44	0.51	0.64
C_{6im}	5.88	6.16	6.53	0.61	0.68	0.78	0.20	0.22	0.26	4.44	5.11	5.83	3.43	4.14	4.88	3.88	4.61	5.40	5.07	5.74	6.38
C_{7im}	1.00	1.00	1.00	0.13	0.13	0.14	0.12	0.12	0.13	0.16	0.19	0.23	0.20	0.23	0.28	0.33	0.40	0.48	0.76	0.84	0.89
C_{8im}	7.05	7.61	7.97	1.00	1.00	1.00	1.02	1.24	1.66	3.41	4.07	4.73	2.22	2.42	2.62	4.00	4.61	5.22	4.99	5.59	6.28
C_{9im}	7.97	8.22	8.43	0.60	0.81	0.98	1.00	1.00	1.00	5.99	6.34	6.65	8.00	8.32	8.60	7.78	8.21	8.60	6.44	7.13	7.61
C_{10im}	4.32	5.33	6.21	0.21	0.25	0.29	0.15	0.16	0.17	1.00	1.00	1.00	0.34	0.38	0.42	0.59	0.67	0.76	2.48	2.80	3.10
C_{11im}	3.56	4.43	5.11	0.38	0.41	0.45	0.12	0.12	0.13	2.37	2.64	2.94	1.00	1.00	1.00	7.08	7.99	8.88	7.83	8.43	9.00
C_{12im}	2.07	2.48	3.05	0.19	0.22	0.25	0.12	0.12	0.13	1.32	1.49	1.70	0.11	0.13	0.14	1.00	1.00	1.00	5.01	5.64	6.23
C_{13im}	1.13	1.20	1.31	0.16	0.18	0.20	0.13	0.14	0.16	0.32	0.36	0.40	0.11	0.12	0.13	0.16	0.18	0.20	1.00	1.00	1.00

Source: own work

Step 4-5: Table 5 shows the results of ($\tilde{r}_i$) and ($\tilde{w}_i$) of each sub-criterion for both exporters and importers by using equations (3) and (4). The importance weights (w_i) of sub-criteria to be normalized in the next section were calculated by using the equation (5).

Table 5. Importance weights of sub-criteria

Sub-criteria	Export $\tilde{r}_i$ l	m	u	$\tilde{w}_i$ l	m	u	w_i weights	Import $\tilde{r}_i$ l	m	u	$\tilde{w}_i$ l	m	u	w_i weights
C_1	0.341	0.381	0.428	0.019	0.023	0.029	0.023	0.276	0.305	0.344	0.013	0.015	0.019	0.016
C_2	0.685	0.765	0.848	0.037	0.046	0.057	0.047	0.685	0.769	0.857	0.031	0.039	0.048	0.039
C_3	0.926	1.043	1.162	0.050	0.063	0.078	0.064	0.738	0.836	0.938	0.034	0.042	0.052	0.043
C_4	0.702	0.780	0.868	0.038	0.047	0.058	0.048	0.578	0.664	0.761	0.026	0.033	0.042	0.034
C_5	0.500	0.559	0.630	0.027	0.034	0.042	0.034	0.348	0.391	0.452	0.016	0.020	0.025	0.020
C_6	1.763	1.976	2.233	0.096	0.119	0.149	0.121	2.921	3.195	3.525	0.133	0.161	0.197	0.164
C_7	0.560	0.627	0.707	0.030	0.038	0.047	0.039	0.466	0.525	0.591	0.021	0.026	0.033	0.027
C_8	2.083	2.307	2.532	0.113	0.139	0.169	0.141	3.508	3.860	4.223	0.160	0.194	0.236	0.197
C_9	4.226	4.599	4.931	0.230	0.277	0.330	0.279	4.932	5.338	5.662	0.225	0.269	0.316	0.270
C_{10}	0.642	0.730	0.837	0.035	0.044	0.056	0.045	0.727	0.834	0.948	0.033	0.042	0.053	0.043
C_{11}	1.028	1.144	1.274	0.056	0.069	0.085	0.070	1.569	1.790	2.019	0.072	0.090	0.113	0.092
C_{12}	0.896	1.035	1.197	0.049	0.062	0.080	0.064	0.823	0.963	1.119	0.038	0.049	0.062	0.050
C_{13}	0.595	0.665	0.745	0.032	0.040	0.050	0.041	0.356	0.396	0.449	0.016	0.020	0.025	0.020

Source: own work

RESULTS AND DISCUSSION

We normalized the importance weights of criteria by making the sum of the weight values equal to "1" and found the rankings of each criteria and sub-criteria for both exporters and importers separately (Table 6).

Table 6. Comparisons of the criteria and sub-criteria rankings

Criteria	Sub-criteria	Export Normalized weights Criteria	Sub-criteria	Ranking Criteria	Sub-criteria	Import Normalized weights Criteria	Sub-criteria	Ranking Criteria	Sub-criteria
R-A	C_1	0.17884	0.02304	3	13	0.13004	0.01550	3	13
	C_2		0.04601		8		0.03876		8
	C_3		0.06275		6		0.04215		6
	C_4		0.04705		7		0.03363		9
C-E	C_5	0.60489	0.03383	1	12	0.66858	0.01998	1	12
	C_6		0.11970		3		0.16150		3
	C_7		0.03794		11		0.02655		10
	C_8		0.13851		2		0.19415		2
	C_9		0.27492		1		0.26641		1
L-E	C_{10}	0.21627	0.04432	2	9	0.20138	0.04213	2	7
	C_{11}		0.06900		4		0.09026		4
	C_{12}		0.06280		5		0.04885		5
	C_{13}		0.04015		10		0.02014		11

Source: own work

It was revealed in the scope of the study that E-C was given the primary importance with a weight of 0.60 for exporters and 0.67 for importers while the secondary importance was given to L-E (0.22 for exporters, 0.20 for importers) and lastly to R-A (0.18 for exporters and 0.13 for importers) among the main factor groups. Although their rankings are the same, the importance weights of the main factors differ according to exporters and importers.

Findings show that the first three most effective sub-criteria in international commercial terms selection decisions are cost of transportation, cost of goods and mode of payment, respectively and there is no difference concerning the rankings for both exporters and importers. The costs involve not only the freight charges but also the value of the goods and payment terms. Thus, consistent with the results of Suraraksa et al.'s [2020] study, we argue that the companies consider mostly cost related factors while selecting the terms. Since the nature of the trade terms is about sharing the responsibilities of cost and risks between the parties, not surprisingly risk sub-criteria is found to be the fourth factor after the cost related factors for both exporters and importers. Similar to many studies [Malfliet 2011, Bergami 2013] we confirm that risks have a crucial impact on the selection of the terms. However, some studies reveal that country risk has a moderate effect [Yaakub, Szu 2017] and duration for risk taking has a lower effect [Suraraksa et al. 2020]. Another important sub-criteria is the customs/ bureaucracy which ranks fifth for both exporters and importers. Similarly, in international commercial terms selection, Suraraksa et al. [2020] revealed that the international trade laws factor ranks fifth while Yaakub and Szu [2017] found that tariff classification and government regulation are the primary external factors rank after freight and transport issues. We emphasize that companies should take into account additional responsibilities that may arise from customs processes and procedures, particularly in the foreign markets while selecting the terms. We suppose that failure to meet these responsibilities may result in additional costs in terms of time and money in foreign trade operations. The impact of relations with customers/suppliers which refers to the trust and negotiation between buyers and sellers found to be moderate. This finding is inconsistent with the study of Suraraksa et al. [2020] that revealed it has lower effects. We argue that long-term relations in international trade develop trust between parties, but the terms selections should be determined within the framework of written agreements, not verbal negotiations. The mode of transportation was determined as one of the lowest influential factors for both exporters and importers. Conversely, some studies stated that the mode of transportation is one of the effective factors that should be taken into account [Malfliet 2011, Yaakub and Szu 2017]. Our findings may be due to the decision makers perceiving the selection of the right term according to the mode of transport as a rule, rather than a criterion. We notice that not every term is used for every mode of transport, but we argue that the factors previously mentioned are more effective. Firm size is found to be the lowest effective factor. On the other side, some studies indicated that small-sized firms behave more amateurish in their terms selection decisions [Malfliet 2011]. We suppose that rather than the firm size, staff characteristics related to knowledge and the experience concerning the trade activities play an influential role in this regard.

Four factors which are “relations with forwarding agents, type of goods, complexity of transportation and distance” differ according to importers and exporters in their terms selection decisions. Distance is found to be more influential for exporters while type of goods for importers. However, Rosal [2016] stated that the distance has only a statistical effect on imports. Another finding of our study is that exporters give more weight to relations with forwarding agents than the complexity of transportation while importers have opposite views on this point. These findings may be a result of Turkey's imports from countries such as China and Russia and the fact that around 50% of its exports are carried out with relatively close EU countries with higher competition. Thus, we suppose that Turkish exporters may carry out different terms policies with their long distance partners and prefer to deliver goods with forwarding agents with whom they have good relations. On the other hand, importers should consider the responsibilities of costs and risks due to the type of goods and complexity of transportation to find the best mode to receive them smoothly.

CONCLUSIVE REMARKS

In this study, international commercial terms selection decisions that play an important role in foreign trade operations were discussed from the perspective of importers and exporters, and the gap related to the subject in the literature was aimed to be filled. The results were obtained with FAHP, one of the multi-criteria decision-making methods that minimize the uncertainties of the decisions. We concluded that cost-related factors are the most influential ones and apart from a few factors, there is no significant divergence between terms selection decisions of importers and exporters. We suppose that the differences in terms selections between importers and exporters are due to the dissimilarities in competition conditions in foreign markets and product groups. The small sample size and the sample consisting of companies operating in various sectors in a particular region are among the limitations of the study. We suppose that the factors determined in this study will contribute to future studies by analyzing with a larger sample in different regions using different analysis methods.

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REFERENCES

Barney J., 1991. Firm resources and sustained competitive advantage, Journal of Management, 17, 1, 99-120, http://doi.org/10.1177/014920639101700108

Baslangic S.Ö., 2015. Main features of changes in Incoterms 2010, Manas Journal of Social Studies, 4, 5, 73-84. https://dergipark.org.tr/tr/download/article-file/577270

Bello D.C., Briggs F, 2009. Global channels of distribution, in Kotabe, M. and Helsen, K. (Ed.), International Marketing, Sage Publications, London, 398-412.

Bergami R., 2012. Incoterms 2010: The newest revision of delivery terms. Acta Universitatis Bohemiae Meridionalis, 15, 2, 33-40. http://repec.ef.jcu.cz/acta/article/download/420/412

Bergami R., 2013. Managing Incoterms 2010 risks: Tension with trade and banking practices, International Journal of Economics and Business Research, 6, 3, 324-338, http://doi.org/10.1504/ijebr.2013.056126

Blanco E.E., Ponce-Cueto E., 2015. Modeling the cost of international trade in global supply chains, Massachusetts Institute of Technology, ESD Working Paper Series, ESD-WP-2015-05, 1-22. https://dspace.mit.edu/handle/1721.1/97645

Buckley J.J., 1985. Fuzzy hierarchical analysis, Fuzzy Sets and Systems, 17, 3, 233-247, http://doi.org/10.1016/0165-0114(85)90090-9

DiMaggio P.J., Powell W.W., 1983. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields, American Sociological Review, 48, 2, 147-160, http://doi.org/10.2307/2095101

Duncan R.B., 1972. Characteristics of organizational environments and perceived environmental uncertainty, Administrative Science Quarterly, 17, 3, 313-327, http://doi.org/10.2307/2392145

Erramilli M.K., 1992. Influence of some external and internal environmental factors on foreign market entry mode choice in service firms, Journal of Business Research, 25, 4, 263-276, http://doi.org/10.1016/0148-2963(92)90024-6

Hien N., Laporte G., Roy J., 2009. Business environment factors, Incoterms selection and export performance, Operations and Supply Chain Management, 2, 2, 63-78, http://doi.org/10.31387/oscm040017

Hsieh, T. Y., Lu, S. T., Tzeng, G. H. 2004. Fuzzy MCDM approach for planning and design tenders selection in public office buildings, International Journal of Project Management, 22, 7, 573-584. https://doi.org/10.1016/j.ijproman.2004.01.002

ICC, 2021a. Incoterms® 2020. https://iccwbo.org/resources-for-business/incoterms-rules/incoterms-2020/ (01/30/2021)

ICC, 2021b. Incoterms® rules history. https://iccwbo.org/resources-for-business/Incoterms-rules/Incoterms-rules-history/ (01/30/2021)

Lee A.H., Chen W.C., Chang C.J., 2008. A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan, Expert Systems with Applications, 34, 1, 96-107, http://doi.org/10.1016/j.eswa.2006.08.022

Malfliet J., 2011. Incoterms 2010 and the mode of transport: How to choose the right term. Proceedings - Management Challenges in the 21st Century: Transport and Logistics: Opportunity for Slovakia in the Era of Knowledge Economy 163-179. https://biblio.ugent.be/publication/1212622

Rosal I.D., 2016. Factors influencing the choice of delivery terms used in Spanish seaborne container trade, International Journal of Shipping and Transport Logistics, 8, 3, 318-333, http://doi.org/10.1504/ijstl.2016.076261

Saaty T.L., 2008. Decision making with the analytic hierarchy process, International Journal of Services Sciences, 1, 1, 83-98, http://doi.org/10.1504/IJSSci.2008.01759

Sari E.B., 2020. Recovery alternatives decision by using fuzzy based preference selection index method, Logforum, 16, 1, 171-181, http://doi.org/10.17270/J.LOG.2020.386

Shangina O.A., 2007. Main factors in choice of delivery terms. A multiple case study of Japanese and Russian importers in seafood trade with Norway, master's thesis, Department of Social and Marketing Studies, Norwegian College of Fishery Science, University of Tromsø. https://munin.uit.no/handle/10037/969

Stapleton D.M., Pande V., O'Brien D., 2014. EXW, FOB or FCA? Choosing the right incoterm and why it matters to maritime shippers, Journal of Transportation Law, Logistics & Policy, 81, 3, 227-248. https://trid.trb.org/view/1350272

Suraraksa J., Amchang C., Sawatwong N., 2020. Decision-making on Incoterms 2020 of automotive parts manufacturers in Thailand, The Journal of Asian Finance, Economics and Business, 7, 10, 461-470, http://doi.org/10.13106/jafeb.2020.vol7.no10.461

Williamson O.E., 1981. The economics of organization: The transaction cost approach, American Journal of Sociology, 87, 3, 548-577, http://doi.org/10.1086/227496.

Yaakub S., Szu L.Y., 2017. Factors influencing the choice of Incoterms among Malaysian manufacturers. Proceedings - 6th International Conference on Social Science Research 1-11. http://repo.uum.edu.my/23069/

Yaakub S., Szu L.Y., Arbak S., Halim N.A., 2018. Incoterms selection factors and its effect on export performance, Journal of Advanced Research in Business, Marketing and Supply Chain Management, 2, 1, 9-18. https://www.jarims.aibma.org/images/vol22018/sbppg9-18.pdf

Yilmaz M., Ozken A., Sahin N., 2011. The comparative analysis of Incoterms 2000 and 2010 and deficiencies in their implementations in Turkey, Journal of Yasar University, 23, 6, 3814-3825. https://dergipark.org.tr/tr/pub/jyasar/issue/19135/203055

Yiu D., Makino S., 2002. The choice between joint venture and wholly owned subsidiary: An institutional perspective, Organization Science, 13, 6, 667-683, http://doi.org/10.1287/orsc.13.6.667.494

Zadeh L.A., 1965. Fuzzy sets, Information and Control, 8, 3, 338–353, http://doi.org/10.1016/S0019-9958(65)90241-X

Zadeh L.A., 1983. Linguistic variables, approximate reasoning and dispositions, Medical Informatics, 8, 3, 173-186, http://doi.org/10.3109/14639238309016081

CZYNNIKI WYBORU WARUNKÓW INCOTERMS® WŚRÓD EKSPORTERÓW I IMPORTERÓW – APLIKACJA (FAHP) DLA ROZMYTEJ ANALIZY HIERARCHICZNEGO PROCESU

STRESZCZENIE. Wstęp: Są dostępne badania analizujące jakie czynniki i w jaki sposób wpływają na wybór warunków Incoterms®, jednak istotność wagi poszczególnych czynników osobno dla eksporterów i importerów nie są należycie zbadana. Praca ta ma na celu uzupełnienie tej luki w badaniach poprzez zbadania wpływu wyboru warunków Incoterms® oraz sprawdzenie czy są różnice pomiędzy importerami i eksporterami. W tym celu przeprowadzone analizę wagi poszczególnych czynników dla obu grup.

Metody: Stworzono model koncepcyjny oparty na różnych podejściach, poprzednich badaniach oraz decyzjach ekspertów. Dane zostały zebrane poprzez pocztę mailową od 19 eksporterów Incoterms®, wśród których 9 jest importerami, a 10 eksporterami. Następnie przeprowadzono analizę Fuzzy Analytical Hierarchy Process (FAHP) przy zastosowaniu średniej geometrycznej w celu określenia istotności wag poszczególnych kryteriów.

Wyniki: W wyniku przeprowadzonej analizy stwierdzono, że najistotniejszym czynnikiem wpływającym na wybór INCOTERMS zarówno dla eksporterów, jak i dla importerów są koszty transportu, podczas gdy najmniej istotnym czynnikiem jest wielkość firmy. Istotność czterech czynników: relacje ze spedycjami, typ wyrobów, kompleksowość transportu oraz odległość, różniła się w zależności od grupy. Relacje ze spedytorami oraz odległość były istotniejszym czynnikiem dla eksporterów, podczas gdy typ wyrobów i kompleksowość transportu miały większe znaczenie dla importerów.

Wnioski: W trakcie badania ustalono, że czynniki związane z kosztami mają istotniejszy wpływ na podejmowane decyzje oraz, że z kilkoma wyjątkami, nie ma istotnych różnic pomiędzy czynnikami wpływającymi na decyzję pomiędzy importerami a eksporterami. Mała próba badawcza złożona dodatkowo z przedsiębiorstw operujących w różnych sektorach gospodarki były głównymi ograniczenia tych badań. Niemniej mogą one stanowić podstawę do dalszych pogłębionych badań w tym zakresie.

Słowa kluczowe: Incoterms®, FAHP, eksport, import, handel zagraniczny

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ORIGINAL PAPER

HYPOTHESES CONCERNING COMPLEXITY SURGES IN MODERN AND FUTURE INDUSTRIAL INFORMATION SYSTEMS

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ABSTRACT. **Background:** This paper has the central aim to provide an analysis of increases of system complexity in the context of modern industrial information systems. An investigation and exploration of relevant theoretical frameworks is conducted and accumulates in the proposition of a set of hypotheses as an explanatory approach for a possible definition of system complexity based on information growth in industrial information systems. Several interconnected sources of technological information are investigated and explored in the given context in their functionality as information transferring agents, and their practical relevance is underlined by the application of the concepts of Big Data and cyber-physical, cyber-human and cyber-physical-cyber-human systems.

Methods: A systematic review of relevant literature was conducted for this paper and in total 85 sources matching the scope of this article, in the form of academic journals and academic books of the mentioned academic fields, published between 2012 and 2019, were selected, individually read and reviewed by the authors and reduced by careful author selection to 17 key sources which served as the basis for theory synthesis.

Results: Four hypotheses (H1-H4) concerning exponential surges of system complexity in industrial information systems are introduced. Furthermore, first foundational ideas for a possible approach to potentially describe, model and simulate complex industrial information systems based on network, agent-based approaches and the concept of Shannon entropy are introduced.

Conclusion: Based on the introduced hypotheses it can be theoretically indicated that the amount information aggregated and transferred in a system can serve as an indicator for the development of system complexity and as a possible explanatory concept for the exponential surges of system complexity in industrial information systems.

Key words: complexity, complex systems, industrial systems, information, cyber-physical systems, Big Data.

INTRODUCTION

Today, it is possible to identify the increasingly strong impact of accelerating technological developments and its changes. The rising potency of technology in areas like general computer processing power, sensors, Artificial Intelligence AI, machine learning, robotics and automation technology often breaks through the limits of the anticipated growth rates and manifests in modern interconnected approaches for value creation, for example smart manufacturing, the internet of things or cyber-physical systems [McAfee, Brynjolfsson, 2014; Törngren, Sellgren, 2018]. Underlying drivers for the possible exponential development of technology are the often mentioned "Moore´s Law" which shows that the number of transistors per microchip increased by the power of 10 in the last 40 years , "Metcalf´s Law" can also be mentioned which states that computing hardware becomes more powerful, small and more embedded over time and the vastly increased and ever increasing speed of technology adoption by users, as well as "Butter´s Law of photonics", which says the amount of data one can transmit using optical fiber is doubling every nine months, "Rose´s Law", which states that the number of qubits in quantum computers is growing exponentially and the concept of "Big

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Data" referring to the exponential growth of information generated by modern systems [Gimpel, Röglinger, 2015]. The potentially exponential nature of technological and informational growth is often primarily ascribed but not limited only to information technologies and it is possible to identify a wide variety of converging technological fields where exponential growth can be observed [Nagy et.al, 2012]. These developments underline the potential of exponential technological and informational growth as an autocatalytic process to cause significant technological paradigm shifts which often lead to severe changes in systems impacted and supposedly governed by human behaviour, often by making systems more interconnected, non-linear and as a result more complex for the linearly thinking human mind to comprehend and to predict and therefore at the same time cause and effect for its central characteristic of increasing system complexity [McAfee, Brynjolfsson, 2014, Gimpel, Röglinger, 2015, Törngren, Sellgren, 2018, Spencer, 2017]. The increasing complexity of human socio-technical systems in relation to exponential digital technologies can be regarded as a crucial impact factor for human society. It is defined by many researchers as the most essential characteristic of modern society since technological and economic advances ultimately lead to an increasingly interconnected and complex system of systems. [Mourtzis et.al, 2019, Duan et. al, 2019, Freund, Al-Majeed, 2020]. The idea of the central importance of increasingly technologized and complex systems is supported by the thoughts of many researchers who regard obtaining an understanding of complex systems as essential for handling the design and transformation process of modern complex engineered systems of organizational value creation [Törngren, Sellgren, 2018]. Consequently, obtaining an in-depth understanding of the nature of possible surges in system complexity and their possible connection to an exponentially progressing development of technology and information can therefore be regarded as an important aspect to understand the transformative impact of these developments on the value added for human society in general and for individual systems in the sphere of engineering and system design in particular. [Horvath, Geritsen, 2012, Freund, Al-Majeed, 2020]. This paper has the central aim to provide a first theoretical considerations through the introduction of a set of hypotheses concerning the interconnected nature of information growth and complexity as the origin of increases of system complexity. This is achieved through reviewing and analysing current relevant literature in relevant research fields in a first step. In a second step the findings are applied to networks of sources of technological information in the context of modern systems of industrial information technologies, like cyber-physical, cyber-human and cyber-physical-cyber-human systems. This is achieved by establishing a set of assumptions and definitory notations concerning the nature of technology and the influence of technological growth on the complexity of a given system in the sections to follow. This allows the construction of a logically consistent and coherent argument that proposes that technology and information can be regarded as indicator for system complexity as a conclusion to this article.

METHOD

The definitions and concepts presented in this study are largely based on secondary sources and research, meaning a systematic foundational review of relevant literature. Information on the core research complexes "information", "complexity" and "systems" is mostly available in (academic) books, professional journals, academic journals, reports or internet sources, mainly published in the research fields of philosophy, information technology, physics, engineering and business studies, as demonstrated by the following sections of this chapter. This paper quotes a wide range of sources in the form of basic theoretical considerations, expressed though the introduction and discussion of relevant definitions to allow a coherent pursuit of the previously mentioned aim of research through summarizing and synthesizing previous sources to develop a set of hypotheses out which directions for new future research may be derived. In total 85 sources matching the scope of this article, in the form of academic journals and academic books of the mentioned academic fields, published between 2012 and

2020, were selected, individually read and reviewed by the authors and reduced by careful author selection to 17 key sources which are contributing to the theoretical foundation to this article.

A DEFINITION OF INFORMATION

To avoid potential misunderstanding it is now necessary to provide the definitions for the terms of "information", "data" , "agent", "environment of an agent" and the "relationship of data and information".

It is necessary to state that the term "Information" is itself to be regarded as a polymorphic phenomenon and a poly-semantic concept with many possible meanings. The term "information" is now defined for this paper according to the notions established by Meijer under the assumption that information is generated through the interactions of a set of communicating agents. The term information shall therefore be defined as "(…) *anything that an agent can sense, detect, observe, perceive, infer or anticipate*" [Meijer, 2013]. An agent shall be defined according to Meijer as:

"(…) *a description of an entity that acts on its environment. Note that agents and their environments are also information, as the can be perceived by other agents. An agent can be an electron, an atom, a molecule, a cell, a human, a computer program, a market, an institution, a society, a city, a country or a planet. Each of these can be described as acting on their environment, simply because they interact with it*" [Meijer, 2013].

The idea of the environment of an agent is again defined according to Meijer as the following statement. "*The environment of an agent consists of all the information interacting with it*" [Meijer, 2013]. The environment of an agent shall from this point onwards be regarded as a synonym of the term "system". The term "data" is now described as the basic individual items of information, obtained and conserved through observation and data storage but devoid of an attributed context. There are many kinds of data existing, like sensory data, geographical data or network data [Duan et.al, 2019]. As a logical consequence of the presented definitions of the term data and information the relationship of data and information can be described as the following concept: Data + *storing / recovering by an agent / set of agents in a given environment→ Information.* Consequently, any form of stored and recoverable data through the means of an agent in a system shall be regarded as information. This results in the core assumption that if data is stored and recoverable in any given form it shall be regarded as information. It can now be concluded that data and information represent the building blocks for any technology. The relationship of data, information and technology can be defined on the basis for Hypothesis 1 (H1).

Agent based information and data hypothesis

(H1) The amount of information in a system is represented by the amount of data stored and recoverable by agents contained in the system.

The next chapter now provides further information on how information could be generated via the introduction of different sources of information.

TECHNOLOGICAL SOURCES OF INFORMATION

To further expand on the notions of H1, it is possible to classify the following agents and agent combinations as major sources of information under the assumptions of a modern, interconnected technological environment or system [Based on: Duan et.al, 2019, Gimpel, Röglinger, 2015]. The following sources of information in the form of agents are hypothesized for this paper:

- Machine generator (M): Autonomously generated by machine activity through sensors and instruments, for example the amount of information generated and stored by a smart factory or an artificial intelligence.
- Machine-machine generator constellation (MC): The combination of autonomously

generated by machine activity through sensors and instruments that processed by another machine, for example the amount of information generated and stored by a smart factory that is again processed by an artificial intelligence.

- Human generator (H): Generated by human activities, for example a poem memorized by the human brain that generated the poem.
- Human-human generator constellation (HC): Generated by human activities, for example a poem memorized by the human brain that generated the poem and that is also memorized by the other human brains.
- Human-machine generator (HM): The combination of human activity and autonomous machine activity, for example uploading a photo of the poem to the internet with an app on a smartphone device.
- Human-machine generator constellation (HMC): The alternating process of generating and processing information by humans and machines in a tandem, for example uploading a photo of the mentioned poem to the internet with a smartphone device which gets processed by an algorithm to generate advertisements for an app on the smartphone of the user who uploaded the photo, which stimulates the user to buy and download the app.

The described sources of information are indicating that different types of agents represent collections of basic functions which can be placed in an interconnected relation in the form of a heterogenous network system where their position and inherent internal functioning leads to different flows information being created and stored in the system. Any of such systems shall be named industrial information system. Based on (1)-(6) and H1, Hypothesis 2 (H2) results.

Agent based information flow hypothesis

(H2) Any type of information flow in a given industrial information system can be explained by a given combination of sources of information positioned in a network constellation in the form of agents.

A system is now defined as the concept of portioning an operating entity into a set of interacting units with specific relationship among them. A system therefore represents not only physical objects but also immaterial concepts like information and can maintain both system external and system internal interactions [Jalil & Perc, 2017, Mourtzis et.al, 2019]. Consequently, for this paper a system is regarded as an open system. Based on this statement a system is defined as a network of a given number of agents which are characterized by the ability to interact with each other and the system external world by transferring, storing and circulating information in the network topology and which are assumed to be representable by the mentioned sources of information (1)-(6) as expressed in H1 and H2. A network therefore comprises a system of at least two elements that are connected and that exchange information between them and the system external world. One example for such a network could be any kind of machine-machine generator feedback loop. Figure 1 illustrates the core assumptions made in H1 and H2 through the establishment of a hypothetical network system in which three machine-generator agents circulate information in a MC constellation.

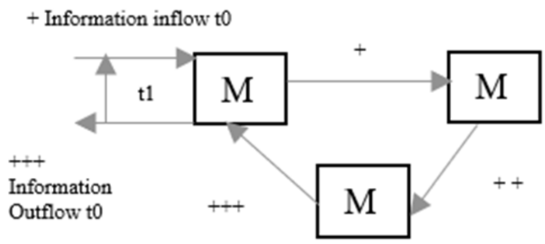

Fig. 1. MC constellation network

Figure 1 shows, that any type of network consisting of technology sensitive agents is expected to lead to a cascadic growth of circulated information if a non-distorted feedback loop is in place. H1 is now accumulating in the practical context in the concepts of cyber-physical systems (CPS), cyber-human systems (CHS) and cyber-physical-cyber-human systems (CPCHS). These concepts are briefly described in the next section to underline the practical relevance of the systemic combination of the sources (1) to (6).

SOURCES OF INFORMATION IN THE CONTEXT OF INDUSTRIAL INFORMATION SYSTEMS

The concept of cyber-physical systems (CPS), cyber-human systems (CHS) are representative concepts of the many upcoming and innovative practical manifestations of different networks topologies with different agent combinations in the context of industrial information systems. A CPS can be described as a new generation of systems that blend the knowledge of physical artifacts and engineered systems due to integrated computational and physical capabilities. CPS are established in order to produce a global intelligent behavior featuring autonomy, self-control and self-optimization and are expected to be a decisive driving force for advances in different applicative domains including manufacturing control and for opening up new areas of innovation [Horvarth, Gerritsen, 2012, Gaham et. al, 2013, Törngren, Sellgren, 2018, Mourtzis et.al, 2019]. A CHS can be defined as the concept that humans have an increasingly interconnected relationship with computer systems and represents an integral factor to establish a functioning CPS. This development is exemplified in the increasing human-machine interaction through new computer systems, the internet, mobile devices, improved sensor technology and possible future applications like brain-machine interfaces and leads to human lives and decision-making increasingly merging with technology [Gimpel, Röglinger, 2015, Freund, Al-Majeed, 2020]. CPS and CHS are expected to continuously co-evolve and converge to human-in-the-loop cyber-physical systems or cyber-physical-cyber-human systems (CPCHS) as they are directly linked to each other [Garcia et.al, 2019]. The provided definitions also make it evident, that a CPS/ CHS/ CPCHS represents a specific network topology with an agent combination of the mentioned sources (1)-(6) that manifests in a practical context of complex economic value creation, for example intelligent manufacturing infrastructure, and therefore shows that the merging of the physical and virtual is already a reality that comes to life. Figure 2 now illustrates the basic layout of a completely integrated cyber-physical-cyber-human system.

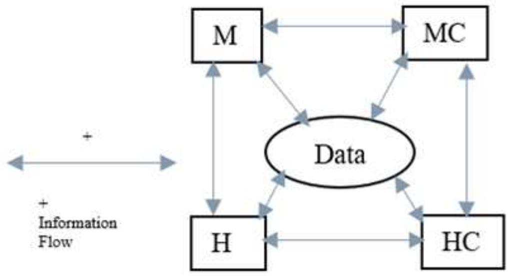

Fig. 2. Basic Layout CPCHS

Figure 2 shows that a CPCHS can be described as a network of human, machine / physical object (M, MC, H, HC) and data interaction enabled through a rich multi-directional information flow in a network topoplogy [Garcia et.al, 2019]. As a result, the illustrated structure of a CPCHS is characterized by the characteristics of complexity, volatility, uncertainty and ambiguity as it is characterized by highly interconnected constellation of agent types [Gimpel & Röglinger, 2015, Mourtzis et. al., 2019]. This concept can now be applied to the basic structure of Figure 1 and the proposed information sources (1)-(6). Figure 3 now provides an example CPCHS model.

Figure 3 shows, that any type of CPCHS can be expected to lead to a cascadic growth of circulated information if an undistorted feedback loop is in place [Jalil & Perc, 2017]. This now allows the introduction of hypothesis 3(H3).

Cascadic growth of information in industrial information systems hypothesis

(H3) Any type of information flow in a given industrial information system in the form of CPS, CHS or CPCHS can be expected to generate cascadic growth of circulated information if an undistorted feedback loop is in place.

After presenting hypothesis H3 it appears now necessary to provide further information on the concept of exponential increases in generated information through introducing and applying the concept of "Big Data" to the notions of H1-H3.

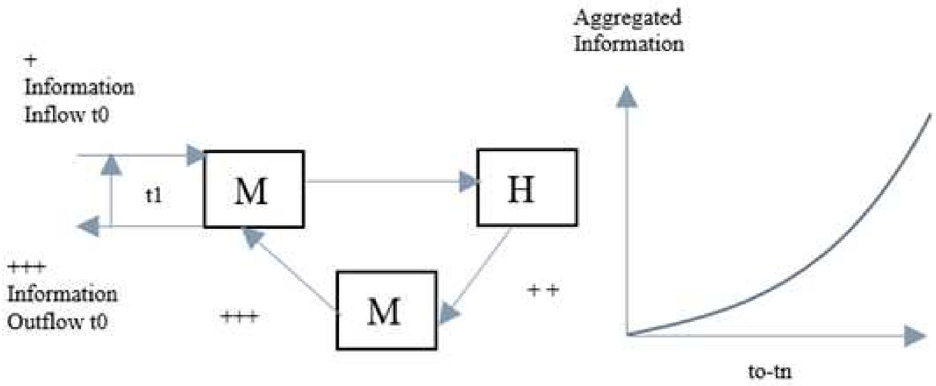

Fig. 3. CPCHS Example

THE CONCEPT OF "BIG DATA" APPLIED TO COMPLEXITY THROUGH SHANNON ENTROPY

Due to the already in the context of CPCHS introduced characteristics of velocity, volume and variety, big data is also defined as a "complex polymorphic object" in the ranges of exabytes and beyond which represent accumulations of extensive datasets which are highly complex and hard to process [Riahi, 2018]. Since CPCHS share these characteristics with the concept of "Big Data" H2 and H3 are supported by the notion of a CPCHS also an entity characterised by the concept of a "complex polymorphic object". The concept of "Big Data" is underlined by the amount of data of 175 zetabytes that is projected to be generated world-wide in the next years up until 2025, which represents a rapid increase to the amount of 2 zetabytes generated in 2010 and the amount of 26 zetabytes generated in 2017, which represents an assumed 87.5 fold increase in 15 years (2010-2025) [Statista, 2018]. These numbers also underline the steady increases in mass data storage capacities of modern information systems (for example the increases in hard disk storage capacity from a few megabyte to several terabyte in the last two decades through the convergence of continuously improving physical and mass storage systems into cloud data systems [Gimpel, Röglinger, 2015]. Based on this it is now possible to explore how these developments concerning the capability of modern systems to aggregate information can be linked to the notion of complexity.

COMPLEXITY AS INFORMATION

It is possible to introduce the idea of a common dominator of complexity by linking the notion of complexity with notion of system entropy. The entropy of a system is in this context regarded as a measure of disorder in the system. Additionally, the concept of energy entropy can directly be linked to the concept of Shannon Entropy, which measures the information content of a message [Li, 2016, Mourtzis et. al, 2019]. This shows that complexity, when brought into the context of industrial information systems, appears to have a common metric for complexity in the form of energy translated to information under the conception of Shannon Entropy. The notion of complexity as information contained in a system is also supported by variety of researchers in the field [Terrazas et.al, 2015, Törngren, Sellgren, 2018]. The entropy of a system of messages is defined by Shannon as described in equation (1).

$$(1) \qquad H(P) = -\sum_{i \in A} pi \; log2 \; pi$$

In this formula pi is the probability of message i in A, which can be identified exactly as the formula for Gibb's entropy in physics. The use of base-2 logarithms ensures that the code length is measured in bits (binary digits).

It can now be seen that the communication entropy of a system is maximal, and the predictability is minimal when all the messages have equal probability and thus are typical [Li, 2016]. Consequently, Shannon Entropy can be regarded a measure of the information content of data, where information content refers to what the underlying data could contain, as opposed to the more intuitive notion of what it does contain. Therefore, Shannon Entropy is essentially about quantifying predictability or conversely randomness in information [Mourtzis et. al, 2019].

INFORMATION AS A METRIC FOR COMPLEXITY

The degree of complexity of system shall now be determined through Shannon Entropy and therefore by the aggregated amount of information contained in the system with an increase of system complexity resulting from any increase in the amount of information transferred and aggregated in the system and vice versa [Terrazas et.al, 2015]. The already introduced concept of Shannon Entropy can serve as an explanatory approach to why the amount information contained in a system can serve as a metric for complexity. The concept of Shannon Entropy can additionally be linked to the context of complex systems through principle of maximum entropy which states that that complex systems tend to maximize entropy production under their present constraints while evolving over time [Hanel et. al, 2014, Jalil & Perc, 2017].

Hypothesis 4 (H4) now results.

Complexity of industrial information systems hypothesis.

(H4) The complexity of an industrial information system is defined by the amount of information contained and produced in the system with more information leading to more complexity and vice versa.

Figure 4 now summarizes the assumptions made in H1-H4. Figure 4 now summarizes the assumptions made in H1-H4.

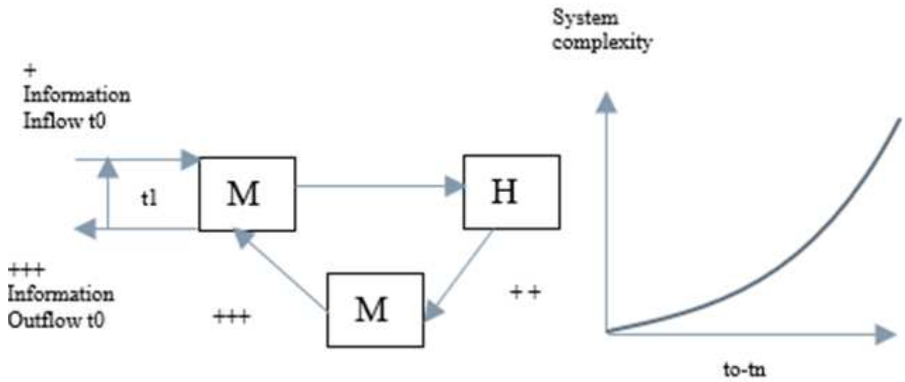

Fig. 4. Development of Complexity in a CPCHS

CONCLUSIONS

The results of this paper show that it is possible to construct a theoretical connection between informational growth and the growth of system complexity. Based on H1 – H4 it can be theoretically indicated that the amount information aggregated and transferred in a system can serve as an indicator for the development of system complexity and as a possible explanatory concept for the exponential surges of system complexity in industrial information systems, like CPCHS, CPS or CHS. This paper provides furthermore first foundational ideas for a possible approach to potentially describe, model and simulate complex industrial information systems based on network, agent-based approaches and the concept of Shannon entropy and thus underlines the potential and the possible applicability of the proposed argumentation in both theoretical and practical contexts. Consequently, it appears necessary to further explore the validity of the hypotheses proposed by conducting further research for example through more specified literature review, system simulations or case study research, especially in the area of the notion of complexity and the practical applications of complex industrial information systems in the form of CPS, CHS and CPCHS.

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REFERENCES

Duan et. al., 2019. Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda, International Journal for Information Management, 48, http://doi.org/10.1016/j.ijinfomgt.2019.01.021

Freund L., Al-Majeed S., 2020. Cyber-Physical Systems as Sources of Dynamic Complexity in Cyber-Physical-Systems of Systems, 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), Sakheer, Bahrain, 2020, 1-5, http://doi.org/10.1109/3ICT51146.2020.9312015

Gaham M., Bouzouia B., Achour N., 2015. Human-in-the-Loop Cyber-Physical Production Systems Control (HiLCP2sC): A Multi-objective Interactive Framework Proposal. In: Borangiu T., Thomas A., Trentesaux D. (eds) Service Orientation in Holonic and Multi-agent Manufacturing. Studies in Computational Intelligence, 594. Springer, Cham. http://doi.org/10.1007/978-3-319-15159-5_29

Garcia et. al, 2019. A human-in-the-loop cyber-physical system for collaborative assembly in smart manufacturing, Procedia CIRP, 81, 600-605, http://doi.org/10.1016/j.procir.2019.03.162

Gimpel H., Röglinger M., 2015. Digital transformation: changes and chances, Project Group Business and Information Systems Engineering (BISE) of the Fraunhofer Institute for Applied Information Technology FIT, https://eref.uni-bayreuth.de/id/eprint/29908

Hanel et. al., 2014. How multiplicity determines entropy and the derivation of the maximum entropy principle for complex systems, Proc Natl Acad Sci U S A., 111, 19, 6905–6910, http://doi.org/10.1073/pnas.1406071111.

Horvarth I. Gerritsen B., 2012. Cyber physical systems: concepts, technologies and implementations, Proceedings of TMCE 2012, May 7–11, 2012, Karlsruhe, Germany, ISBN 978-90-5155-082-5.

Jalili M., Perc M., 2017. Information cascades in complex networks, Journal of Complex Networks, 5, 665–693, http://doi.org/10.1093/comnet/cnx019

Li H., 2016. Information Efficiency of Communications for Networked Control in Cyber-Physical Systems: When Carnot Meets Shannon, 2016 IEEE 55th Conference on Decision and Control (CDC), 2016, 12-14, http://doi.org/10.1109/CDC.2016.7798536

McAfee A., Brynjolfsson E., 2014. The second machine age, W.W. Norton & Company

Meijer D., 2013. Information: What do you mean?, Syntropy Journal Syntropy 2013 (3): 1-49 ISSN 1825-796

Mourtzis et. al., 2019. Modelling and quantification of industry 4.0 manufacturing complexity based on information theory: a robotics case study, International Journal of Production Research, 57,22, 2019. http://doi.org/10.1080/00207543.2019.1571686

Nagy et. al., 2012. Statistical Basis for Predicting Technological Progress, Statistical Basis for Predicting Technological Progress. PLoS ONE, 8, 2, http://doi.org/10.1371/journal.pone.0052669

Riahi et.al., 2018. Big Data and Big Data Analytics: Concepts, Types and Technologies, International Journal of Research and Engineering, 5, 9, http://doi.org/10.21276/ijre.2018.5.9.5

Spencer D., 2016. Work in and beyond the Second Machine Age: the politics of production and digital technologies, Work, employment and society, 31, http://doi.org/10.1177/0950017016645716

Terrazas et. al., 2015. Complexity measurement based on information theory and Kolmogorov complexity, Artificial Life, 21, 2, 1-20

Törngren M. Sellgren U., 2018. Complexity Challenges in Development of Cyber-Physical, Systems, Springer International Publishing AG, part of Springer Nature 2018, 2018,478-503, http://doi.org/10.1007/978-3-319-95246-8_27

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ORIGINAL PAPER

THE SYSTEM OF DATE LABELLING IN THE FOOD SUPPLY CHAIN – THE WEAK LINKS FROM THE PERSPECTIVE OF FINAL CONSUMERS

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ABSTRACT. **Background:** Open date labelling influences the role that final consumers play as actors in the food supply chain in waste prevention and reduction. The aim of this study was to examine the date labelling system from the perspectives of consumers' experience taking into consideration both technical aspects of date labels readability as well as their understanding of the concept of the shelf-life dates.
Methods: The face to face interview method (n=1145) was applied with the use of the interview questionnaire. Research was conducted in Poland.
Results: Despite declared interest in date labelling, consumers of food products experience difficulties with the system in force. Identified problems cover the physical layer of food packaging such as the font size, the presence of information, its readability and accessibility, and the occurrence of two date types on the basis of food quality and safety concept. Problems with correct interpretation of 'use by' and 'best before' dates were more often observed in the group of youths and with vocational education. The difficulties with too small font of the date information were more often claimed by the elderly food buyers.
Conclusions: Actions for improvement should be undertaken by FBO's, legislators and educators in order to achieve economic, environmental and social benefits from clear and consumer-friendly date labelling system. The actions should be matched to a given population group because different sub-groups face separate problems with the dates on food packaging.

Key words: date labelling, use by date, minimum durability date, shelf-life, food packaging, food waste.

INTRODUCTION

A global challenge to reduce food waste has a great potential to improve sustainability of the food supply chains [Bhat and Jõudu 2019, Kowalska 2017]. Food waste contributes to the environmental impact of the food sector. According to FAO data, one-third of all food produced for human consumption is lost or wasted globally, which is equal to ca. 1300 million tons per year [FAO 2019]. Every year almost 90 million tons of food are wasted in the EU countries, which is about 20% of EU food production [Fusions 2016]. Global food waste generates significant negative environmental effects in addition to the unnecessary usage of resources consumed in the manufacture of the wasted food [Krishnan et al. 2020]. The recognition of food waste as a pressing sustainability challenge represents a growing concern in the political agenda of national and international organizations [Lemaire and Limbourg 2019, Papargyropoulou et al. 2014]. The Sustainable Development Goals (SDGs) for sustainable consumption and production aim at halving global food waste at retail and consumer levels as well as reducing food losses along production and supply chains [United Nations 2015]. It is important how the parties in the supply chain (producers, retailers and

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consumers) deal with this information. Several types of initiatives that differ in terms of their aims and characteristics were discussed in literature, including information and capacity building, which focuses most strongly on motivating consumer's food waste avoidance behaviour and strengthening consumer's abilities [Aschemann-Witzel et al. 2017]. Food loss and waste management in all segments of the supply chain requires proper handling of a food product. Often important reason for food disposal is not consuming the product before its expiration. Not understanding the concept of food labelling is related to throwing out unused food. A risk-based approach was developed in the EU according to which perishable food is labelled with the 'use by' date, in contrast to microbiologically stable food products, which are marked with the minimum durability date ('best before'). Recent works show that some people tend to treat minimum durability dates as if they were the 'use by' dates. Confusion over the interpretation of date labels at the consumption stage results in consumer discarding safe and edible food contributing to the global food waste [Patra et al. 2020, Soethoudt et al. 2013]. Considering this, and with half of the global mass of wasted food which is discarded in households, understanding the meaning of shelf-life dates and proper handling of 'best before'-labelled food is crucial in preventing wastage of food [Dobernig and Schanes 2019, Fusions 2016].

Packaging is argued in literature to have a great potential as far as its contribution to sustainable development is concerned. It can contribute to efficient resource utilization in the supply chain, as well as to avoiding product waste by providing sufficient protection and preservation of its content [Lindh et al. 2016]. One of the most important functions of packaging is the communication with consumers and other actors in the supply chain from the manufacturer to the end of life cycle [Grönman et al. 2013]. Food packaging is a carrier of information about a product which includes inter alia open date labelling. Driven by a readable code for retail employees and by consumers open date labeling has been a major benefit at retail in achieving effective stock rotation. It is intended to be understandable in the supply chain both by consumers and individuals who are responsible for the product and for ensuring high product quality and food safety to consumers [Newsome 2014].

Final consumers are the last actors in the food supply chain. Their role is crucial, as their individual preferences and lack of awareness can exacerbate food loss and waste [Toussaint et al. 2021, Bhattacharya and Fayezi 2021]. The role of final consumers as the actors in the food supply chain in food waste prevention and reduction covers several routines and practices such as planning and shopping, maintenance of proper conditions and time of storage, rational consumption and food sharing [Ocicka and Raźniewska 2018]. In the EU the discussion began on the need and justification of 'best before' labelling on some food products [Council of the European Union 2014]. The topic in ambiguous as some studies showed consumer's uncertainty about product freshness or even a higher likelihood of throwing away the product with no 'best before' date [Secondi 2019; Samotyja 2015]. Moreover, dates first appeared on food packages as populations became further removed from food production and their ability to determine product freshness decreased [Newsome 2014]. Therefore it seems that the dates are not necessarily redundant but there are some barriers that stop efficient flow of information in the supply chain to the final consumer. Therefore, the aim of this study was to examine the date labelling system from the perspectives of consumers' experience taking into consideration both technical aspects of food labels readability as well as their understanding of the shelf-life dates concept. This paper is structured as follows. The next section details the methodology providing an explanation of the research approach, subsequent section presents the findings and discussion. Finally, the paper finishes with conclusions with closing remarks.

MATERIAL AND METHODS

The research was conducted in Poland in 2019. The research sample (n=1145) was selected using the quota method (selection criteria: age, sex and place of residence) and met the demand for maintaining the relative representativeness of the research population. The structure of the research sample was presented in Table 1. Respondents declared the systematic purchase of food products. The face to face interview method was applied with the use of the interview questionnaire. It contained 20 questions regarding perception and understanding the date labelling system, perception of health risk related to consumption of food past 'use by' or 'best before' dates and household food-waste behaviour. In the present work the selected issues were presented regarding consumer interest in date labelling and also consumers' experiences and problems they face with the shelf-life labelling. Consumers' understanding and interpretation of date labelling system were also examined.

Table 1. The structure of the research sample

Variable	Characteristics	Percentage (%)
Gender	female	45.3
	male	54.7
Age	under 20	2.2
	20 - 29	17.3
	30 - 39	20.0
	40 - 49	13.4
	50 - 59	14.7
	60+	32.4
Education	vocational	18.2
	secondary	31.1
	bachelor degree	21.7
	master degree	29.0

Source: own work

RESULTS

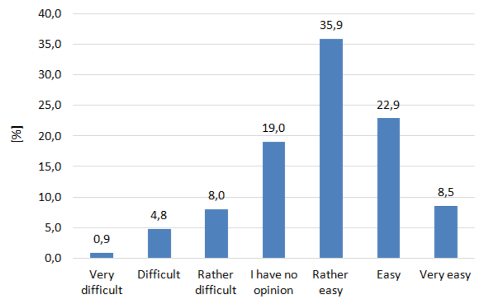
In Table 2 the data about respondents' propensity and circumstances for checking shelf-life dates on food packaging was presented. Nearly 94% of respondents in this study declared checking the shelf-life information. Most often they look for the dates at the point of purchase than before consumption, during a pantry and fridge overview and finally during unpacking of food after purchase. In comparison to women, men less often pay attention to the discussed issue during shopping. One male in ten does not check the dates at all. The behaviour of young people below 20 stands out from the population – one quarter of them do not check the dates printed on the food packaging. The highest interest in reading the date labels was showed among respondents with higher education whereas in the group of people with vocational education it was less often observed. This group also represents the highest percentage of these who do not check the date labels at all. An European survey highlighted that over 80% of European Union citizens checked the 'use by' and 'best before' dates on food packaging when shopping and preparing meals. Women more often than men admitted that they check the dates. This practice was more popular with 55+ population than with young people [European Commission 2015].

Table 2. Circumstances for checking shelf-life dates on food packaging

		At the point of purchase	During unpacking at home	Before consumption	During fridge and pantry overview	I do not check the dates
Total		55.1	5.5	25.8	7.6	5.9
Gender	female	58.3	4.7	26.5	7.9	2.6
	male	51.0	6.7	25.1	7.5	9.8
Age	under 20	40.0	4.0	28.0	4.0	24.0
	20 - 29	52.0	4.6	28.1	10.7	4.6
	30 - 39	56.1	7.0	27.6	2.2	7.0
	40 - 49	53.9	4.6	27.0	8.6	5.9
	50 - 59	59.3	6.0	22.2	7.8	4.8
	60+	55.6	5.5	24.4	9.3	5.2
Education	vocational	47.2	5.5	23.6	14.6	9.0
	secondary	55.8	6.4	24.9	5.2	7.8
	bachelor degree	56.5	4.2	31.0	6.7	1.7
	master degree	58.9	5.9	23.4	6.9	5.0

Source: own work

In the opinion of more than 67% respondents the system of date labelling of food is easy (Figure 1). Nearly 20% of people buying food had no opinion, and nearly 14% admitted that this system is difficult for them.



Source: own work

Fig. 1. Evaluation of food date labelling system by consumers

Further investigation showed that despite declarations and common interest in the date labels, food consumers face difficulties with finding, reading and understanding the shelf-life information (Table 3). Four in ten respondents stated that they had problems with finding this information on the packaging. Nearly 20% noticed that the information was unreadable (it was hidden or blurred). In the opinion of 13% of respondents the font was too small to read the date. Surprisingly, negligible percentage of respondents (2.4%) said that they were not able to understand the information. Only 20% of respondents have never had problems with reading the information about the 'use by' or 'best before' date. The percentages were higher in the group of the male than in the group of female respondents. Taking the age of respondents into consideration, there are differences between the analyzed sub-groups. People over 50 less often than others said that they had never experienced problems with reading the date labels. At the same time they more often, in comparison to younger respondents, pointed out that the size of the font was the reason for problems. Nearly half of respondents below 30, more than in other groups, had problems with finding the date on the food packaging. About 5% of respondents admitted that the date information was removed after the package had been opened. In a study of Świda et al. [2018] it was shown that the older the consumers were, the more problems with finding the expiration date they had. Eye tracking revealed that the time required to find the date strongly depended on where exactly this information was printed on the packaging.

Table 3. Problems that consumers experience with reading shelf-life date on the food packaging

		Finding the date was difficult	Font was too small	Information was unreadable (it was hidden or blurred	I was not able to understand the information	The date was removed after the package had been opened	I have never had any problems
Total		40.0	13.1	19.2	2.4	5.2	20.1
Gender	female	40.9	13.3	21.3	2.3	5.8	16.4
	male	38.9	12.5	17.0	2.5	4.3	24.8
Age	under 20	44.0	8.0	8.0	0.0	4.0	36.0
	20 - 29	44.7	3.6	17.8	3.0	7.1	23.9
	30 - 39	39.8	11.5	17.7	1.8	7.1	22.1
	40 - 49	38.6	8.5	19.6	2.0	7.2	24.2
	50 - 59	38.7	16.7	22.0	2.4	1.2	19.0
	60+	38.5	20.2	20.2	2.5	4.1	14.5
Education	vocational	37.4	21.7	20.7	3.9	3.4	12.8
	secondary	41.7	14.9	19.2	1.5	5.8	16.9
	bachelor degree	41.9	7.1	17.4	3.3	7.1	23.2
	master degree	38.6	11.5	19.3	1.9	3.7	24.9

Source: own work

In accordance with Regulation, mandatory food information shall be marked in a visible place in such a way as to be easily visible, clearly legible and, where appropriate, indelible. It shall not in any way be hidden, obscured, detracted or interrupted by any other written or pictorial matter or any material [Regulation (EU) No. 1169/2011]. The study highlighted four reasons for problems which food consumers face: (1) the location of the print, (2) no legibility of the print, (3) font size, (4) the possibility of removing overprinted date. All of them are on the side of entities which place food on the market. These issues should be handled with a special care as they may constitute a weak link in the food date labelling system. The fifth identified reason for problems occurring during reading the dates is related to consumer knowledge and awareness. We asked our respondents about the meaning of the 'best before' date using the date formats presented in Table 4. The correct interpretation of the 'best before' date is that this food can be consumed past this date although its quality may not be optimal. Over 60% of respondents were able to give the correct answer. About 20% of them thought that one should not consume such food, 5% of respondents were not able to interpret the meaning of the 'best before' date. The incorrect answers that food should not be consumed after passing the 'best before' date occurred more often in the group of elder respondents than younger ones. Despite the fact that people below 20 rarely gave incorrect interpretation of minimum durability date relatively high percentage of them, in comparison with other groups, was not able to answer the question at all. Respondents with vocational education had the highest problems with interpretation of the 'best before date'.

Table 4. Interpretation of the 'best before' date

		After this date			
Best before 05.06.2020		Food can be consumed, its quality is good	Food can be consumed, its quality may not be good	Food should not be consumed	I do not know
Total		13.9	61.1	19.9	5.1
Gender	female	11.2	62.9	20.5	4.5
	male	15.6	58.8	19.8	5.8
Age	under 20	4.0	76.0	4.0	16.0
	20 - 29	8.1	77.7	12.2	2.0
	30 - 39	14.9	63.2	19.3	2.6
	40 - 49	10.5	64.1	19.6	5.9
	50 - 59	16.6	53.8	24.3	5.3
	60+	17.3	51.3	23.8	7.3
Education	vocational	19.8	45.0	23.3	11.9
	secondary	13.3	61.1	22.5	3.2
	bachelor degree	9.5	72.7	14.9	2.9
	master degree	13.6	63.2	18.9	4.3

Source: own work

Nearly 80% respondents were able to correctly interpret the meaning of the 'use by' date (Table 5). Additionally, when it comes to this date type, young people had the highest problems with assigning its meaning. One quarter of people under 20 was not able to give any answer, in comparison to a few percent in other groups, although they knew that expired food labelled with the 'use by' date should not be consumed. In turn, the last issue was not so clear in the group of seniors, who were most likely to consume the expired food products – over 21% would consume them under certain conditions. Inadequate interpretation was also observed in the group of respondents with vocational education. Only 71% of them knew that food should not be eaten after its 'use by' date, the others would consume it or were not able to answer this question. Labuza et al. [2008] stated that in the US in 2001 fewer people were able to identify correctly the meaning of the date labels on milk products than in the 1980's. Leib et al. [2016] pointed that millennials tend to regard date labels as food safety indicators instead of making a distinction between the 'use by' and 'best before' dates. The obtained results should encourage food business operators (FBO's) to use the efficient means to enhance awareness of final food consumers represented by young generation through information flows. Bipolarity in the youngest part of population was observed. On the one hand young people know what should not be done after food expiration, on the other hand – one quarter of them do not read the date labels and the same number is not able to give any interpretation of the 'use by' date. It implies the need of personalization of the action taken to make the message suitable for the particular recipient.

Table 5. Interpretation of the 'use by' date

		After this date			
Use by 05.06.2020		Food can be consumed, its quality is good	Food can be consumed, its quality may not be good	Food should not be consumed	I do not know
Total		3.7	12.4	79.0	4.9
Gender	female	3.7	12.8	78.7	4.8
	male	3.7	11.8	79.6	4.9
Age	under 20	0.0	4.2	70.8	25.0
	20 - 29	2.6	7.7	87.2	2.6
	30 - 39	1.8	13.2	82.4	2.6
	40 - 49	3.9	9.8	81.7	4.6
	50 - 59	6.0	11.3	78.6	4.2
	60+	4.3	16.8	72.0	6.8
Education	vocational	7.5	11.4	70.6	10.4
	secondary	4.1	15.1	76.8	4.1
	bachelor degree	2.9	10.9	84.2	2.1
	master degree	1.6	10.6	82.9	5.0

Source: own work

To verify respondents' self-esteem regarding the dates it was examined which problems with interpretation are experienced by people who said that the date- labelling system is easy (Table 6). The results are far from ideal. Only two thirds gave the correct answer that food can be consumed after passing the minimum durability date. Slightly more than 20% respondents in this group believe that consumption of food products past best before date is undesirable. Regarding the 'use by' date, 83% of respondents who felt good with the date labelling system correctly matched the meaning of this date type. These results are only a few percentage points higher than those obtained in the entire population tested. The results showed that a certain percentage of respondents (nearly 14 %) for whom the system was easy would not consume food after the 'use by' date. They prove that despite respondents' thinking that the system of date labelling is easy, their actual knowledge is not satisfactory. This observation highlights the need to take appropriate action at the level of legislators and FBO's to improve the food date labelling system.

Table 6. Interpretation of the shelf-life dates by consumers who claimed that the system of date labelling is easy

	After this date			
	Food can be consumed, its quality is good	Food can be consumed, its quality may not be good	Food should not be consumed	I do not know
Best before 05.06.2020	12.7%	65.5%	20.3%	1.6%
Use by 05.06.2020	3.0%	11.5%	83.4%	2.1%

Source: own work

Previous studies showed that despite the fact that consumers are aware of the differences between the 'use by' and 'best before' dates, they have difficulties in correctly referring them to the quality and safety of a given food product. In Belgium only 70% of respondents were able to tell the differences between the two types of date labelling [Van Boxstael et al. 2014]. It was found that less than 60% of teenagers in Greece were able to prove their knowledge of the labelling system in the selection test regarding 'use by' dates and only 20% in relation to the 'best before' dates [Gialitakis and Chryssochoidis 2006].

CONCLUSIONS

The analysis of the food date labelling system from the perspective of final consumers indicated its weaknesses which do not allow for the effective fulfillment of its role. The system is not fully efficient in terms of supporting the policy of safe and sustainable food chains. The presented data show two kinds of underlying problems that final consumers face. The first one is related to technical aspects of food packaging – design of the label and packaging, quality of the print and the size of the font. Compliance with applicable law in terms of regulated issues is important but may not be enough. It is important that presented information is clearly shown and accessible. This is the area within which the action should be undertaken by the FBO's. The second problem arises from consumers' understanding of the food labelling concept. Misinterpretation of minimum durability dates negatively affects the mass of edible food present on the market and can contribute to the environmental burden resulting from throwing away manufactured products. Lack of consumers' certainty regarding the safety of expired food exacerbates this problem. And finally, lack of education in the area of 'use by' date concept affects consumers' safety. Actions targeted at a specific population should be undertaken by FBO's, legislators and educators in the pointed areas in order to achieve economic, environmental and social benefits from clear and consumer-friendly date labelling system. Apart from taking actions aimed at educating the society, it is necessary to make young people more interested in shelf-life dates, and help seniors to familiarize themselves with the information. Improvement of the date labelling system can contribute to safe and sustainable food supply chain.

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REFERENCES

Aschemann-Witzel J., de Hooge I., Rohm E.H., Normann A., Bonzanini Bossle M., Grønhøj A., Oostindjer M., 2017. Key characteristics and success factors of supply chain initiatives tackling consumer-related food waste – A multiple case study, Journal of Cleaner Production, 155, 2, 33-45. http://doi.org/10.1016/j.jclepro.2016.11.173

Bhat R., Jõudu I., 2019, Emerging issues and challenges in agri-food supply chain, In: Sustainable Food Supply Chains (Accorsi R., Manzini, R.), Academic Press

Bhattacharya A., Fayezi, S., 2021. Ameliorating food loss and waste in the supply chain through multi-stakeholder collaboration, Industrial Marketing Management, 93, 328-343. http://doi.org/10.1016/j.indmarman.2021.01.009

Council of the European Union, 2014. Food Losses and Food Waste in Europe and European Legislation Note From the Netherlands and Swedish Delegations, Supported by the Austrian, Danish, German and Luxembourg Delegations, Brussels

Dobernig K., Schanes K., 2019. Domestic spaces and beyond: Consumer food waste in the context of shopping and storing routines, International Journal of Consumer Studies, 43, 5, 480-489. http://doi.org/10.1111/ijcs.12527

European Commission, 2015. Flash Eurobarometer 425: Food waste and date marking, European Commission. Available from Internet: https://data.europa.eu/euodp/pl/data/dataset/S2095_425_ENG

FAO, 2019. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction, Food and Agriculture Organization of the United Nations. Available from Internet: http://www.fao.org/publications/sofa/en

Fusions, 2016. Estimates of European food waste levels. Available from Internet: https://www.eu-fusions.org

Gialitakis G., Chryssochoidis G., 2006., Schoolchildren's understanding of food labels, Young consumers, 7, 4, 19-25. http://doi.org/10.1108/17473610610717937

Grönman K, Soukka R, Järvi-Kääriäinen, Katajajuuri J.-M., Kuisma M., Koivupuro H.-K., Ollila M., Pitkänen M., Miettinen O., Silvenius F., Thun R., Wessman H., Linnanen L., 2013. Framework for sustainable food packaging design, Packaging Technology and Science, 26, 4, 187-200. http://doi.org/10.1002/Pts.1971

Kowalska A., 2017. The issue of food losses and waste and its determinants, LogForum, 13, 1, 7-18. http://doi.org/10.17270/J.LOG.2017.1.1

Krishnan R., Agarwal R. Bajada Ch., Arshinder K., 2020. Redesigning a food supply chain for environmental sustain-ability – An analysis of resource use and recovery, Journal of Cleaner Production, 242, 118374. http://doi.org/10.1016/j.jclepro

Labuza T.P., Szybis, L.M., Pec, J., 2008. Perishable Refrigerated Products and Home Practices Survey. In Open Dating of Foods. Food & Nutrition Press, Inc.: Trumbull, CT, USA

Leib E.B., Rice Ch., Neff R., Spiker M., Schklair A., Greenberg S., 2016. Consumer perceptions of date labels: National Survey. Available from Internet: https://www.comunicarseweb.com/sites/default/files/consumer-perceptions-on-date-labels_may-2016.pdf

Lemaire A., Limbourg S., 2019. How can food loss and waste management achieve sustainable development goals?, Journal of Cleaner Production,234,1221-1234, http://doi.org/10.1016/j.jclepro.2019.06.226

Lindh H., Williams H., Olsson A., Wikström F., 2016, Elucidating the indirect contri-butions of packaging to sustainable development: a terminology of packaging functions and features, Packaging Technology and Science, 29, 225–246. http://doi.org/10.1002/pts.2197

Newsome R., Balestrin, Ch.G., Baum M.D, Corby J., Fisher W., Goodburn K., Labuza P.T., Prince G., Thesmar H.S., Yiannas F., 2014. Applications and perceptions of date labelling of food. Comprehensive Reviews in Food Science and Food Safety, 13, 745-769. http://doi.org/10.1111/1541-4337.12086

Ocicka B., Raźniewska M., 2018. Food waste reduction as a challenge in supply chains management, LogForum, 14, 4, 549-561. http://doi.org/10.17270/J.LOG.2018.303

Papargyropoulou E., Lozano R., Steinberger J. K,. Wright, N. bin Ujang, Z., 2014, The food waste hierarchy as a framework for the management of food surplus and food waste, Journal of Cleaner Production, 76, 106-115. http://doi.org/10.1016/j.jclepro.2014.04.020

Patra D., Leisnham P.T., Tanui C.K., Pradhan A.K., 2020. Evaluation of global research trends in the area of food waste due to date labelling using a scientometrics approach, Food Control, 115, 107307. http://doi.org/10.1016/j.foodcont.2020.107307

Regulation (EU) No. 1169/2011 of The European Parliament and of The Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004, OJ L 304, 22.11.2011, 18–63

Samotyja U., 2015. Influence of shelf life labelling on the sensory acceptability of potato snacks, British Food Journal, 117, 1, 222-233. http://doi.org/10.1108/BFJ-09-2013-0257

Secondi L., 2019. Expiry dates, consumer behavior, and food waste: how would Italian consumers react if there were no longer "best before" labels?, Sustainability,11, 6821. http://doi.org/10.3390/su11236821

Soethoudt J.M., Van der Sluis A.A., Waarts Y., Tromp S., 2013. Expiry Dates: a Waste of Time? Report No. 1353, Wagenigen University. Avaliable from Internet: https://ec.europa.eu/food/sites/food/files/safety/docs/fw_lib_report_2013_date-marking-and-food-waste_nl-en.pdf

Świda J, Halagarda M, Popek S., 2018. Perceptions of older consumers regarding food packaging as a prerequisite for its improvement: A case study of Polish market, International Journal of Consumer Studies, 42, 358-366. http://doi.org/10.1111/ijcs.12427

Toussaint M., Cabanelas, P., González-Alvarado T. E., 2021. What about the consumer choice? The influence of social sustainability on consumer's purchasing behavior in the Food Value Chain, European Research on Management and Business Economics, 27, 1, 100134, http://doi.org/10.1016/j.iedeen.2020.100134

United Nations, 2015. Resolution adopted by the General Assembly on 25 September 2015, 526 A/RES/70/1, Transforming our world: the 2030 Agenda for Sustainable Development, 527, United Nations. Available from Internet: https://undocs.org/en/A/RES/70/1

Van Boxstael S., Devlieghere F., Berkvens D., Vermeulen A., Uyttendaele M., 2014, Understanding and attitude regarding the shelf life labels and dates on pre-packed food products by Belgian consumers, Food Control, 37, 85-92. http://doi.org/10.1016/j.foodcont.2013.08.043

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ORIGINAL PAPER

EQUIPMENT SELECTION FOR AN E-COMMERCE COMPANY USING ENTROPY-BASED TOPSIS, EDAS AND CODAS METHODS DURING THE COVID-19

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ABSTRACT. **Background:** The importance and market share of e-commerce has been increasing with the COVID-19 pandemic in recent days. Employees sometimes cannot go to the workplace due to epidemics such as COVID-19 that is spreading rapidly around the world, natural disasters and accidents. Companies can continue to serve their customers with the internet infrastructure and computer technologies they will provide to their employees. Thus, e-commerce companies can provide a sustainable competitive advantage in the sector. Working with the right suppliers is one of the important decisions that will improve the service quality of the firms and affect the sustainability of the enterprise.
Methods: This study aims to select the best laptop for a company in the online trade industry using Entropy-based EDAS, CODAS and TOPSIS methods. In the study, 6 alternative laptops have been evaluated according to hard disk capacity, ram, battery power, processor speed, weight, price criteria. The Entropy method has been used to identify the weights of the criteria in the study. These criteria weights have been used in EDAS, CODAS and TOPSIS methods. TOPSIS, EDAS and CODAS methods have been used to determine the best alternative. Also, the correlation between the results of the TOPSIS, EDAS and CODAS methods has been examined with the Spearman Correlation approach.
Results: As a result of the Entropy method, it has been determined that the most important criterion is the hard disk capacity criterion. TOPSIS, EDAS and CODAS method results have been compared and the most suitable alternative has been selected. According to the results of the study, the best alternative has been selected as A5. Spearman Correlation analysis results show that there was a strong positive relationship between the methods used and the results obtained.
Conclusions: The study differs from existing studies in the literature in that it is the first study in which laptop selection was made using TOPSIS, EDAS and CODAS methods together. The results of this study can be compared with the results of future studies that will be carried out using different MCDM methods and different data.

Key words: CODAS; COVID-19; EDAS; Electronic commerce; Laptop selection; TOPSIS.

INTRODUCTION

Nowadays, the popularity of e-commerce has been growing [Urbancokova et al. 2020]. E-commerce sales of the business to consumer (B2C) have been increasing worldwide in recent years. E-commerce sales, which reached $ 3.535 trillion in 2019, are estimated to reach $ 6.542 trillion in 2023 [Statistica 2020, De Matos et al. 2020]. Different new application types emerging to increase customer engagement and gain more economic value contribute to e-commerce development [Xu et al. 2020]. Customer engagement can be defined as a new concept that might comprise product testing, idea improvement, product support and service process development. Customer involvement provides companies with a competitive advantage in revealing customer demands [Chiang et al. 2020]. Consumers are faced with risks and uncertainties in the e-commerce environment, and the reputation of an e-commerce firm is an indicator of its product or service quality. Corporate reputation provides firms with a competitive advantage and reflects the degree

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of customer satisfaction with a firm's products and services [Li et al. 2020]

Considering the concept of B2C and globalization, e-commerce companies need to offer customer participation-oriented products/services and pay attention to corporate reputation to gain a sustainable competitive advantage in the sector and to open up to new markets. E-commerce companies need to benefit from the latest technologies to establish uninterrupted communication with their customers. Firms can respond to customer expectations faster and make their production and service processes more flexible with the internet and computer technology infrastructure they will provide to their employees. Thus, e-commerce companies can achieve sustainable competitive advantage and more successful operation management in the sector. Employees are sometimes absent from their workplaces for reasons such as the COVID-19 epidemic, natural disasters and accidents.

COVID-19 was first reported in Wuhan, China in December 2019 and has spread to many countries around the world. The epidemic disrupted trade and made it compulsory for the working population to stay at home [Debata et al. 2020]. Millions of people were kept at home to prevent the spread of the COVID-19 epidemic. Many people lost their jobs due to the epidemic and the epidemic caused a change in people's lifestyles [Saadat el. 2020, Posel et al. 2021]. Besides, due to the COVID-19 outbreak, air quality has improved and water pollution has increased in some regions around the world as production facilities are closed and people spend more time at home [Saadat et al. 2020].

Many people today cannot imagine their lives without a computer. In-corporate terms, the computer has become an indispensable tool for all employees. The ability to perform complex and repetitive calculations in computers without errors and in a short time has increased the demand for computers. On the other hand, computer usage has become more portable due to developments in information and communication technologies. Furthermore, laptops have played an important role in human life in the information age due to their capabilities and portability. Therefore, choosing an efficient laptop according to the needs of the buyers is critical. Multi-Criteria Decision Making (MCDM) methods are used to determine the most suitable alternative in cases where there are more than one alternative and criteria [Ulutaş and Cengiz 2018].

In today's competitive environment, business managers usually have to choose among alternatives for choosing raw materials, machinery and location. It is very important to work with the right suppliers in improving the service quality of the enterprises and ensuring the sustainability of the enterprise. Companies generally use MCDM methods for such selection problems. In this study, it was tried to determine the most suitable laptop by using Entropy-based EDAS, CODAS and TOPSIS methods for a company in the online trade sector.

The rest of this paper has been organized as follows. A literature review about studies conducted using CODAS, EDAS and TOPSIS methods was included in the second part. Entropy, EDAS, CODAS and TOPSIS methods were included in the methodology section, which is the third part of the study. The fourth part of the study consists of the application step in which the alternatives were ranked and the discussion part. In the fifth section, a general evaluation of the study has been made.

LITERATURE REVIEW

MCDM methods are widely used in many different areas. In the literature, there are many studies in which MCDM methods such as AHP, TOPSIS, EDAS, CODAS, ARCAS, COPRAS, VIKOR, ELECTRE and PROMETHEE are used [Mardani et al. 2015, Rezaei 2015, Chatterjee et al. 2018, Badi et al. 2018, Stanujkic et al. 2017, Jayant and Sharma 2018, Kaplinski et al. 2019, Zhang et al. 2019, Siksnelyte-Butkiene et al. 2021]. TOPSIS method is one of the MCDM methods widely used in the different application areas. EDAS and CODAS methods are new MCDM methods that have been implemented in different fields in the last few years [Behzadian et al. 2012, Stanujkic et al. 2017, Palczewski and Salabun 2019, Zhang et al. 2019, Mathew and Thomas 2019, Aldalou and Perçin 2020, Aytekin and Durucasu 2021, Simic et al. 2021]. Some of the studies were carried out using TOPSIS, EDAS and CODAS methods can be seen in Table 1.

Table 1. Studies using TOPSIS, EDAS and CODAS methods

Author (Year)	**Method**	**Application**
Vimal at al. (2012)	TOPSIS	selection of the best supplier of a company in the manufacturing industry
Ghorabaee et al. (2015)	EDAS, VIKOR, TOPSIS SAW and COPRAS	inventory classification
Hanine et al. (2016)	AHP and TOPSIS	ETL software selection problem of a business intelligence project.
Chitnis and Vaidya (2016)	DEA and TOPSIS	measure the efficiency of bank branches in India.
Kahraman et al. (2017)	fuzzy EDAS	selection of solid waste disposal site
Juodagalvienė et al. (2017)	SWARA and EDAS	selection of the house shape
Ghorabaee et al. (2017)	EDAS, TOPSIS, COPRAS and WASPAS	evaluation of the airlines
Turskis et al. (2017)	AHP and EDAS	cultural heritage structures ranking problem of renovation projects
Stević et al. (2017)	DEMATEL, EDAS, MABAC, COPRAS and MULTIMOORA	supplier selection in a construction firm
Trinkūnienė et al. (2017)	fuzzy AHP, SAW, TOPSIS, COPRAS and EDAS	evaluation of quality assurance in contractor contracts
George et al. (2018)	TOPSIS	selection of portable generators in a manufacturer company
Ecer (2018)	fuzzy AHP and EDAS	selection the best third-party logistics provider
Karabasevic et al. (2018)	SWARA and EDAS	personnel selection in the IT sector
Erkayman et al. (2018)	fuzzy DEMATEL and EDAS	selection of the best ERP development strategy of a furniture company.
Liang et al. (2018)	EDAS and ELECTRE	evaluation of the cleaner production for gold mines
Ghorabaee et al. (2018)	fuzzy SWARA, fuzzy CRITIC and fuzzy EDAS	evaluation of construction equipment.
Badi et al. (2018)	CODAS	selection of the best desalination plant location
Mathew and Thomas (2018)	interval-valued EDAS, interval-valued TOPSIS and interval-valued CODAS methods	evaluation a flexible manufacturing system.
Aggarwal et al. (2018)	EDAS	selection of smartphones in the Indian market
Ulutaş (2019)	Entropy-based EDAS	performance analysis of logistics firms
Adalı and Tuş (2019)	CRITIC, EDAS, CODAS and TOPSIS	hospital site selection
Kundakcı (2019)	MACBETCH and EDAS	selection of the best boiler alternative
Yalçın and Pehlivan (2019)	fuzzy TOPSIS, fuzzy CODAS, fuzzy COPRAS, fuzzy EDAS, fuzzy ARAS, fuzzy WASPAS	personnel selection
Behzad et al. (2019)	EDAS, MABAC, CODAS and VIKOR	evaluation of waste management performance.
Altıntaş (2020)	Entropy-based TOPSIS and EDAS	evaluation of competition performance of G 7 countries.
Deng et al. (2020)	BWM and TOPSIS	comparing the hazardous waste inventory risk of different companies
Liang (2020)	intuitionistic fuzzy EDAS	evaluation of energy-saving design projects
Ecer et al. (2021)	interval rough CODAS	evaluation of renewable energy resources
Ersoy (2021)	DEA and TOPSIS	performance evaluation of distance education.

TOPSIS, EDAS and CODAS methods were used in many different sectors. For determining the criteria used in this study, previous studies were examined for the selection of laptops. The methods and criteria used in the studies on laptop selection in the literature can be seen in Table 2.

It is understood from Table 2 that there is no study in which Entropy-based TOPSIS, EDAS and CODAS methods were used together for laptop selection. For this reason, it is thought that this study will be the first study for the laptop selection problem. Table 2 was used to determine the criteria used in the study.

Table 2. Criteria and methods for laptop selection

Author (Year)	Method	Criteria
Srichetta and Thurachon (2012)	Fuzzy AHP	Harddisk capacity, RAM capacity, CPU speed, monitor resolution, weight, price, durability, beauty
Pekkaya and Aktogan (2014)	AHP, DEA, TOPSIS and VIKOR	Speed, capacity, brand, image, peripherals and price
Lakshmi et al. (2015)	TOPSIS	Specification, size, weight, warranty, wi-fi, battery life, with or without OS, keyboard and touch board pad,
Kalyani et al. (2016)	TOPSIS	Design or style, technical support, memory, reviews
Kecek and Demirağ (2016)	MOORA and TOPSIS	Speed, brand, capacity, display, environmental equipment and other features, price
Siew et al. (2016)	AHP	Price, speed (RAM, dimension, etc.), weight, color, design, warranty period, technical service
Adalı and Işık (2017)	MULTIMOORA and MOOSRA	Processor speed, storage, memory (RAM), cache memory, display card memory, cost, screen resolution, screen size, weight, brand reliability
Aytekin and Kuvat (2018)	AHP	Operating system, processor features, RAM capacity, hard disk features, screen resolution, graphics card feature, battery life, brand, design, weight, screen size, price range, service support, product vendor, user comments and suggestions, warranty terms
Ulutaş and Cengiz (2018)	CRITIC and EVAMIX	Service, design, brand reliability, RAM, processor speed, cache, cost, graphics card memory, screen resolution, harddisk capacity, weight
Stanujkic et al. (2018)	PIPRECIA and EDAS	Manufacturer, diagonal screen size, processor type, processor tact, price, cache memory, RAM, battery, HDD, graphics, weight
Yorulmaz et al. (2019)	TOPSIS	Processor speed, number of processor cores, RAM, hard disk capacity
Mitra and Goswami (2019)	AHP and SAW	Processor, color, hard disk capacity, brand, operating system, screen size, RAM
Çakır and Pekkaya (2020)	AHP, Fuzzy AHP and DEMATEL	Price of the product, brand image, running speed, storage capacity, other properties and laptop peripherals, monitor properties

MATERIALS AND METHOD

This study was carried out in an e-commerce company in Turkey. Due to the rapidly spreading COVID 19 epidemic, natural disasters and accidents, employees sometimes cannot come to the workplace. The company managers want to take advantage of technology to keep track of customer orders and the online trade operation process in a quality and uninterrupted manner. For this reason, the company wants to buy a 15.6-inch laptop with an i5 processor and Windows operating system and weighing less than 2 kg for its employees. In this way, company employees will have the opportunity to do their work on the internet in some cases without going to the workplace, and it will be tried to ensure that the operation management continues uninterrupted for the customer order and delivery process. In the study, 6 alternative laptops were evaluated according to the 6 criteria.

The criteria used in the study have been determined based on expert opinions and the literature review. These criteria were hard disk capacity (C1) (in GB), RAM (C2) (in GB), battery power (C3) (in Wh), processor speed (C4) (in GHz), weight (C5) (in Kg) and price (C6) (in TL). Data regarding the alternatives and criteria used in the study were obtained on 06 November 2020 from different firms. The Entropy method has been used to identify the weights of the criteria in the study. Criteria weights obtained by the Entropy method have been used in EDAS, CODAS and TOPSIS methods. The 6 alternative laptops have been ranked according to EDAS, CODAS and TOPSIS methods. Microsoft Excel 2016 program has been used to apply Entropy, EDAS, CODAS and TOPSIS methods. The hierarchical structure of the study was shown in figure 1. the alternatives were respectively expressed as A1, A2 ….A6 in figure 1. Entropy, EDAS, CODAS and TOPSIS methods used in the study were explained below.

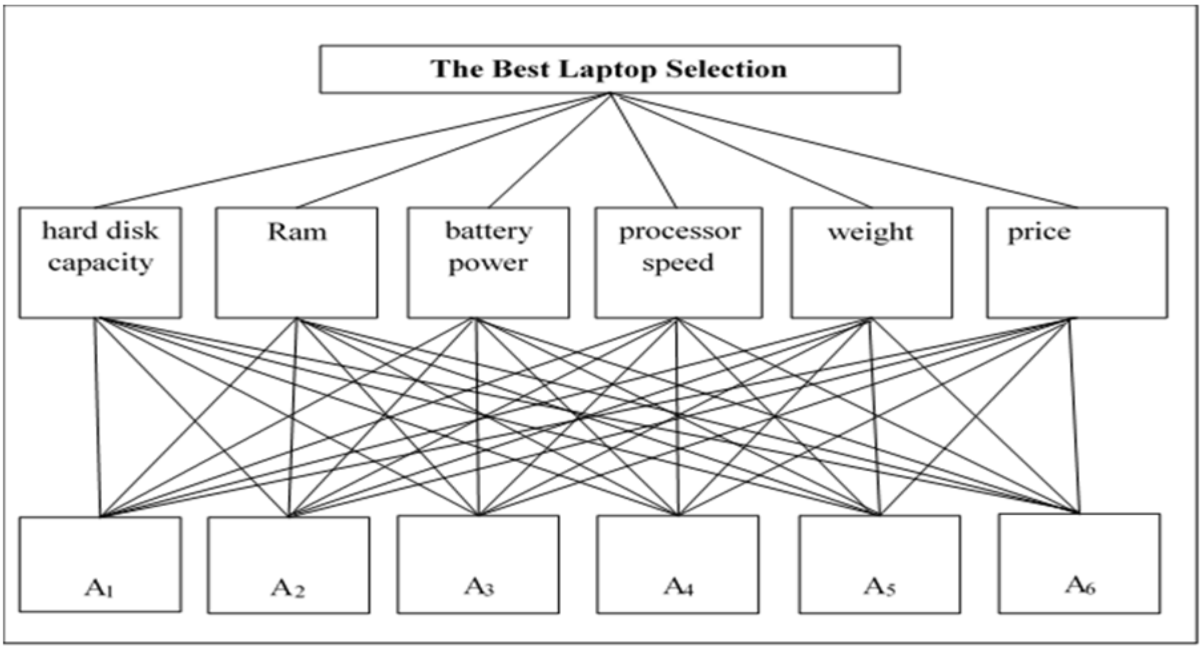

Fig. 1. The framework of laptop selection

ENTROPY METHOD

The concept of entropy, first proposed by Shannon in 1948, was developed as a weighting method by Wang and Lee in 2009 [Aytekin, Karamaşa 2017]. The Entropy method consists of the following steps [Wang and Lee 2009, Aytekin and Karamaşa 2017, Wang et al. 2017, Ulutaş 2019, Dehdasht et al. 2020]:

Step 1: Creation of decision matrix.

There are alternatives in the rows of the B_{ij} decision matrix and criteria in the columns. The decision matrix is shown below.

$$B_{ij} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \dots & b_{mn} \end{bmatrix} \quad (1)$$

Step 2: Normalizing the decision matrix.

The B_{ij} decision matrix is normalized using equation 2.

$$t_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}} \qquad j = 1, 2, ..., n \quad (2)$$

Step 3: Calculation of entropy values.

After normalizing the decision matrix, the entropy values for the criteria were calculated using equation (3).

$$e_j = -h \sum_{i=1}^{m} t_{ij} \ln t_{ij} \qquad j = 1, 2, ..., n \quad (3)$$

Where h is a constant, let $h = (\ln(m))^{-1}$

Step 4: Calculating the degree of diversification.

The degree of divergence of the intrinsic information of each criterion calculated by using equation (4).

$$d_j = 1 - e_j \tag{4}$$

Step 5: Calculation of objective weight of criterion

The objective weight for each criterion can be calculated from equation (5).

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{5}$$

TOPSIS METHOD

The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) method is a widely used MCDM method in different areas [Kolios et al. 2016, Wang et al. 2017, Mathew and Thomas 2019, Ersoy, 2021]. The TOPSIS method first was developed by Hwang and Yoon in 1981 [Hwang and Yoon 1981, Chen 2000, Ersoy 2021]. The TOPSIS method is based on the principle of determining the distances of the alternatives subjected to evaluation from the positive ideal solution and negative ideal solution [Chen 2000, Ersoy 2021]. The phases of the TOPSIS method have been given below [Hwang and Yoon 1981, Shih et al. 2007, Chitnis and Vaidya 2016, You et al. 2017, Ersoy 2021].

Step 1: Creating the decision matrix (A).

There are $i,\ i = 1, 2, ..., m$ alternatives in the rows of the decision matrix A_{ij} and $j,\ j = 1, 2, ..., n$ criteria in the columns. The decision matrix is shown below.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{6}$$

Step 2: Creating the normalized decision matrix (R).

The normalized decision matrix is calculated using equation (7).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad i = 1, 2, ..., m \quad j = 1, 2, ..., n \tag{7}$$

R_{ij} normalized decision matrix is shown below.

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{8}$$

Step 3: Creating the weighted normalized decision matrix (Y).

First, the weight values (w_i) for the evaluation criteria are determined. Then the Y_{ij} matrix is created by multiplying the elements in each column of the matrix by the corresponding value of w_i. The weighted normalized value y_{ij} is obtained as in equation (9).

$$y_{ij} = w_j . r_{ij} \tag{9}$$

Y_{ij} normalized decision matrix is shown below.

$$Y_{ij} = \begin{bmatrix} w_1 r_{11} & w_1 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix} \tag{10}$$

Step 4: Creating a positive ideal set (A^*) and negative ideal set (A^-).

To create the ideal solution set, the largest of the weighted column values in Y_{ij} matrix is chosen. The positive ideal solution set is obtained from equation (11).

$$A^* = \left\{ (\max_i y_{ij} \mid j \in J), (\min_i y_{ij} \mid j \in J') \right\} \quad (11)$$

The negative ideal solution set is created by choosing the smallest of the weighted column values in Y_{ij} matrix. The negative ideal solution set is obtained from equation (12).

$$A^- = \left\{ (\min_i y_{ij} \mid j \in J), (\max_i y_{ij} \mid j \in J') \right\} \quad (12)$$

In both equations, J benefit (maximization) and J' loss (minimization) value.

Step 5: Calculating the distance of each alternative to the positive ideal solution and the negative ideal solution.

The distance to the positive ideal solution is S_i^* and the distance to the negative ideal solution is S_i^-. The distance to the positive ideal solution is calculated using equation (13) and the distance to the negative ideal solution is calculated using equation (14).

$$S^* = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_j^* \right)^2} \quad (13)$$

$$S^- = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_j^- \right)^2} \quad (14)$$

Step 6: Compute the relative proximity of each alternative to the ideal solution.

The relative closeness (C_i^*) of each alternative to the ideal solution is calculated as in equation (15).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (15)$$

Where, $0 \le C_i^* \le 1$.

EDAS METHOD

The Evaluation Based on Distance from Average Solution (EDAS) method was first developed by Ghorabaee et al. [2015]. In this developed method, the average solution is used to evaluate the alternatives. Positive distance average (PDA) and negative distance average (NDA) are two separate measures used to evaluate alternatives. The best alternative is chosen considering these two distances [Ghorabaee et al. 2015, Kahraman et al. 2017, Chatterjee et al. 2018, Adalı and Tus 2019). The phases of the EDAS method were as follows [Ghorabaee et al. 2015, Stanujkic et al. 2017, Chatterjee et al. 2018, Aggarwall et al. 2018, Adalı and Tuş 2019].

Step 1: Creation of decision matrix (X).

$$X = \left[X_{ij} \right]_{n \times m} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (16)$$

Where X_{ij} demonstrates the performance value of i th alternative on j th criterion.

Step 2: Determine the average solution considering to all criteria.

$$AV = \left[AV_j \right]_{1xm} \quad (17)$$

Where,

$$AV_j = \frac{\sum_{i=1}^{m} x_{ij}}{m} \quad (18)$$

Step 3: Calculate the positive distance from average (PDA) and the negative distance from average (NDA) matrices according to the sort of criteria (cost and benefit).

$$PDA = \left[PDA_{ij}\right]_{nxm} \quad (19)$$

$$NDA = \left[NDA_{ij}\right]_{n\times m} \quad (20)$$

If j th criterion is beneficial,

$$PDA_{ij} = \frac{\max(0, (x_{ij} - AV_j))}{AV_j} \quad (21)$$

$$NDA_{ij} = \frac{\max(0, (AV_j - x_{ij}))}{AV_j} \quad (22)$$

And if j th criterion is non-beneficial

$$PDA_{ij} = \frac{\max(0, (AV_j - x_{ij}))}{AV_j} \quad (23)$$

$$NDA_{ij} = \frac{\max(0, (x_{ij} - AV_j))}{AV_j} \quad (24)$$

where PDA_{ij} and NDA_{ij} demonstrate the positive and negative distance of i th alternative from average solution in terms of j th criterion, respectively

Step 4: Calculate the weighted sum of PDA and weighted sum of NDA for all alternatives.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \quad (25)$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \quad (26)$$

Where w_j is the weight of j th criterion.

Step 5: Normalize the SP and SN values for all alternatives.

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \quad (27)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \quad (28)$$

Step 6: Calculate the appraisal score (AS) for all alternatives.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \quad (29)$$

Where $0 \le AS_i \le 1$

Step 7: Ranking of the alternatives considering the descending values of AS.

The alternative with the biggest AS value is the best.

CODAS METHOD

CODAS (Combinative Distance-based Assessment) method was first developed by Ghorabaee et al. [2016]. In the CODAS method, which is based on the choice of alternatives based on the distances to the negative ideal solution, the preference of the alternatives is determined by the Euclidean (Euclidean) and Taksicab (Taxicab) distances [Ghorabaee et al., 2016; Bakır and Alptekin, 2018]. The application steps of the CODAS method were given below [Ghorabaee et al. 2016, Badi et al. 2018, Mathew and Sahu 2018, Bakır and Alptekin 2018].

Step 1: Creating a decision matrix (X) with alternatives and criteria.

$$X = \left[x_{ij}\right]_{n\times m} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (30)$$

Where $x_{ij}\,(x_{ij} \ge 0)$ denotes the performance value of i th alternative on j th criterion.

Step 2: Compute the normalized decision matrix.

$$n_{ij} = \begin{cases} \dfrac{x_{ij}}{\max_i x_{ij}} & if \ \ j \in N_b \\ \dfrac{\min_i x_{ij}}{x_{ij}} & if \ \ j \in N_c \end{cases} \qquad (31)$$

The values N_b and N_c in equation (31) express the benefit and criteria, respectively.

Step 3: Compute the weighted normalized decision matrix.

This calculation, which is based on multiplying the column elements belonging to the normalized decision matrix with the relevant weight coefficients, is realized with equation (32).

$$r_{ij} = w_j n_{ij} \qquad (32)$$

Step 4: Determine the negative-ideal solution point (NIS).

Using equation (33), the smallest values of the columns in the weighted matrix are selected.

$$ns = \lfloor ns_j \rfloor_{1\times m} \qquad ns_j = \min_i r_{ij} \qquad (33)$$

Step 5: Calculate the Euclidean and Taxicab distances of alternatives from the negative-ideal solution.

Calculation of Euclidean distances (E_i) and Taxicab distances (T_i) values were shown in equations (34) and (35), respectively.

$$E_i = \sqrt{\sum_{j=1}^{m} (r_{ij} - ns_j)^2} \qquad (34)$$

$$T_i = \sum_{j=1}^{m} \left| r_{ij} - ns_j \right| \qquad (35)$$

Step 6: Creation of Comparative evaluation matrix.

A Comparative evaluation matrix is created from equation (36).

$$\begin{aligned} R_a &= [h_{ik}]_{n\times n} \\ h_{ik} &= (E_i - E_k) + (\psi(E_i - E_k) \times (T_i - T_k)) \end{aligned} \qquad (36)$$

Where $k \in \{1, 2, ..., n\}$ and ψ denotes a threshold function recognizes the equality of the Euclidean and as given equation (37).

$$\psi(x) = \begin{cases} 1, & if \ |x| \geq \tau \\ 0, & if \ |x| \leq \tau \end{cases} \qquad (37)$$

In this function, τ is the threshold parameter that can be set by the decision-maker. It is recommended to set this parameter at a value between 0,01 and 0,05. If the difference between Euclidean distances of two alternatives is less than τ, these two alternatives are also compared by the Taxicab distance [Ghorabaee et al. 2016, Badi et al. 2018]. In this study τ value was taken 0,02.

Step 7: Calculate the assessment score of each alternatives.

$$H_i = \sum_{k=1}^{n} h_{ik} \qquad (38)$$

By ranking the H_i scores of the alternatives in descending order, the alternatives are ranked from the best to the worst.

RESULTS AND DISCUSSION

The weight values of the criteria used in the study have been identified as a result of the Entropy method. In the decision matrix have used in EDAS, TOPSIS and CODAS method, some criteria should be expressed as benefit and others as cost. In the study, price and weight criteria were accepted as non-benefit (cost) criteria others were accepted as benefit criteria. The best alternative was determined by comparing EDAS, TOPSIS and CODAS methods. The results of Entropy, EDAS, TOPSIS and CODAS methods used in the study were given below, respectively.

Entropy Method Results

In the first stage of the Entropy method, the decision matrix, which includes the criteria and alternatives, was created in Table 3. In Table 3, alternatives were respectively expressed as A1, A2, …., A6 and criteria as C1, C2, …., C6.

After the decision matrix was created, the normalized decision matrix shown in Table 4 was obtained using equation (2).

Table 3. Decision Matrix

Alternative	Criteria					
	Hard disk capacity (GB)	Ram (GB)	Battery power (Wh)	Processor speed (GHz)	Weight (Kg)	Price (TL)
	C1	C2	C3	C4	C5	C6
A1	256	8	41	1,6	1,77	7347,16
A2	256	8	32	1,0	1,8	6919,99
A3	256	8	53	1,6	1,9	8400
A4	256	8	41	1,0	1,75	6808,9
A5	512	8	35	1,6	1,7	8479,99
A6	256	4	35	1,6	1,7	7499,99

Table 4. Normalized decision matrix

	C1	C2	C3	C4	C5	C6
A1	0,1429	0,1818	0,1730	0,1905	0,1667	0,1616
A2	0,1429	0,1818	0,1350	0,1190	0,1695	0,1522
A3	0,1429	0,1818	0,2236	0,1905	0,1789	0,1848
A4	0,1429	0,1818	0,1730	0,1190	0,1648	0,1498
A5	0,2857	0,1818	0,1477	0,1905	0,1601	0,1866
A6	0,1429	0,0909	0,1477	0,1905	0,1601	0,1650

Table 5. Entropy values and criteria weights

Results	C1	C2	C3	C4	C5	C6
e_j	0,976	0,987	0,992	0,988	1,000	0,998
$d_j = 1 - e_j$	0,024	0,013	0,008	0,012	0,000	0,002
w_j	0,405	0,221	0,134	0,199	0,007	0,034

After the decision matrix was normalized, entropy values and criterion weights were calculated. These calculated values were given in Table 5.

It is understood from Table 5 that the criteria with the highest weight is C1. Criteria weights obtained as a result of the Entropy method were used in EDAS, CODAS and TOPSIS methods.

TOPSIS Method Results

TOPSIS method has been implemented to the decision matrix given in Table 3. The normalized decision matrix shown in Table 6 has been obtained using equation (7).

Table 6. Normalized decision matrix

	C1	C2	C3	C4	C5	C6
A1	0,3333	0,4364	0,4175	0,4573	0,4079	0,3944
A2	0,3333	0,4364	0,3258	0,2858	0,4149	0,3715
A3	0,3333	0,4364	0,5397	0,4573	0,4379	0,4510
A4	0,3333	0,4364	0,4175	0,2858	0,4033	0,3655
A5	0,6667	0,4364	0,3564	0,4573	0,3918	0,4553
A6	0,3333	0,2182	0,3564	0,4573	0,3918	0,4027

Table 7. Ranking of the alternatives according to the TOPSIS method

Alternatives	S_i^*	S_i^-	C_i^*	Rank
A1	0,136	0,060	0,308	3
A2	0,142	0,048	0,254	5
A3	0,135	0,066	0,327	2
A4	0,140	0,050	0,263	4
A5	0,025	0,147	0,857	1
A6	0,145	0,034	0,192	6

Then, the distance to the positive ideal solution (S_i^*), the distance to the negative ideal solution (S_i^-) and the relative proximity of each alternative to the ideal solution (C_i^*) were calculated. Values of S_i^*, S_i^-, C_i^* and ranking of the alternatives were given in Table 7.

According to the ranking in Table 7, it was understood that the best alternative is A5, third place is A1 and fourth is A4.

EDAS Method Results

EDAS method has been applied to the decision matrix can be seen in Table 3. Average solutions of the criteria were calculated with equation (18). Table 8 shows the average solutions (AV_j) of the criteria.

Table 8. Average solutions of criteria

Criteria	C1	C2	C3	C4	C5	C6
AV_j	298,667	7,333	39,500	1,400	1,770	7576,005

Table 9. Ranking of the alternatives according to the EDAS method

Alternatives	SP_i	SN_i	NSP_i	NSN_i	AS_i	Rank
A1	0,055	0,058	0,162	0,667	0,414	3
A2	0,023	0,140	0,068	0,192	0,130	5
A3	0,094	0,062	0,279	0,643	0,461	2
A4	0,029	0,115	0,085	0,339	0,212	4
A5	0,338	0,019	1,000	0,889	0,944	1
A6	0,029	0,174	0,086	0,000	0,043	6

After calculating the PDA and NDA, weighted total positive values (SP_i), weighted total negative values (SN_i), weighted normalized positive values (NSP_i), weighted normalized negative values (NSN_i) and appraisal scores (AS_i) were calculated. Table 9 shows the EDAS method results and the ranking of alternatives. It is understood from Table 9 that the best alternative is A5. The second rank is A3, and the last is A6.

CODAS Method Results

The CODAS method was applied to the decision matrix given in Table 3. The decision matrix shown in Table 10 was obtained using equation (31).

Later, Euclidean distances (E_i) and Taxicab distances (T_i) values and the assessment score (H_i) of each alternative were calculated. Table 11 shows the results of the CODAS method and the ranking of the alternatives.

Table 10. Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6
A1	0,5	1	0,77358	1	0,96045	0,92674
A2	0,5	1	0,60377	0,625	0,94444	0,98395
A3	0,5	1	1	1	0,89474	0,81058
A4	0,5	1	0,77358	0,625	0,97143	1
A5	1	1	0,66038	1	1	0,80294
A6	0,5	0,5	0,66038	1	1	0,90785

Table 11. Ranking of the alternatives according to the CODAS method

Alternatives	E_i	T_i	H_i	Rank
A1	0,13553	0,21279	-0,00720	3
A2	0,11082	0,11717	-0,15518	5
A3	0,14365	0,23861	0,04159	2
A4	0,11315	0,14059	-0,14129	4
A5	0,24259	0,39608	0,63766	1
A6	0,07525	0,08664	-0,36802	6

DISCUSSION

In the study, 6 alternative laptops were ranked according to EDAS, CODAS and TOPSIS methods. Comparison of the alternatives according to the results of EDAS, CODAS and TOPSIS methods can be seen in Table 12.

Table 12. Comparison of the ranking results

Alternative	TOPSIS	EDAS	CODAS
A1	3	3	3
A2	5	5	5
A3	2	2	2
A4	4	4	4
A5	1	1	1
A6	6	6	6

It can be understood from Table 12 that while A5 is in the first place in all three methods, A6 is in the last place. According to the TOPSIS, EDAS and CODAS methods results, the ranking of the alternatives was A5 > A3 > A1 > A4 > A2 > A6. Besides, the correlation between the results of the TOPSIS, EDAS and CODAS methods has been examined with the Spearman Correlation approach. The correlation results can be seen in Table 13. When Table 13 is examined, it is possible to say that there is a strong positive relationship between the methods used and the results obtained.

Table 13. The Spearman's correlation coefficient between the methods and the results

Correlations					
			TOPSIS	EDAS	CODAS
Spearman's rho	TOPSIS	Correlation Coefficient	1,000	1,000**	1,000**
		Sig. (2-tailed)	.	.	.
		N	6	6	6
	EDAS	Correlation Coefficient	1,000**	1,000	1,000**
		Sig. (2-tailed)	.	.	.
		N	6	6	6
	CODAS	Correlation Coefficient	1,000**	1,000**	1,000
		Sig. (2-tailed)	.	.	.
		N	6	6	6
**. Correlation is significant at the 0.01 level (2-tailed).					

Source: Author's calculation in the SPSS24 statistics software

CONCLUSIONS

Nowadays, the demand for computers is increasing day by day with personal or corporate needs and developments in science and technology. This demand for computer technologies has led to the diversification of computer types such as desktop computers, laptops, tablets, netbooks, gaming computers and network computers. Laptops are preferred over desktop computers due to their lightweight and portable features. Choosing the most suitable laptop for businesses is a decision-making problem. MCDM methods are generally used in cases where there are multiple criteria and alternatives. TOPSIS, EDAS and CODAS methods are some of the MCDM methods.

In this study, 6 different laptop alternatives were evaluated by TOPSIS, EDAS and CODAS methods according to the criteria of hard disk capacity, RAM, battery power, processor speed, weight and price for the laptop selection of an e-commerce company. The weights of the criteria used in the study have been calculated by the Entropy method. According to the Entropy method results, the criteria with the highest weight is the hard disk capacity criterion with 0.405. This criterion is followed by ram, processor speed, battery power, price, weight criteria. The alternatives were ranked according to the TOPSIS, EDAS and CODAS method results and the best alternative was selected as A5. According to the results of the study, the last alternative in the ranking was A6. According to the result of Spearman Correlation analysis, it is possible to say that there is a strong positive relationship between the methods used and the results obtained.

As with many other studies, this study has some limitations. The use of 6 criteria and 6 alternatives in the study is one of the limitations of the study. The other limitation is that the work has been carried out in Turkey. Another limitation is that the study was conducted in the field of online commerce. Future studies on this subject can be carried out in different sectors and different countries. Besides, different MCDM methods and different criteria can be used in future studies. There may be future work topics in applications for the selection of different machinery and equipment, location selection, or supplier evaluation. By taking different values in future studies, the CODAS method can be used with other MCDM methods.

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REFERENCES

Adalı E.A., Işık A.T., 2017. The multi-objective decision making methods based on MULTIMOORA and MOOSRA for the laptop selection problem, Journal of Industrial Engineering International, 13, 229-237. http://doi.org/10.1007/s40092-016-0175-5

Adalı E.A., Tuş A., 2019. Hospital site selection with distance-based multi-criteria decision-making methods, International Journal of Heathcare Management, 1-11. http://doi.org/10.1080/20479700.2019.1674005

Aggarwal A., Choudhary C., Mehrotra D., 2018. Evaluation of Smartphones in Indian Market using EDAS, Procedia Computer Science, 132, 236-243. http://doi.org/10.1016/j.procs.2018.05.193

Aldalou E., Perçin S., 2020. Financial Performance Evaluation of Food and Drink Index Using Fuzzy MCDM Approach, International Journal of Economics and Innovation, 6(1), 1-19. http://doi.org/10.20979/ueyd.650422

Altıntaş F., 2020. Analysis of Competition Performances of G 7 countries with Entropy based TOPSIS and EDAS Methods, Social Mentality and Researcher Thinkers Journal, 6(31), 737-748. http://doi.org/10.31576/smryj.521

Aytekin A., Durucasu H., 2020. Nearest solution to references method for multicriteria decision-making problems. Decision Science Letter, 10(2), 111-128. http://doi.org/10.5267/j.dsl.2020.11.007

Aytekin A., Karamaşa Ç., 2017. Analyzing Financial Performance of Insurance Companies Traded In BIST via Fuzzy Shannon's Entropy Based Fuzzy TOPSIS Methodology, Alphanumeric Journal, 5(1), 71-84. http://doi.org/10.17093/alphanumeric.323832

Aytekin A., Kuvat O., 2018. Determination of the importance levels of criteria evaluated in laptop selection by AHP: Application of 1st and 2st grade computer engineering students, Manas Journal of Social Studies 7(4), 193-211. Available on the Internet: https://dergipark.org.tr/tr/pub/mjss/issue/43010/520776

Badi I., Ballem M.A., Shetwan A.G., 2018. Site selection of desalination plant in Libya by using Combinative Distance-based Assessment (CODAS) Method, International Journal for Quality Research, 12(3), 609-624. http://doi.org/10.18421/IJQR12.03-04

Bakır M., Alptekin N., 2018. A new approach in service quality assesment: An application on airlines through CODAS method, Business & Management Studies: An International Journal, 6(4), 1336-1353. http://doi.org/10.15295/bmij.v6i4.409

Behzad M., Zolfani S.H., Pamucar D., Behzad M., 2020. A comparative assessment of solid waste management performance in the Nordic countries based on BWM-EDAS, Journal of Cleaner Production, 266, 1-11. http://doi.org/10.1016/j.jclepro.2020.122008

Behzedian M., Otaghsara S.K., Yazdani M., Ignatius J., 2012. A state-of the-art survey of TOPSIS applications, Expert Systems with Applications, 39(17), 13051-13069. http://doi.org/10.1016/j.eswa.2012.05.056

Chatterjee P., Banerjee A., Mondal S., Boral S., Chakraborty S., 2018. Development of a Hybrid Meta-Model for Material Selection Using Design of Experiments and EDAS Method, Engineering Transactions, 66(2), 187-207. Available on the Internet: http://et.ippt.pan.pl/index.php/et/article/view/812

Chen C.T., 2000. Extensions of the TOPSIS for group decision-making under fuzzy environment, Fuzzy Sets and Systems, 114(1), 1-9. http://doi.org/10.1016/S0165-0114(97)00377-1

Chiang C-T., Yang M-H., Koo T-L. Liao C.H., 2020. What drives costumer engagement behavior? The impact of user participation from a sociotechnical perspective, Journal of Electronic Commerce Research, 21(3), 197-214. Available on the Internet: http://www.jecr.org/node/612

Chitnis A., Vaidya O.S., 2016. Efficiency ranking method using DEA and TOPSIS (ERM-DT): case of an Indian bank, Benchmarking: An International Journal, 23(1), 166-182. http://doi.org/10.1108/bij-09-2013-0093

Çakır F.S., Pekkaya M., 2020, Determination of Interaction Between Criteria and the Criteria Priorities in Laptop Selection Problem. International Journal of Fuzzy Systems, 22, 1177–1190. http://doi.org/10.1007/s40815-020-00857-2

Debata B., Patnaik P., Mishra A. 2020. COVID-19 pandemic! It's impact on people, economy, and environment, Journal of Public Affairs An International Journal, 20(4), 1-5. http://doi.org/10.1002/pa.2372

De Matos C.A., Curth M, Garcia A.D.S., 2020. Customer loyalty in the online context: Understanding trust in different parties, Journal of Electronic Commerce Research, 21(4), 237-251. http://www.jecr.org/node/615

Deng F., Li Y., Lin H., Miao J., Liang X., 2020. A BWM-TOPSIS Hazardous Waste Inventory Safety Risk Evaluation, International Journal of Environmental Research and Public Health, 17(16), 1-18. http://doi.org/10.3390/ijerph17165765

Dehdasht G., Ferwati M.S., Zin R.M., Abidin N.Z., 2020. A hybrid approach using entropy and TOPSIS to select key drivers for a successful and sustainable lean construction implementation, PLoS ONE, 15(2), 1-32. http://doi.org/10.1371/journal.pone.0228746

Ecer F., 2018. Third-party logistics (3PLs) provider selection via fuzzy AHP and EDAS integrated model, Technological and Economic Development of Economy, 24(2), 615–634. http://doi.org/10.3846/20294913.2016.1213207

Ecer F., Pamucar D., Mardani A., Alrasheedi M., 2021. Assessment of renewable energy resources using new interval rough number extension of the level based weight assessment and combinative distance-based assessment, Renewable Energy, 170, 1156-1177. http://doi.org/10.1016/j.renene.2021.02.004

Erkayman B., Khorshidi M., Usanmaz B., 2018. An integrated fuzzy approach for ERP deployment strategy selection under conflicting criteria, Atatürk University Journal of Economics and Administrative Sciences, 32(3), 807-823. Available on the Internet: https://dergipark.org.tr/tr/download/article-file/503853

Ersoy Y. 2021. Performance Evaluation in Distance Education by Using Data Envelopment Analysis (DEA) and TOPSIS Methods, Arabian Journal for Science and Engineering, 46(2), 1803-1817. http://doi.org/10.1007/s13369-020-05087-0

George J., Singh A. Bhaisare A.K., 2018. Implementation of TOPSIS Technique for Supplier Selection, International Research Journal of Engineering and Technology (IRJET), 5(6), 2582-2585. Available on the Internet: https://www.irjet.net/archives/V5/i6/IRJET-V5I6484.pdf

Ghorabaee M.K., Zavadskas E.K., Olfat L., Turskis Z, 2015. Multi-Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS), INFORMATICA, 26(3), 435-451. http://doi.org/10.15388/Informatica.2015.57

Ghorabaee M. K., Zavadskas E.K., Turskis Z., Antucheviciene J., 2016. A New Combinativ Distance-Based Assessment (CODAS) Method For Multi-Criteria Decision Making, Economic Computation and Economic Cybernetics Studies and Research, 3(50), 25-44. Available on the Internet: http://www.ecocyb.ase.ro/Articles2016_3.htm

Ghorabaee M.K., Amiri M., Zavadskas E.K., Turskis Z., Antucheviciene J., 2017. A new hybrid simulation-based assignment approach for evaluating airlines with multiple service quality criteria, Journal of Air Transport Management, 63, 45-60. http://doi.org/10.1016/j.jairtraman.2017.05.008

Ghorabaee M.K, Amiri M., Zavadskas E.K., Antucheviciene J., 2018. A new hybrid fuzzy MCDM approach for evaluation of construction equipment with sustainability considerations, Archives of Civil and Mechanical Engineering, 18(1), 32–49. http://doi.org/10.1016/j.acme.2017.04.011

Hanine M., Boutkhoum O., Tikniouine A., Agouti T., 2016. Application of an integrated multi criteria decision making AHP TOPSIS methodology for ETL software selection, SpringerPlus, 5, 1-17. http://doi.org/10.1186/s40064-016-1888-z

Hwang C.L., Yoon K., 1981, Multiple Attributes Decision Making Methods and Applications, Springer, New York. http://doi.org/10.1007/978-3-642-48318-9

Jayant A., Sharma J., 2018. A comprehensive literature review of MCDM techniques Electre, Promethee, Vikor and Topsis applications in business competitive environment, International Journal of Current Research, 10(2), 65461-65477.

Juodagalvienė B., Turskis Z., Šaparauskas J., Endriukaitytė A., 2017, Integrated Multi-criteria Evaluation of House's Plan Shape based on The EDAS and SWARA Methods. Engineering Structures and Technologies, 9(3), 117-125. http://doi.org/10.3846/2029882X.2017.1347528

Kahraman C, Ghorabaee M.K., Zavadskas E.K., Onar, S.C., Yazdani, M., Oztaysi B.,

2017. Intuitionistic fuzzy EDAS method: an application to solid waste disposal site selection, Journal of Environmental Engineering and Landscape Management, 25(1), 1-12. http://doi.org/10.3846/16486897.2017.1281139

Kalyani K.S., Nagarani S., Maragatham L., Kumar N.D., 2016. Multi criteria decision making for selecting the best laptop. IJCTA (International Journal of Control Theory and Applications), 9(36), 437-441.

Kaplinski O., Peldschus F., Nazarko J., Kaklauskas A. Baušys R., 2019. MCDM, operational research and sustainable development in the trans-border Lithuanian–German– Polish co-operation, Engineering Management in Production and Services, 11(2). 7-18. http://doi.org/10.2478/emj-2019-0007

Karabasevic D., Zavadskas E.K., Stanujkic D., Popovic G., Brzakovic M., 2018. An Approach To Personnel Selection In The It Industry Based On The EDAS Method, Transformations in Business & Economics, 17(2), 54-65. Available on the Internet: http://www.transformations.knf.vu.lt/44/article/anap

Kecek G., Demirağ F., 2016. A comparative analysis of TOPSIS and MOORA in laptop selection, Research on Humanities and Social Sciences, 6(14), 1-9. Available on the Internet: https://www.iiste.org/Journals/index.php/RHSS/article/view/32077/32947

Kolios A., Mytilinou V., Lozano-Minguez E., Salonitis K., 2016, A Comparative Study of Multiple-Criteria Decision-Making Methods under Stochastic Inputs, Energies, 9(7), 1-21. http://doi.org/10.3390/en9070566

Kundakcı N., 2019. An integrated method using MACBETH and EDAS methods for evaluating steam boiler alternatives, Journal of Multi-Criteria Decision Analysis, 26, 27-34. http://doi.org/10.1002/mcda.1656

Lakshmi T.M., Venkatesan V.P., Martin A., 2015. Identification of a Better Laptop with Conflicting Criteria Using TOPSIS, International Journal of Information Engineering and Electronic Business, 6, 28-36. http://doi.org/10.5815/ijieeb.2015.06.05

Li X., Liao Q., Luo X(R)., Wang Y., 2020., Juxtaposting impacts of social media interaction experiences on e-commerce reputation, Journal of Electronic Commerce Research, 21(2), 75-95. Available at: http://www.jecr.org/node/602

Liang W., Zhao G., Luo S., 2018. An Integrated EDAS-ELECTRE Method with Picture Fuzzy Information for Cleaner Production Evaluation in Gold Mines, IEEE Access, 6, 65747-65759. http://doi.org/10.1109/ACCESS.2018.2878747

Liang Y., 2020. An EDAS Method for Multiple Attribute Group Decision-Making under Intuitionistic Fuzzy Environment and Its Application for Evaluating Green Building Energy-Saving Design Projects, Symmetry, 12(3), 1-12. http://doi.org/10.3390/sym12030484

Mardani A., Jusoh A., Nor K.M.D., Kahalifah Z., Zakwan N., Valipour A., 2015. Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014, Economic Research-Ekonomska Istraživanja, 28(1), 516-571. http://doi.org/10.1080/1331677X.2015.1075139

Mathew M., Sahu S., 2018. Comparison of new multi-criteria decision making methods for matiral handling equipment selection. Management Science Letters, 8(3), 139-150. http://doi.org/10.5267/j.msl.2018.1.004

Mathew M., Thomas J., 2019. Interval valued multi criteria decision making methods for the selection of flexible manufacturing System, International Journal of Data and Network Science, 3, 349-358. http://doi.org/10.5267/j.ijdns.2019.4.001

Mitra S., Goswami S.S., 2019, Application of Integrated MCDM Technique (AHPSAW) for the Selection of Best Laptop Computer Model, International Journal for Research in Engineering Application & Management (IJREAM), 4(12), 1-6. http://doi.org/10.18231/2454-9150.2019.0091

Palczewski K., Salabun W., 2019. The fuzzy TOPSIS applications in the last decade, Procedia Computer Science, 159, 2294-2303. http://doi.org/10.1016/j.procs.2019.09.404

Pekkaya M., Aktogan M., 2014. Laptop Selection: A comparative analysis with DEA, TOPSIS and VIKOR. The International Journal of Economic and Social Research, 10(1), 107-125. https://dergipark.org.tr/tr/pub/esad/issue/6069/81670

Posel D., Oyenubi A., Kollamparambil, U., 2021. Job loss and mental health during the COVID-19 lockdown: Evidence from South Africa. PLoS ONE, 16(3), 1-15. http://doi.org/10.1371/journal.pone.0249352

Rezaei J. 2015. A Systematic Review of Multi-criteria Decision-making Applications in Reverse Logistics, Transportation Research Procedia, 10, 766-776. http://doi.org/10.1016/j.trpro.2015.09.030

Saadat S., Rawtani D., Hussain C.M., 2020. Environmental perspective of COVID-19, Science of the Total Environment, 728, 1-8. http://doi.org/10.1016/j.scitotenv.2020.138870

Shih H-S., Shyur H-J, Lee E.S., 2007. An extension of TOPSIS for group decision making, Mathematical and Computer Modelling, 45(7-8), 801-813. http://doi.org/10.1016/j.mcm.2006.03.023

Siew L.W., Wai C.J., Hoe L.W., 2016. An empirical study on the preference of laptop in Malaysia with analytic hierarchy process model, SCIREA Journal of Computer Science and Technology, 1(2), 127-141. Available on the Internet: http://www.scirea.org/journal/PaperInformation?PaperID=218

Siksnelyte-Butkiene I., Streimikiene D., Balezentis T., Skulskis V., 2021, A Systematic Literature Review of Multi-Criteria Decision-Making Methods for Sustainable Selection of Insulation Materials in Buildings. Sustainability, 13(2), 1-21. http://doi.org/10.3390/su13020737

Simic V., Karagoz S., Deveci M., Aydin N., 2021. Picture fuzzy extension of the CODAS method for multi-criteria vehicle shredding facility location, Expert Systems with Applications, 175, 1-37. http://doi.org/10.1016/j.eswa.2021.114644

Srichetta P., Thurachon W., 2012. Applying Fuzzy Analytic Hierarchy Process to Evaluate and Select Product of Notebook Computers, International Journal of Modeling and Optimization, 2(2), 168-173. http://doi.org/10.7763/IJMO.2012.V2.105

Stanujkic D., Zavadskas E.K., Ghorabaee M.K., Turskis Z., 2017. An Extension of the EDAS Method Based on the Use of Interval Grey Numbers, Studies in Informatics and Control, 26(1), 5-12. http://doi.org/10.24846/v26i1y201701

Stanujkic D., Jevtic M., Ivanov B., 2018, An approach for laptop computers evaluation using multiple-criteria desicion analysis, 263-267. Proceeding of International Scientific Conference, 16-17 November 2018, GABROVO. Available on the Internet: http://unitech-selectedpapers.tugab.bg/2018/papers/s4_p64.pdf

Stević Ž., Pamučar D., Vasiljević M., Stojić G., Korica S., 2017. Novel Integrated Multi-Criteria Model for Supplier Selection: Case Study Construction Company, Symmetry, 9(11), 1-34. http://doi.org/10.3390/sym9110279

Statista., 2020. E-Commerce: Retail e-commerce sales worldwide from 2014 to 2023, Available on the Internet: www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/ 2020. Accessed: 2 January 2021.

Trinkūnienė E., Podvezko V., Zavadskas E.K., Jokšienė I., Vinogradova I., Trinkūnas V., 2017. Evaluation of quality assurance in contractor contracts by multi-attribute decision making methods, Economic Research-Ekonomska Istraživanja, 30(1), 1152–1180. http://doi.org/10.1080/1331677X.2017.1325616

Turskis Z., Morkunaite Z., Kutut V., 2017. A hybrid multiple criteria evaluation method of ranking of cultural heritage structures for renovation projects, International Journal of Strategic Property Management, Vo21(3), 318-329. http://doi.org/10.3846/1648715X.2017.1325782

Ulutaş A., Cengiz E., 2018. Laptop selection for a business with CRITIC and EVAMIX method, The Journal of International Social Research, 11(55), 881-887. http://doi.org/10.17719/jisr.20185537260

Ulutaş A., 2019. The performance analysis of logistics companies with Entrophy based EDAS method, International Journal of Economics and Administrative Studies, 23, 53-66. http://doi.org/10.18092/ulikidince.458754

Urbancokava V., Kompan M., Trebulova Z., Bielikova M., 2020. Behavior-based customer demography prediction in e-commerce, Journal of Electronic Commerce Research, 21(2), 96-112. Available at: http://www.jecr.org/node/603

Vimal J., Chaturverdi V., Dubey A.K., 2012. Application of TOPSIS method for supplier selection in manufacturing industry. International Journal of Research in Engineering & Applied Sciences (IJREAS), 2(5), 25-35.

Yalçın N., Pehlivan N.P., 2019. Application of the Fuzzy CODAS method based on fuzzy envelopes for hesitant fuzzy linguistic term sets: A case study on a personnel selection problem, Symmetry, 11(4), 1-27. http://doi.org/10.3390/sym11040493

Yorulmaz M., İç Y.T., Seyrek A., 2019. Development of a Decision Support System for Computer Replacement Decisions, International Journal of Informatics Technologies, 12(3), 195-202. http://doi.org/10.17671/gazibtd.510657

Zhang S., Gao H., Wei G., Wei Y., Wei C., 2019. Evaluation Based on Distance from Average Solution Method for Multiple Criteria Group Decision Making under Picture 2-Tuple Linguistic Environment, Mathematics, 7(3), 1-16. http://doi.org/10.3390/math7030243

You P., Guo S., Zhao H., Zhao H. 2017. Operation performance evaluation of power grid enterprise using a hybrid BWM-TOPSIS method, Sustainability, 9(12), 1-15. http://doi.org/10.3390/su9122329

Wang T.C., Lee H D., 2009, Developing A Fuzzy TOPSIS Approach Based on Subjective Weights and Objective Weights, Expert Systems with Applications, 36(5), 8980-8985. http://doi.org/10.1016/j.eswa.2008.11.035

Wang E., Alp N., Shi J., Wang C., Zhang X., Chen H., 2017, Multi-criteria building energy performance benchmarking through variable clustering based compromise TOPSIS with objective entropy weighting, Energy, 125, 197-210. http://doi.org/10.1016/j.energy.2017.02.131

Xu X., Wu J-H., Li Q., 2020. What drives consumer shopping behaviour in live streaming commerce?, Journal of Electronic Commerce Research, 21(3), 144-167. Available at: http://www.jecr.org/node/609

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ORIGINAL PAPER

IMPACT OF GREEN SUPPLY CHAIN MANAGEMENT ON FINANCIAL AND ENVIRONMENTAL PERFORMANCE: MEDIATING ROLE OF OPERATIONAL PERFORMANCE AND THE MODERATING ROLE OF EXTERNAL PRESSURES

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ABSTRACT. Background: Green supply chain management (GSCM) practices are considered as vital practices in tackling environmental issues faced by firms. This study examines the relationship between GSCM, environmental and financial performance of firms. Further, the study examines the mediating role of operational performance between the relationships of GSCM-environmental performance and GSCM-financial performance. Additionally, the moderating role of external pressures (regulatory and customer pressures) has been examined on the relationship of GSCM and operational performance.

Methods: Data from 277 executives working in different industries of Pakistan (where GSCM practices have been adopted) has been collected for the study.

Results: The results of the mediated regression analysis confirm the partial mediation of operational performance between GSCM, environmental and financial performance. The results of moderated regression analysis confirm that presence of external pressures enhances the relationship between GSCM and operational performance.

Conclusions: These results suggest that the adoption of GSCM practices in Pakistan can be fruitful for the companies. Mandatory requirement by regulatory authorities can also be helpful in adoption of the GSCM practices which ensure environmental performance of firms and consequently the betterment of overall environment.

Key words: Customer Pressures, Financial Performance, Environmental Performance, Green Supply Chain Management, Regulatory Pressures.

INTRODUCTION

Environmental issues including rapid depletion of natural resources, contamination of the atmosphere, global warming and decline in biological diversity leads to the degradation of the ecosystem. Last few decades have seen a massive rise in mass awareness regarding these environmental issues resulting in an ever-increasing demand for eco-friendly products and systems. Modern day organizations now clamour for systems and mechanisms that make them "environment friendly" and help them in positioning themselves as "Green". One among many such mechanisms is green supply chain management (GSCM).

Green supply chain management (GSCM) is a process that involves management of both upstream and downstream supply chain through green supply chain management practices in order to minimize the general effect of forward as well as reverse supply flows on the environment [Solér et al., 2010].

These practices can be classified as: (i) internal practices and (ii) external practices [Zhu et al., 2005]. However, research suggests that in order to study GSCM in a better way,

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a uni-dimensional green supply chain management (GSCM) construct is more appropriate that includes all its dimensions [Zhu et al., 2013].

Since the seminal work in the area of GSCM, researchers and practitioners have been examining the antecedents of GSCM and its effect on different organizational level outcomes. Among others, market performance, financial performance and top management commitment [Blome et al., 2014], and institutional pressures [Zhu et al., 2013] have been identified as key antecedents of GSCM. Likewise, green procurement, green supplier development and supplier performance [Blome et al., 2014] and organizational performance [Diab et al., 2015] have been identified as key outcomes of GSCM.

Organizational performance being the ultimate objective of firm is the most important outcome for any system. More recently, organizational performance has been divided into two sub parts including financial and environmental performance. Previous research has linked GSCM with both financial [Feng et al., 2018; Khan, Qianli, 2017] and environmental performance [Seman et al., 2019]. However, the results of existing literature on these relationships are mixed, inconsistent and confusing, thus requiring more in depth analysis to identify the possible linkages (direct or indirect) between the variables.

Inconclusive results of the direct relationship provide a guideline to look for the mechanisms that can help in understanding the indirect relationship between GSCM, environmental and financial performance. In line to this thought, we present operational performance as a possible underlying mechanism that can help in understanding the relationship between GSCM, environmental and financial performance in a better way. GSCM practices enhance the operational efficiency that can ultimately help in improving financial and environmental performance. Previous research also suggests that operational efficiencies caused by GSCM can lead to better organizational performance [Feng et al., 2018].

Furthermore, evidence suggests that the adoption of environment friendly strategies by organizations is a reaction to the external stakeholders including customers and regulatory authorities [e.g. see, Lee et al., 2012]. This stance appears logical as significant initiatives are being taken at global level to ensure environment protection. For instance, United Nations (UN) agenda for sustainable development 2030 emphasises on achievement of healthy environment and same is evident in UN sustainable development goals (goal number 6: clean water and sanitation, goal number 7: affordable and clean energy and goal number 13: climate action). Thus, the legal framework of countries and pressures from legal authorities and customers can be influential in adoption of such strategies.

Researchers have also suggested studying GSCM and its relation with organizational performance in context of external pressures. Keeping in view these practical considerations and calls for research, we examine external pressures as moderator between GSCM and operational performance of organization. The purpose of this study is thus three-fold: (i) to examine the relationship between GSCM, environmental and financial performance (ii) to examine operational performance as a mediator between GSCM, environmental and financial performance and (iii) to examine the moderating role of external pressures on relationship of GSCM and operational performance.

Our study adds to the existing body of knowledge in several different ways. Firstly, given the inconclusive nature of results on the relationship between GSCM, environmental and financial performance, it is important to understand the mechanisms that can help in explaining these relationships. We thus examine operational performance as a mediator between these relationships. Mediation analysis has not gained much attention by researchers in this area. Although, Feng et al., [2018] have examined the mediating role of operational performance between GSCM and financial performance, the mediating role of operational performance between GSCM and environmental performance is yet to be explored in literature. Secondly, we add to the existing body of knowledge by examining the moderating role of external pressures on the relationship of GSCM and operational performance. By doing so, we also respond to the call for future research by Feng et al. [2018]. Lastly, the context of our study is different from any previous research in the area of GSCM. Our study is concerned with an emerging economy i.e. Pakistan. So, we also add to the existing literature by reporting the results from a different context.

Rest of the paper follows this sequence: Next section describes literature review and hypotheses development followed by methodology. After that, results are explained and discussed. Paper ends with a conclusion, implications and directions for future research.

LITERATURE REVIEW

Green Supply Chain Management and Financial Performance

Within the perspective of GSCM, companies are currently adopting the practices of environmentally friendly supply chain as a priority for both environmental sustainability and financial performance. It is possible to achieve better financial results through cost and resource management.

Researchers have revealed that GSCM practices have a positive association with the economic performance of an enterprise [Rao, Holt, 2005]. Sustainable business activities are helpful in increasing revenue, operating cash flows and pre-tax income [Ameer, Othman, 2012].

GSCM can economically boost the performance of the firm in two aspects [Hart, 1995]. First, by cutting waste costs and energy costs as part of GSCM, companies can gain financial benefits directly. Second, by enhancing their commitment and business reputation through environmentally friendly practices, companies can increase financial benefits from indirect ways [Schmidt et al., 2017]. Greater environmental performance can be attained through the implementation of pollution prevention techniques, this leads to zero waste which ensures that no pollution control costs and high waste disposal costs are expended, which means lower costs to tackle environmental waste and for waste treatment due to the usage of toxic substances [Klassen and McLaughlin, 1996].

Cross country and cross industry evidence suggests that green practices like green supply chain management (GSCM) improves the financial and economic position of a business when implemented appropriately, not always raising revenues, but certainly improving economic performance [Zhu et al., 2010]. However, the empirical studies on the subject shows mixed results too regarding the direction of the relationship between GSCM and financial performance. For instance, Sezen and Çankaya [2013] found no significant associations between adoption of GSCM/green activities and enhancement in financial outcomes for firms in Turkey. Likewise, studies suggest that GSCM does not have a direct impact on economic growth but can indirectly enhance it [Zhu et al., 2010]. The meta-analysis of Golicic and Smith [2013] also confirms the inconclusive results on the subject. Despite of the inconclusive evidence, the positive relationship between GSCM and financial performance is well supported by the theory. From Pakistani perspective, Jawaad and Zafar [2019] reported optimistic effects of GSCM on financial performance. They indicated that due to higher prices imposed by suppliers sometimes for their environmental friendly raw materials, packaging and, in general, fewer suppliers in the market, manufacturers experience lower cost efficiency and substantial increase in EBITDA in this sector at the beginning stages of implementation of GSCM. Keeping in view the above discussion, we propose that

Hypothesis 1: Green supply chain management (GSCM) is positively related to financial performance.

Green Supply Chain Management (GSCM) and Environmental Performance

GSCM practices are progressively known as a systematic and extensive mechanism for achieving better environmental performance. The literature provides substantial proof that GSCM enhance environmental performance of different industries [Kumar et al., 2019; Zhu et al., 2013].

The reduction of hazardous materials and solid waste through the use of sustainable raw materials with organizational support ensures that environmental contamination is reduced.

Environmental performance examines the company's ability to decrease pollution, improve efficiency and avoid the use of dangerous substances. The GSCM activities include all efforts to limit the negative environmental effects of a firm's products and services. Such efforts have a beneficial impact on enhancing environmental performance by decreasing the usage of solid wastes or liquid wastes and dangerous substances, reducing the occurrence of ecological accidents and also improving health [Eltayeb et al., 2011].

GSCM eliminates damage to the environment because collaboration among functions, suppliers as well as customers enables to recognize and resolve environmental problems [Wong et al., 2015]. Through collaboration, pollution and waste in manufacturing, transportation procedures and products in use can be decreased by implementing green-design and green-packaging. Researchers [e.g. Zailani et al. 2012] reported that GSCM if implemented appropriately have strong optimistic impact on environmental outcomes/performance. The basic philosophy behind the green idea is to improve the environmental sustainability, but companies are adopting the green idea as "kill two enemies with one bullet". Because, GSCM can minimize emissions and manufacturing costs, as well as stimulate economic growth, build competitive benefits in terms of customer satisfaction, credibility and positive image, and provide greater opportunities to sell their products to environmentally friendly countries [Khan, Qianli, 2017]. Luthra et al. [2016] stated that, with the implementation of sustainable design in supply chain management, 80% of environmental impacts could be managed/controlled. Green product design supports product reuse and recycling, which help companies to enhance their environmental performance and also offer opportunities to lower their costs by adopting green design in supply chain management. Thus, we propose that:

Hypothesis 2: Green supply chain management (GSCM) is positively related to environmental performance.

Mediating Role of Operational Performance between GSCM and Financial Performance

With the implementation of various sustainable practices, businesses are increasing their profitability through supply chain operations. Excellent operational performance shows the ability to fulfil customer's demand in the form of time and quick distribution of superior goods and services, waste disposal and operational flexibility in manufacturing processes [Wong et al., 2015].

Product quality, operational efficiency or distribution are the foundation for service quality which leads to financial benefits and customer retention. Operational efficiency helps in cost reduction while at the same time addressing growing customer's needs for eco-friendly high quality products, contributing to greater financial performance. Cost reduction is considered to be the most significant element for businesses to adopt eco-friendly practices in their operations of supply chain.

GSCM activities are not intended to gain profit and shares in new markets but adopted to achieve the objectives of cost reduction as well as resource efficiency though minimizing damage to the environment. It is the improved operational performance which creates new sales, productivity and reduction of costs. In other words, enhanced operational efficiency indirectly improves financial performance [Feng et al., 2018]. Some researchers found that the absence of a systematic relationship between adoption of green supply chain management (GSCM) practices and financial performance to be a possible obstacle [Stefan and Paul, 2008]. The performance of the firm in terms of profitability can be increased if its operating costs are decreased.

Operational performance improvements lowers the material usage and waste creation and therefore cut the costs of buying and handling or discharging products. Sustainable environmental programs not only enhance resource efficiency, but also enhance financial performance. Sustainable management of companies can boost productivity/ competitiveness through greater environmentally friendly-efficiency. The above discussion shows that GSCM enhances operational performance of firms which in turn enhances the financial performance. Thus, we propose that

Hypothesis 3: Operational performance mediates the association of GSCM and financial performance.

Mediating Role of Operational Performance between GSCM and Environmental Performance

Green supply chain management involves product design for re-use, product recycling and reduced energy usages, which improves the use of material and minimize waste in production of goods, thereby enhancing eco efficiency [Green et al., 2012]. By implementing GSCM practices, companies may boost their operational efficiency by reducing the cost, maintaining the quality of products and delivery service [Yusuf et al., 2013].

Manufacturers can maintain a good strategic and economic position in cooperation with their business partners, customers and vendors if they incorporate sustainable development in a way that minimizes the cost [Vachon and Klassen, 2006].

Firms implement environment friendly supply chain in a way that helps them in reducing their environmental/ecological impacts through operational efficiency [Svensson, 2007]. A company's operational functions confronts environmental issues directly as it is the primary source for operating emissions. Improved operational performance shows the customer satisfaction in the form of low cost products, maintaining the quality of products and delivery service, efficiency and reduction of waste in manufacturing [Wong et al., 2015].

By focusing on environmental friendly design, organizations can fulfil the requirements for green design through green procurement and can gain more opportunities in new markets. It requires coordination with vendors for the procurement of green products and materials/parts.

Effective cooperation leads to improved logistics and new product development functions in response to sudden changes in the market enabling firms to attain higher operational performance, eliminate waste and more efficient use of resources. Improved performance is a major driver for companies looking for the execution of environmentally friendly practices [Zhu et al., 2010, 2013]. GSCM can be used to evaluate product design and manufacturing processes. Proactive management of the environment highlights the use of emissions prevention in production processes rather than of emissions control technologies [Klassen and Whybark, 1999].

Hypothesis 4: Operational performance mediates the association of GSCM and environmental performance.

Moderating Role of External Pressure between GSCM and Operation Performance

Environmental laws and future economic advantages of implementing sustainable policies have driven industries to follow various environmental management practices. Customers and regulators are constantly enforcing the corporations to produce the products that enhance operational efficiency and minimize adverse effects on environment [Kleindorfer et al., 2005].

Companies have to face lower demands from customers and also increased penalties imposed by government, when their eco-friendly practices are doubtful [Klassen, McLaughlin, 1996]. Therefore, it becomes increasingly important for supply chain firms to comply with regulations in order to conduct environment friendly strategies. Green supply chain practices (GSCM) help businesses to have good image by mitigating environmental damage in stakeholder's mind, community, consumers/customers, employees and government. This good image is very essential for customer satisfaction and loyalty as well as staff [Hoffman, 2001]. Successful green practices can improve the relationships between companies and all the stakeholders involved.

Increasing environmental importance has pushed regulators to stringently enforce their environmental policies and regulations [Jayaram and Avittathur, 2015]. It is necessary for firms to incorporate their supply chain processes in order to reduce costs and meet customer and environmental standards. Customers play a major role in the sustainable supply chains. Researchers indicated that pressures from buyer or customer as a driving force for adopting the practices of GSCM. Chavez et al. [2014] concluded that customer pressure is a significant antecedent factor for the formulation of green practices, which then leads to gain operational efficiency.

A number of stakeholders and organizational pressures are important driving factors for businesses to follow environmentally friendly supply/value chain. Regulatory or administrative interference is really a driving force for incorporating GSCM activities [Gonzalez-Benito and Gonzalez-Benito, 2006]. Consumers expect more quality, reliability and value from goods, and with increasing awareness of the environment, this level of pressure generates new business opportunities [Paquette 2005]. Keeping in view the above discussion, we propose that Hypothesis 5: External pressures moderate the relationship of GSCM and operational performance in a way that the relationship will be strong when external pressures are high. The Figure 1 depicts the model of the study.

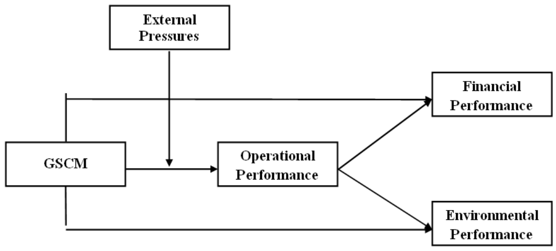


Fig. 1. Research Model

METHODS

Sample and data collection procedure

Data for this study were gathered from executives of several industries like manufacturing, pharmaceutical, logistics, electronic, and agricultural products working in Pakistan. The data were gathered from executives of the private as well as public sector firms. These industries were located in different cities including Islamabad, Rawalpindi, Faisalabad, Sialkot, Lahore, Peshawar, and Mirpur (AJandK). The reason of choosing various industries was that green supply chain management (GSCM) plays its role in every industry and all companies in one industry aren't incorporating GSCM practices. Thus, we had to look for companies around different sectors that implement GSCM. Using convenience sampling, surveys were distributed to 420 executives working in such companies. Participation in the survey was voluntary. Out of 420 surveys distributed, 313 were returned, 36 were not appropriate/ usable and 277 responses were found usable for analysis. So, the response rate of the study is 65%. Demographic characteristics of the sample reveal that 63.5% of the respondents were male. 49.1% of the respondents had either a bachelors (16 year education) degree or above. A large proportion of respondents i.e. 32.9% (n=91) were from logistics while 28.2% (n=78) respondents were from pharmaceuticals, 17.7% (n=49) respondents were from food industries, 12.3% (n=34) were from electronic industries and 9.0% (n=25) were from chemicals industry.

Measures

All study variables were measured using five point likert scale ranging from 1 to 5 (where 1 = Strongly Disagree and 5 = Strongly Agree) except financial performance. For, financial performance the scale was (1= Much worst, 2= somewhat worst 3=Stayed the same, 4= somewhat better, 5= Much better).

Green supply chain management (GSCM)

GSCM was measured using 7 item scale of Zhu et al. (2010). Sample item of the scale include: "In my organization cross-functional cooperation is exercised for environmental improvements". Cronbach alpha reliability of the scale was .768.

Operational performance

Operation performance was measured using 6 item scale which of Flynn et al. [2010]. Sample item of the scale includes: "Our Company can quickly respond to changes in market demand". Cronbach alpha reliability of the scale was .767.

Financial performance

Financial performance was measured by using 4 item scale of Flynn et al. [2010]. Sample item of the scale include: "Growth in sales", "Growth in profit". Cronbach alpha reliability of the scale was .701.

Environmental Performance

The 5 item scale developed by Zhu et al., (2010), was used to measure the environmental performance. Sample item of the scale includes "Decrease in consumption for hazardous/harmful/toxic materials". Cronbach alpha reliability of the scale was .773.

External Pressures

We considered external pressures as a sum of regulatory pressure and customer pressure in this study. The external pressures were measured by using 10 item scale developed by Eltayeb and Zailani [2010]. Sample item of the scale are: "there are frequent government inspections or audits on my firm to ensure that the firm is in compliance with environmental laws and regulations", "Increased awareness of environmental issues among our customers." Cronbach alpha reliability of external pressure was .857.

Control Variables

We conducted one way-ANOVA in order to identify the control variables. The results are shown in Table 1.

The results as shown in Table 1 indicate that no demographic variable causes distortion in dependent variables. Hence, no demographic variable was controlled in regression analysis.

Table 1. One-way ANOVA

	OP		FP		EP	
Sources of variations	**F Statistics**	**p-value**	**F Statistics**	**p-value**	**F Statistics**	**p-value**
Gender	1.060	.304	.915	.340	.038	.846
Age	1.244	.292	1.676	.156	.951	.210
Education	.503	.733	.530	.713	.628	.643
Industry	2.273	.062	.862	.487	.590	.370
Job Position	1.290	.274	2.038	.089	.964	.428
Experience	.843	.493	1.395	.236	1.793	.130

OP= Operational Performance, FP= Financial Performance, EP= environmental Performance

RESULTS

Descriptive Statistics and Correlation Analysis

The results for descriptive statistics and correlation analysis are shown below in Table 2.

Table 2. Descriptive Statistics and Correlation Analysis

Variable	Mean	Std. Deviation	GSCM	OP	EP	FP	EXP
GSCM	3.68	.666	1				
OP	3.79	.683	.636**	1			
EP	3.77	.717	.361**	.347**	1		
FP	3.79	.727	.680**	.870**	.366**	1	
EXP	3.86	.661	.459**	.499**	.544**	.458**	1

n=277, **=p<0.01, GSCM= Green Supply Chain Management, OP= Operational Performance, EP= Environmental Performance, FP= Financial performance, EXP= External Pressure

The results of correlation analysis as shown in table-2 indicates a positive association between green supply chain and financial performance (r=.680, p< 0.01), which initially supports H1. The results also show that GSCM is correlated with environmental performance (r=.361, p< 0.01). This provides initial support for hypothesis H2.

Mediated regression analysis

We used Preacher and Hayes [2008] macro for examining the mediating mechanisms. The results of mediation analysis are shown in Table 3.

Table 3. Mediated Regression Analysis

	B	P-value	LLCI	ULCI
STUDY MODEL-1 (GSCM → OP→FP)				
Direct effect:				
GSCM → FP	0.23	0.000	0.15	0.31
Indirect effect:				
GSCM → OP→FP	0.59		.39	.64
		R^2	**0.40**	
		F-stat	**186.6 (0.000)**	
STUDY MODEL-2 (GSCM → OP→EP)				
Direct effect:				
GSCM → EP	0.24	0.002	0.08	0.39
Indirect effect:				
GSCM → OP → EP	0.14		.01	.27
		R^2	**0.41**	
		F-stat	**62.4 (0.000)**	

n=277, GSCM=Green supply chain management, OP=operational performance, FP=Financial performance, EP=Environmental performance

In study model 1, the direct impact of GSCM on financial performance is investigated and the results of regression analysis show that GSCM positively influences the financial performance of the organization (β=0.23, p<0.01). These results support hypothesis H1. In study model 2, the direct impact of GSCM on environmental performance has been investigated and the outcomes which were obtained from regression analysis show that GSCM positively effects environmental performance (β=0.23, p<0.05).

In order to verify mediation, the findings of bootstrap for indirect effect are also shown in the table above. The indirect effect of operational performance (OP) lies between LLCI= .39 to ULCI= .64. So, the indirect impact on financial performance due to GSCM is significant. Therefore, it can be concluded that the association between GSCM and financial performance is partially mediated by operational performance. Thus hypothesis H3 is also supported.

The indirect effect of operational performance (OP) on the association of GSCM and environmental performance lies between LLCI= .01 to ULCI= .27. Therefore, the association between GSCM and environmental performance is also partially mediated by operational performance. Thus, hypothesis H4 has also been supported.

Moderated Regression Analysis

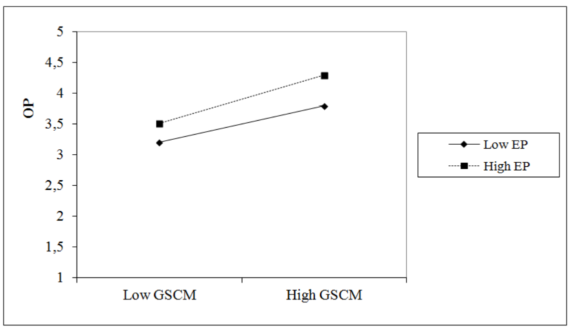
The results of moderation analysis are shown in Table 4.

Table 4. Moderated Regression Analysis

Predictor(s)	OP		
	B	R^2	ΔR^2
Step-I			
GSCM (IV)	.529***		
EXP (Mod)	.271***	.458	.458***
Step-II			
GSCM x EXP	.110*	.467	.009*

n=277, *=p<0.05, **=p<0.01, ***=p<0.001,
GSCM=Green supply chain management, EXP= External pressure, OP=operational performance

The table above indicates the results of the moderation regression analysis. The results of regression analysis show that external pressures moderates the relationship between GSCM and operational performance (β = .110, $p<0.05$) thus H5 is supported. For better understanding, the interactive effect of GSCM and external pressures on operational performance have been plotted in Figure 2.



GSCM= Green Supply Chain Management, EP= External Pressure, OP= Operational Performance

Fig. 2. Interactive Effect of GSCM and External Pressures on Operational Performance

DISCUSSIONS AND CONCLUSION

Numerous studies have been conducted on green supply chain management and its implications on organizational performance in different countries [e.g. see, Wong et al., 2015]. Still, there remains a deficiency of clear knowledge and evidence of how green/environmentally friendly supply chain impacts financial performance directly and indirectly [Golicic, Smith, 2013].

This study examined the mediating role of operational performance on relationships of (i) GSCM and financial performance and (ii) GSCM and environmental performance. This study also examined the moderating role of external pressures (regulatory pressure and customer pressure) on the association of GSCM and operational performance to test whether the association between them is stronger or weaker due to such pressures. Overall results of the study support the formulated hypothesis.

First hypothesis of the study was that GSCM is positively related with financial performance of the organization. The results support this hypothesis. As stated previously, GSCM contribute to cost reductions for the consumption of energy, waste management and disposal of waste, material procurement which enhances revenue/sales growth. Our results are in line with Jawaad and Zafar [2019] who also reported positive effects of GSCM on the financial performance of the Pakistani companies. Numerous preceding studies also reported an optimistic association between green practices/activities and firm performance in terms of profitability [Rao, Holt, 2005; Zhu et al., 2013].

Second hypothesis of the study was that GSCM is positively related with environmental performance. The results of the study support hypothesis 2. There is also substantial evidence in the literature that green supply chain management (GSCM) enhance environmental performance positively [Kumar et al., 2019]. Green supply chain management enhances efficiency and collaboration between business partners which leads to improved environmental outcomes, reduces pollution and saves costs [Rao and Holt, 2005]. Thus, GSCM leads to better environmental performance in our study too.

Hypothesis H3 and H4 were related to the mediation of operational performance between the relationship of GSCM-financial performance and GSCM-environmental performance respectively. The results confirm partial mediation for both relationships. These results indicate that GSCM puts emphasis on the creation of resource as well as operational efficiency which GSCM activities are not intended to gain profit and shares in new markets but adopted to achieve the objectives of cost reduction and resource efficiency though minimizing damage to the environment. It is the improved operational performance which creates new sales, productivity and reduction of costs.

GSCM involves product design for reuse, product recycling and reduced energy usage, which improves the use of material and minimizes waste in production of goods, thereby enhancing environment performance.

Lastly, hypothesis-5 was related to the moderation of external pressures on GSCM-operational performance relationship. The results suggest that the external pressures moderate the association of green supply chain management and operational performance in a manner that the association will be strong when external pressures are high.

Customer pressure and regulatory pressure from government are strongly linked to the execution of GSCM practices. The results suggests that enterprises adopt green supply chain management practices because they face pressure from regulatory authorities, customers and environmental regulations formed by central and regional governments and client countries. Organizations that are environmentally responsible make themselves most desirable to shareholders/investors and customers.

Our results must be interpreted with caution as they are related specifically to Pakistan and might differ for other countries/ contexts. Overall, these results of the study show that implementing and adopting green practices such as green supply chain management (GSCM) practices in Pakistan is crucial for various industries in response of external pressures from different stakeholders. Higher external pressures from various stakeholders and the organization's internal mandatory green practices drive companies to effectively implement GSCM practices that ultimately lead to enhanced environmental and financial performance.

In Pakistan, protection of the environment has become a progressively important issue. Government officials/policymakers could do more to educate manufacturers about the implementation of green supply chain management practices. Policymakers should be proactive in the development of environmental regulations in order to encourage the development of green supply chains by manufacturing companies as a systematic and integral approach so that Pakistani companies are able to incorporate green supply chain management (GSCM) practices successfully with appropriate guidance and regulations. Implementation of GSCM practices can lead towards eco-friendly environment and can be an important indicator for country's seriousness towards achievement of UN SDGs regarding environment.

Like any other study, our study has some limitations. First, we considered GSCM as a uni-dimensional construct in line to the recommendation of several researchers. GSCM has also been conceptualized as multi-dimensional construct with internal and external practices. It can be an interesting investigation to see that how these practices are related to environmental and financial performance separately. We propose that future researchers might do so. Secondly, we treated customer and regulatory pressures combined as external pressures. They could have been treated separately and independently. Third, our data collection design is cross-sectional. Although, the primary reason for collecting data at one time and not using time lags was that our study involved data collection from executives who are not readily available and data collection from executives thus becomes a challenge.

Lastly, the data collected for the study is only for Pakistani companies. The study may be replicated in other countries/ contexts. We propose that future researchers might explore some other mediating and moderating mechanisms.

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REFERENCES

Ameer R., Othman R., 2012. Sustainability practices and corporate financial performance: a study based on the top global corporations. Journal of Business Ethics, 108 (1), 61–79. http://doi.org/10.1007/s10551-011-1063-y

Blome C., Hollos D., Paulraj A., 2014. Green procurement and green supplier development: antecedents and effects on supplier performance. International Journal of Production Research, 52(1), 32-49. http://doi.org/10.1080/00207543.2013.825748

Chavez R., Yu W., Feng M., Wiengarten F., 2016. The effect of customer-centric green supply chain management on operational performance and customer satisfaction. Business Strategy and the Environment, 25(3), 205-220. http://doi.org/10.1002/bse.1868

Diab S.M., Al-Bourini F.A., Abu-Rumman A.H., 2015. The impact of green supply chain management practices on organizational performance: a study of Jordanian food industries. Journal of Management and Sustainability, 5, 149. http://doi.org/10.5539/jms.v5nIp149

Eltayeb T.K., Zailani S., Ramayah T., 2011. Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes. Resources, Conservation and Recycling, 55(5), 495–506. http://doi.org/10.1016/j.resconrec.2010.09.003

Feng M., Yu W., Wang X., Wong C.Y., Xu M., Xiao Z., 2018. Green supply chain management and financial performance: The mediating roles of operational and environmental performance. Business Strategy and the Environment, 27(7), 811-824. http://doi.org/10.1002/bse.2033

Flynn B.B., Huo B., Zhao X., 2010. The impact of supply chain integration on performance: A contingency and configuration approach. Journal of Operations Management, 28(1), 58-71. http://doi.org/10.1016/j.jom.2009.06.001

Golicic S.L., Smith C.D., 2013. A meta-analysis of environmentally sustainable supply chain management practices and firm performance. Journal of Supply Chain Management, 49(2), 78–95. http://doi.org/10.1111/jscm.12006

Gonzalez-Benito J., Gonzalez-Benito O., 2006. The role of stakeholder pressure and managerial values in the implementation of environmental logistics practices. International Journal of Production Research, 44 (7), 1353–1373. http://doi.org/10.1080/00207540500435199

Hart S.L., 1995. A natural-resource-based view of the firm. Academy of Management Review, 20 (4), 986-1014. http://doi.org/10.5465/amr.1995.9512280033

Hoffman A.J., 2001. Linking organizational and field-level analyses: The diffusion of corporate environmental practice. Organization and Environment, 14(2), 133-156. http://doi.org/10.1177/1086026601142001

Jawaad M., Zafar S., 2019. Improving sustainable development and firm performance in emerging economies by implementing green supply chain activities. Sustainable Development, 28(1), 25-38. http://doi.org/10.1002/sd.1962

Jayaram J., Avittathur B., 2015. Green supply chains: A perspective from an emerging economy. International Journal of

Production Economics, 164, 234-244. http://doi.org/10.1016/j.ijpe.2014.12.003

Khan S.A.R., Qianli D., 2017. Impact of green supply chain management practices on firms' performance: an empirical study from the perspective of Pakistan. Environmental Science and Pollution Research, 24(20), 16829-16844. http://doi.org/10.1007/s11356-017-9172-5

Klassen R.D., Whybark D.C., 1999. Environmental management in operations: the selection of environmental technologies. Decision Sciences, 30(3), 601-631. http://doi.org/10.1111/j.1540-5915.1999.tb00900.x

Kleindorfer P.R., Singhal K., Van Wassenhove L.N., 2005. Sustainable operations management. Production and Operations Management, 14 (4), 482-492. http://doi.org/10.1111/j.1937-5956.2005.tb00235.x

Kumar A., Zavadskas E.K., Mangla S.K., Agrawal V., Sharma K., Gupta D., 2019. When risks need attention: adoption of green supply chain initiatives in the pharmaceutical industry. International Journal of Production Research, 57(11), 3554-3576. http://doi.org/10.1080/00207543.2018.1543969

Lee S., Kim S., Choi D., 2012. Green supply chain management and organizational performance. Industrial Management and Data Systems, 112(8), 1148-1180. http://doi.org/10.1108/02635571211264609

Luthra S., Garg D., Haleem A., 2016. The impacts of critical success factors for implementing green supply chain management towards sustainability: an empirical investigation of Indian automobile industry. Journal of Cleaner Production, 121, 142-158. http://doi.org/10.1016/j.jclepro.2016.01.095

Paquette J.R., 2006. The supply chain response to environmental pressures (Doctoral dissertation, Massachusetts Institute of Technology). http://dspace.mit.edu/handle/1721.1/7582

Preacher K.J., Hayes A.F., 2008. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods, 40(3), 879-891. http://doi.org/10.3758/BRM.40.3.879

Rao P., Holt D., 2005. Do green supply chains lead to competitiveness and economic performance?. International Journal of Operations and Production Management, 25 (9–10), 898–916. http://doi.org/10.1108/01443570510613956

Schmidt C.G., Foerstl K., Schaltenbrand B., 2017. The supply chain position paradox: green practices and firm performance. Journal of Supply Chain Management, 53(1), 3-25. http://doi.org/10.1111/jscm.12113

Seman N.A.A., Govindan K., Mardani A., Zakuan N., Saman M.Z.M., Hooker R.E., Ozkul S., 2019. The mediating effect of green innovation on the relationship between green supply chain management and environmental performance. Journal of Cleaner Production, 229, 115-127. http://doi.org/10.1016/j.jclepro.2019.03.211

Sezen B., Cankaya S.Y., 2013. Effects of green manufacturing and eco-innovation on sustainability performance. Procedia-Social and Behavioral Sciences, 99, 154-163. http://doi.org/10.1016/j.sbspro.2013.10.481

Solér C., Bergström K., Shanahan H., 2010. Green supply chains and the missing link between environmental information and practice. Business Strategy and the Environment, 19(1), 14-25. http://doi.org/10.1002/bse.655

Stefan A., Paul L., 2008. Does it pay to be green? A systematic overview. Academy of Management Perspectives, 22(4), 45-62. https://www.jstor.org/stable/27747478

Svensson G., 2007. Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example. Supply Chain Management–An International Journal, 12 (4), 262–266. http://doi.org/10.1108/13598540710759781

Vachon S., Klassen R.D., 2006. Extending green practices across the supply chain: The impact of upstream and downstream integration. International Journal of Operations and Production Management, 26(7), 795-821. http://doi.org/10.1108/01443570610672248

Wong C.Y., Wong C.W.Y., Boon-itt S., 2015. Integrating environmental management into supply chains: A systematic literature review and theoretical framework. International Journal of Physical Distribution and Logistics Management, 45(1/2), 43–68. http://doi.org/10.1108/IJPDLM-05-2013-0110

Yusuf Y.Y., Gunasekaran A., Musa A., El-Berishy N.M., Abubakar T., Ambursa H.M., 2013. The UK oil and gas supply chains: An empirical analysis of adoption of sustainable measures and performance outcomes. International Journal of Production Economics, 146(2), 501-514. http://doi.org/10.1016/j.ijpe.2012.09.021

Zailani S., Jeyaraman K., Vengadasan G., Premkumar R., 2012. Sustain- able supply chain management (SSCM) in Malaysia: A survey. International Journal of Production Economics, 140(1), 330-340. http://doi.org/10.1016/j.ijpe.2012.02.008

Zhu Q., Sarkis J., Geng Y., 2005. Green supply chain management in China: Pressures, practices and performance. International Journal of Operations and Production Management, 25(5), 449-468. http://doi.org/10.1108/01443570510593148

Zhu Q., Geng Y., Fujita T., Hashimoto S., 2010. Green supply chain management in leading manufacturers: Case studies in Japanese large companies. Management Research Review, 33(4), 380-392. http://doi.org/10.1108/01409171011030471

Zhu Q., Sarkis J., Lai K., 2013. Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices. Journal of Purchasing and Supply Management, 19(2), 106–117. http://doi.org/10.1016/j.pursup.2012.12.001

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ORIGINAL PAPER

HOW TO MEASURE OMNICHANNEL? MARKETING INDICATOR-BASED APPROACH – THEORY FUNDAMENTALS

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ABSTRACT. **Background**: The ability to assess a situation is one of the key competences of companies operating on the market. One should know if one functions as well as their competitors, better or perhaps worse. In the case of the omnichannel concept, it is difficult to answer this question, since so far there has been no recognized standard for its evaluation. The aim of the article is to present the theory fundamentals of omnichannel measurement and evaluation in an indicator-based form.

Methods: The theoretical part features a systematic literature review based on the Scopus abstract and citation database. In the research part, an original indicator-based omnichannel measurement and evaluation theory was presented. The idea was based on the following ideas: marketing mix, benchmarking, OTIFEF, AHP.

Results: In the scientific literature, the dominant evaluation of omnichannel is based on financial measures, which, according to the author of this article, does not reflect the essence of the functioning of this concept. Therefore, the research part presents relational omnichannel indicators - individual (4) and aggregate (11) - based on non-financial measures.

Conclusions: There are currently no reference omnichannel evaluation instruments. The creation and functioning of such a standard would allow to form objective opinions. The standardization of the omnichannel measurement would enable to perform comparative analyses, the results of which could be used to further improve trade and distribution processes in companies using this sales strategy.

The research approach adopted in the article fits very well with the assumptions of the omnichannel concept. The proposed measurement and evaluation theory is simple and universal, and its application is not constrained by any limitations. It enables both individual and comparative evaluation.

Key words: omni-channel, marketing mix, benchmarking, omnichannel indicators, systematic literature review, expert research.

INTRODUCTION

Modern trade and distribution have recently been dominated by omnichannel. A great deal of talk and writing has been going on about one company being more omnichannel in its character than the other. Should or must omnichannel be considered only in relationships that exist between companies? Or is it possible to evaluate omnichannel within only one company, analyzing the conditions offered by it in various sales (distribution) channels?

When evaluating a given business concept, a certain characteristic dichotomy can be noticed – an opinion is formed on the basis of financial and (or) non-financial measures. When analyzing this state of affairs in a more detailed way, one can discover the following regularity - in the vast majority of cases, evaluation based on financial measures is almost always present - an advanced, diverse set of measures / indicators can be observed.

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Non-financial measures, which generally relate to operating activities, constitute a definite minority. They are used less frequently, usually as a complement to evaluation based on financial measures.

In the opinion held by the author of this article, only non-financial evaluation allows to capture the strict essence of omnichannel. It is true that the omnichannel effects are visible (bear influence) in financial evaluation, but it should be treated as an indirect (additional) opinion. It is the reliance on non-financial measures that touches the gist of omnichannel - it allows direct measurement and evaluation of the scale of this phenomenon.

The aim of this article is bring the attention of the academic community to an original scientific theory concerning an indicator-based evaluation of omnichannel that relies on non-financial measures. The undertaken topic is valid and important, as there have been no guidelines for omnichannel measurement so far. The development of a universal theory of evaluation, applicable in every trade and distribution line, will allow to evaluate this phenomenon both in the internal (individual) and external (collective) - comparative - aspects. The original concept presented in this article is a voice in the discussion regarding the approach to omnichannel measurement and evaluation.

THEORETICAL BACKGROUND

Assumptions of the literature analysis

A systematic literature review was carried out in October 2020 on the basis of the Scopus abstract and citation database. This database is recommended by the Ministry of Science and Higher Education in Poland as the leading database of journals for scientists in the discipline of management and quality science, which is represented by the author of this article. The analysis of the literature consisted in searching for selected characteristic words and phrases in three places: title, abstract and keywords. The conducted literature review is both quantitative - the number of publications, and qualitative - the way of presenting the research topic.

The selection includes articles published since 2012. This is due to the fact that the term "omnichannel retailing" was formulated for the first time in December 2011 [Rigby, 2011] - since then it has been part of the industry terminology. Due to the fact that the spelling of the word omnichannel has a huge impact on the results of a literature review, the search was carried out in parallel in both notation systems: omni-channel and omnichannel.

Systematic review of publications

As part of the omnichannel-related topic, the following was selected in the Scopus database: a total of 370 articles with the "omni-channel" notation and 367 articles with the "omnichannel" notation, with only about 30 articles being common (repeated) for both notation systems. The relationships of omnichannel with the remaining thematic lines in this article are presented in Table 1.

Table 1. Popularity of the approach to the research topic according to the number of articles

thematic line	number of articles - potential	number of articles - substantive	list of articles - authors
omni-channel & measure	10	6	Acquila-Natale & Chaparro-Peláez, 2020; Klein et al., 2020; Patti et al., 2020; Cakir et al., 2019; Fuchs et al., 2017; Ma, 2017
omnichannel & measure	9	5	Chaparro-Peláez et al., 2020; Roy et al., 2020; Valentini et al., 2020; Buldeo Rai et al., 2019; Zhang et al., 2019
omni-channel & indicator	7	6	Pereira & Frazzon, 2020; Cakir et al., 2019; Liu et al., 2018; Martino et al., 2017; Beloborodova & Martynova, 2016; Cavender & Kincade, 2015
omnichannel & indicator	4	3	Chaparro-Peláez et al., 2020; Rivero Gutiérrez & Samino García, 2020; Martino et al., 2017
omni-channel & rate	11	5	Leung et al, 2020; MacCarthy et al., 2019; Jin et al., 2018; Tao et al., 2018; Bernon et al., 2016

thematic line	number of articles - potential	number of articles - substantive	list of articles - authors
omnichannel & rate	6	3	Liu & Xu, 2020; Fisher et al., 2019; Park & Kim, 2019
omni-channel & metric	5	4	Klein et al., 2020; Patti et al., 2020; Cakir et al., 2019; Ailawadi & Farris, 2017
omnichannel & metric	4	3	Roy et al., 2020; Adivar et al., 2019; Ailawadi & Farris, 2017
omni-channel & ratio	5	3	Hu & Xu, 2019; Ryu et al., 2019; Jin et al., 2018
omnichannel & ratio	1	1	Liu & Xu, 2020
omni-channel & index	3	2	Kim et al., 2018; Liu et al., 2018
omnichannel & index	0	0	
omni-channel & coefficient	2	2	Jiang et al., 2020; Yu et al., 2019
omnichannel & coefficient	0	0	
omni-channel & standard	8	1	Fuchs et al., 2017
omnichannel & standard	8	1	Radzevičė & Banytė, 2020
omni-channel & instrument	2	0	
omnichannel & instrument	3	0	
omni-channel & meter	0	0	
omnichannel & meter	1	0	
omni-channel & gauge	0	0	
omnichannel & gauge	0	0	
omni-channel & pointer	0	0	
omnichannel & pointer	0	0	

Source: own research

Table 2. Detailed literature review on omnichannel measurement and evaluation

author	area	method	task	result
Acquila-Natale & Chaparro-Peláez, 2020	distribution logistics	the tests of measurement instrument	level of channel integration	the systematic set of indicators in six different areas along the shopping process
Chaparro-Peláez et al., 2020	electricity markets	the mystery shopper technique	channel integration of electricity	the structured set of indicators
Jiang et al., 2020	pricing decisions	the retailer Stackelberg game	boost service value	the market scale expansion coefficient
Klein et al., 2020	digital media	the information and signaling theory	assessing cross-media exposure	the media entropy metric
Leung et al, 2020	order demand	the machine learning, time series data, neuro-fuzzy inference system	predictive forecasting	the hour-to-hour fast-changing arrival rates of e-commerce orders
Liu & Xu, 2020	online returns	the expected profit models	decision on pricing and ordering	the purchase ratio via an online channel
Patti et al., 2020	customer service	the review of literature, journey mapping	improving customer service delivery	the perception-based, operational and outcome-based metrics
Pereira & Frazzon, 2020	demand forecasting	the clustering, neural networks, simulation	synchronization of demand	the lead time, backorders and operational costs indicators
Radzevičė & Banytė, 2020	consumer behaviour	the Stimulus-Organism-Response model, behaviour literature	factors of irrational consumers behaviour identification	the standard of cognition of consumer behaviour
Rivero Gutiérrez & Samino García, 2020	distribution logistics	the Delphi method, statistical analysis with SPSS	distribution of health products	the set of indicators involve 19 different criteria grouped into 4 categories
Roy et al., 2020	customer's experience	the case study	emotional journey of consumers	the psychophysiological and self-reported measures
Valentini et al., 2020	customer channel preferences	the latent class cluster analysis	respond differently to promotions	the measure motivations, opportunities, abilities
Adivar et al., 2019	performance management	the statistical model	assessing the success of retailers	the comprehensive performance metrics – 4 competitive dimensions and 7 perspectives
Buldeo Rai et al., 2019	city logistics	the case-study research	parcel distribution	the improve distribution efficiency – parcel volume, stop density, delivery failure and urban regulation
Cakir et al., 2019	financial measures	the systematic literature review	development of financial and non-financial metrics	the customer experience and customer satisfaction measures

author	area	method	task	result
Fisher et al., 2019	sales	the quasi-experiment, difference-in-differences approach	faster delivery	the online store penetration rate
Hu & Xu, 2019	organic agricultural supply chain	the theory differential game, bi-level programming,	contracts of cooperation, decision modes	the online and offline marginal income ratio
MacCarthy et al., 2019	fulfil orders	the mathematical approach	picking operations	the picking rates
Park & Kim, 2019	consumer behavior	the survey study, partial least squares	consumers' personality trait	the adoption omnichannel service rate
Ryu et al., 2019	distribution channels	the stochastic frontier analysis	technical efficiencies of small-scale enterprises	the technology gap ratio
Yu et al., 2019	operating incomes	the symbiosis theory	establishing retail system	the symbiosis coefficient
Zhang et al., 2019	time management	the empirical method	fulfilment time	the key performance measure - fast fulfilment
Jin et al., 2018	services	the own theoretical model	mode of order fulfillment	the buy online and pick up in store customers' arrival ratio
Kim et al., 2018	shopping	the algorithm considering shopping route and stay time in a area	navigation of consumer	the consumer moving path similarity index
Liu et al., 2018	logistics services	the fuzzy analytic hierarchy process	evaluation of integration level	the logistics index system
Tao et al., 2018	strategy	the system dynamics, simulation	sensitivity analysis	the users' retention rate
Ailawadi & Farris, 2017	managing distribution	the literature review, case study	relationship between distribution and marketing objectives	the set of old and new distribution depth metrics
Fuchs et al., 2017	promotion	the interoperable couponing trial	cross-retailer coupon distribution and validation	the technical coupon standards
Ma, 2017	logistics service	the scenario-based role playing experiment	customer satisfaction and purchase intentions	the three variables - delivery time, shipping charges, purchase importance
Martino et al., 2017	decision support	the case study	correct time management in fashion sector	the set of key performance indicators
Beloborodova & Martynova, 2016	trade	the case study	analysis of Russian e-commerce market	the main indicators of e-commerce
Bernon et al., 2016	returns management	the mixed methods approach, convergent design	levels of consumer retail returns	the return rates
Cavender & Kincade, 2015	brand management	the case study, recontextualization techniques	develop a luxury brand management framework	the key dimensions of brand management operations

Source: own research

Table 2, based on Table 1, contains an original summary of the literature review in the field of omnichannel measurement and evaluation in the following section: area, method, task, result.

In the context of the review of the methodological approach used by other scientists, two columns seem to be the most interesting - method and result. The "method" column shows instrumental approaches to the topic of omnichannel measurement. The "result" column - the result of the research implementation - measures of omnichannel evaluation.

Summary of literature analysis

The question of omnichannel measurement and evaluation was noticed for the first time in 2015 (the oldest publication in Table 2). Looking at the number and age of publications, the measurement and evaluation of omnichannel is a highly topical issue that has recently been widely discussed in the scientific community - a large increase in the latest articles.

Individual scientists represent different research areas, dealing with various detailed research tasks within them. Some scientists focus more on marketing issues, some on strictly logistic issues. The technical approach to the subject (method) is also very diverse - from standard literature analyses and case studies, to advanced interdisciplinary theories as well as optimization and simulation approaches. The results of the research are specific omnichannel measures - more often single than aggregate (conglomerates of measures / indicators), which take the form of standard (more often) than more exotic (less often) nomenclature.

RESEARCH FRAMEWORK

The concept presented in this article was inspired by the OTIFEF (on time, in full, error free) measure. It is a conglomerate of indicators related to the logistics area, assessing three aspects of operational activity - timeliness, completeness and error-free deliveries (non-financial measures). These indicators can be considered independently - separate calculation and analysis: OT (on time), IF (in full), EF (error free), and interdependently - in the form of tandems: OTIF (on time, in full), OTEF (on time, error free), IFEF (in full, error free), or the OTIFEF treble (on time, in full, error free). The result of a given indicator (whether individual or aggregate) is given in bare units or as a percentage. The obtained result can be interpreted individually (within the company) or comparatively (industry benchmarking). This approach enables a three-criteria evaluation of the functioning of the supply chain - both internal and external. Based on the opinions of logistics managers expressed in the Master of Business Administration (MBA) programmes, the author of this article has repeatedly heard that OTIFEF has been the most important key measure for assessing modern operational logistics of both a single company and a supply chain.

In the case of this article (omnichannel measurement and evaluation), its author decided to base the scientific approach on the marketing-mix concept. The marketing mix is defined as a conglomerate of four interdependent components - 4P: product, price, promotion, place. Each of these elements will constitute an omnichannel evaluation criterion. Then, under each criterion, it was necessary to determine what would be the basis for measurement. In the case of product, it is their number. In the case of price, it is its level. In the case of promotion, it is the amount (level) of a discount. In the case of place, it is the number of channels. The author of this article decided to apply an indicator-based approach. It requires a juxtaposition of two values. The concept used by the author of this article adopts the omnichannel benchmarking approach, where the denominator is represented by the base (comparative) channel, and the numerator is represented by the alternative (compared) channel. Thus, the indicator is relational in nature, comparing the inter-channel conditions. In the author's opinion, this approach touches in a tangible way the essence of omnichannel - the possibility of direct evaluation of the offer in individual channels.

In accordance with omnichannel postulates, the consumer should not experience differences in the level of service between individual channels - in other words: the level of customer service in each channel should be the same.

RESEARCH RESULTS

Omnichannel indicators - individual approach

The general schematic of the omnichannel indicator is presented in Formula 1.

$$OC_{cryterium} = \frac{a_{ch\,II}}{a_{ch\,I}} \quad (1)$$

where:

- OC (omnichannel) - omnichannel of a given criterion; the criteria are: product, price, promotion, place;
- a (attribute) - an attribute subject to measurement; the number of products within the product, the price level within the price, the amount of a discount within the promotion, the number of channels within the place;
- ch I (channel) - base, comparative channel (denominator);
- ch II (channel) - alternative, compared channel (numerator).

Bearing in mind the adopted four criteria, it is possible to determine four individual omnichannel indicators - Formulas 2 to 5.

$$OC_{\text{product}} = \frac{p_{\text{ch II}}}{p_{\text{ch I}}} \quad (2)$$

where:
- OC product - product omnichannel;
- p (product) - number of products;
- ch I (channel) - base, comparative channel (denominator);
- ch II (channel) - alternative, compared channel (numerator).

$$OC_{\text{price}} = \frac{p_{\text{ch II}}}{p_{\text{ch I}}} \quad (3)$$

where:
- OC price - price omnichannel;
- p (price) - price level;
- ch I (channel) - base, comparative channel (denominator);
- ch II (channel) - alternative, compared channel (numerator).

$$OC_{\text{promotion}} = \frac{d_{\text{ch II}}}{d_{\text{ch I}}} \quad (4)$$

where:
- OC promotion - promotional omnichannel;
- d (discount) - amount (level) of a discount;
- ch I (channel) - base, comparative channel (denominator);
- ch II (channel) - alternative, compared channel (numerator).

$$OC_{\text{place}} = \frac{c_{\text{ch II}}}{c_{\text{ch I}}} \quad (5)$$

where:
- OC place - distribution omnichannel;
- c (channel) - number of channels;
- ch I (channel) - base, comparative channel (denominator);
- ch II (channel) - alternative, compared channel (numerator).

Omnichannel measurement - evaluation systems

The indicator-based approach offers three possibilities for obtaining a result:
- numerator > denominator - the offer in the alternative channel is better than in the base channel – the result greater than 1: over omnichannel state;
- numerator = denominator - the offer in both channels is the same - the result is exactly 1: desired omnichannel state;
- numerator < denominator - the offer in the alternative channel is worse than in the base channel - the result is lower than 1: under omnichannel state.

The first evaluation proposal is based on relative assessments:
- 2 - awarded to the channel in which the offer is better than in the other channel (the other channel is evaluated at 1);
- 1 - awarded to both channels if the offers are comparable;
- 0.5 - awarded to the channel where the offer is worse than in the other channel (the other channel is evaluated at 1).

A problematic issue is the case of the denominator, which in the worse channel can never be zero. Hence, for worse evaluation, inspired by the Saaty scale in the AHP method, the author of this article decided to adopt evaluation which is opposite to the better one, i.e. ½ (0.5).

The following is an example that illustrates how omnichannel indicators are calculated. Table 3 contains data for calculations - characteristics of a business situation. Table 4 contains the results of partial evaluations and the relative individual omnichannel indicators calculated on their basis.

When interpreting the results (Tables 3 and 4), both products were also available in channel II, so it was given grade 1 (channel I remains with grade 1). In channel II, product prices are worse (higher), hence it was given grade 0.5 (channel I remains with grade 1). In channel II, product discounts are better (higher), so it was given grade 2 (channel I remains with grade 1). Both products were also available for purchase in channel II in the form of two (same) delivery options, so it was given grade 1 (channel I remains graded at 1).

Table 3. Characteristics of a business situation - data for calculations

channel ID	number of products	level of the price	level of the discount	number of channels,
channel II	product 1 - yes product 2 - yes	product 1 price - 3 PLN product 2 price - 4 PLN	product 1 discount - 5% product 2 discount - 6%	product 1 - 2 product 2 - 2
channel I	product 1 - yes product 2 - yes	product 1 price - 2 PLN product 2 price - 3 PLN	product 1 discount - 3% product 2 discount - 4 %	product 1 - 2 product 2 - 2

Source: own research

Table 4. Results of partial evaluations and individual omnichannel indicators - relative approach

channel ID	product	price	promotion	place
channel II	1	0.5	2	1
channel I	1	1	1	1
OC	**1**	**0.5**	**2**	**1**

Source: own research

In summary, the desired state - omnichannel (result equal to 1) was achieved in terms of product availability and the option of its place (delivery). There no differences in the offer in these elements. In the case of price and promotion, such differentiation already exists. Prices in the alternative channel (II) are too high (result below 1 - under omnichannel state). Discounts in the alternative channel (II) are too high (result greater than 1 - over omnichannel state). The question is whether discounts in the base channel (I) were well received. Does it not indicate the opposite, i.e. there is a need to increase discounts in the base channel (I)?

The other evaluation proposal is based on absolute assessments. In this case, it is based on the specific values of attributes present in individual criteria. However, there is a trap in this metric system. In line with the trend, the higher the numerator is than the denominator, the better the situation in the alternative channel (II) is than in the base channel (I). This is true for product, promotion and place. In the case of price, a higher value of the numerator indicates worse terms of the offer, disrupting the overall logic of the trend of the results. Therefore, in the case of price, the inverse of the 3: 1 / OC price formula should be used in absolute terms. If this was not done, the omnichannel price indicator for product 1 would be 1.50, and for product 2 it would be 1.33. In the absolute metric system there will also be grades which are smaller, equal and larger than 1. In the case of smaller and larger grades, however, the entire spectrum of values will appear, while in the earlier relative metric system, these were only values of 2 or ½ (0.5).

Table 5. Results of partial evaluations and individual omnichannel indicators - absolute approach

channel ID	product	price	promotion	place
channel II product 1	1	3	5	1
channel I product 1	1	2	3	1
channel II product 2	1	4	6	1
channel I product 2	1	3	4	1
OC product 1	**1.00**	**0.67***	**1.67**	**1.00**
OC product 2	**1.00**	**0.75***	**1.50**	**1.00**
OC	**1.00**	**0.71***	**1.59**	**1.00**

* the result is calculated as 1 / OC price (explanation earlier in the text)
Source: own research

Table 5 (based on the same data as before - Table 3) contains the results of partial evaluations and the absolute individual omnichannel indicators calculated on their basis. In the case of the OC indicator, the author of this article arbitrarily assumed that it is the average of the OC product 1 and OC product 2 indicators.

The interpretation of the results in Table 5 is the same as the interpretation of the results presented for the previous relative metric system (paragraphs under Table 4). The only difference is the other resulting numerical values of the indicators.

Omnichannel indicators - aggregate approach

So far, each of the 4 omnichannel indicators has been considered individually and independently. As in the case of the above-mentioned OTIFEF indicator, the omnichannel evaluation can also be considered in a multi-criteria way, in the form of aggregate indicators. In this case, one can obtain 6 two-dimensional indicators, 4 three-dimensional indicators and 1 four-dimensional indicator. Individual indicators and their values (based on the OC results - the last row in Table 5) are presented by Formulas 6 to 16 (descriptions of formulas are unchanged - see *Omnichannel indicators - individual approach*).

$$OC_{product-price} = OC_{product} \bullet OC_{price} = 0{,}71 \quad (6)$$

$$OC_{product-promotion} = OC_{product} \bullet OC_{promotion} = 1{,}59 \quad (7)$$

$$OC_{product-place} = OC_{product} \bullet OC_{place} = 1{,}00 \quad (8)$$

$$OC_{price-promotion} = OC_{price} \bullet OC_{promotion} = 1{,}13 \quad (9)$$

$$OC_{price-place} = OC_{price} \bullet OC_{place} = 0{,}71 \quad (10)$$

$$OC_{promotion-place} = OC_{promotion} \bullet OC_{place} = 1{,}59 \quad (11)$$

$$OC_{product-price-promotion} = OC_{product} \bullet OC_{price} \bullet OC_{promotion} = 1{,}13 \quad (12)$$

$$OC_{product-price-place} = OC_{product} \bullet OC_{price} \bullet OC_{place} = 0{,}71 \quad (13)$$

$$OC_{product-promotion-place} = OC_{product} \bullet OC_{promotion} \bullet OC_{place} = 1{,}59 \quad (14)$$

$$OC_{price-promotion-place} = OC_{price} \bullet OC_{promotion} \bullet OC_{place} = 1{,}13 \quad (15)$$

$$OC_{product-price-promotion-place} = OC_{product} \bullet OC_{price} \bullet OC_{promotion} \bullet OC_{place} = 1{,}13 \quad (16)$$

Three- and four-element measures (Formulas 12 to 16) should be treated in more illustrative categories. A detailed search for the causes of the situation should take place primarily on the basis of a revision of the dual relationships of the individual components of the marketing mix components (Formulas 6 to 11).

Omnichannel criteria - hierarchy of importance

At the end, it was decided to conduct an expert study of the marketing mix criteria. The subjects of the study were Polish scientists publishing about omnichannnel, whose articles were indexed in the Scopus database and/or Web of Science. Nine scientists - omnichannel experts from Poland - were selected, 7 of them agreed to take part in the study. They represent various universities: Wrocław University of Economics (3), Poznan School of Logistics (2), Poznan University of Technology (2). The aim of the expert study was to establish the importance of individual elements of the marketing mix in the light of the implementation of the omnichannel strategy from a scientific perspective - the perspective of a researcher, an expert in the subject. The respondents were asked to fill in 6 fields of the matrix presented as Table 6 (the order of experts is random). The matrix was to be read in the manner of row vs column. If a given marketing mix element (row) is more important than another marketing mix element (column), it was necessary to enter 2. If a given element of the marketing mix (row) is as important as another element of the marketing mix (column), it was necessary to enter 1. If a given element of the marketing mix (row) is less important than another element of the marketing mix (column), it was necessary to enter 0.5 (grade opposite to 2).

When analyzing the mode, Table 6 clearly shows: dominance of product over price, promotion over price, and equivalence of promotion and place. The product-promotion relationship can also be evaluated as neutral (even distribution of responses). Distribution, both in terms of product and price, is treated rather in a secondary way (majority of grades 1 and 0.5).

The results obtained so far should be treated as a subject pilot study. Due to the small sample of experts, research should be extended to include scientists from outside Poland. The results obtained in this way may constitute a basis for introducing weights for the criteria, which would increase the advancement level of the indicator's construction.

Table 6. The hierarchy of importance of the marketing mix elements in the opinion of scientists from Poland dealing with omnichannel

X	product	price	promotion	place
product	**X**	2* 0.5** 2 2 2 1 1	1* 0.5** 2 1 2 0.5 1	0.5* 0.5** 2 1 1 0,5 1
price		**X**	0.5* 0.5** 2 0.5 2 0.5 1	0.5* 0.5** 2 1 1 0.5 1
promotion			**X**	0.5* 1** 1 1 0.5 1 1
place				**X**

* expert 1, ** expert 2, ...
Source: own research

CONCLUSION, LIMITATIONS AND FURTHER RESEARCH

After the emergence and crystallization of the omnichannel concept, it is natural to measure and evaluate this phenomenon. In addition to determining whether a given solution meets the assumptions of the omnichannel concept, another question arises: is this particular solution more or less omnichannel in relation to competing alternatives - other omnichannel solutions? Thus, who (the company) or what (aspect of its offer) is more / less omnichannel than others? Thus, the issue of developing and using a recognized standard for the measurement and evaluation of omnichannel is a key issue (holy grail) for contemporary, modern commerce and distribution.

The original concept of omnichannel measurement and evaluation presented in the article was based on the logic of the marketing mix. The marketing approach, with its dominance of the consumer on the market, fits well with the omnichannel concept. In addition, the 4 elements of the marketing mix adopted as criteria cover a wide and diverse spectrum of trade and distribution. According to the basics of building a scientific theory, the presented original concept is simple and elegant, and can be used to explain various market scenarios.

While the research approach itself does not raise any doubts, the detailed solutions adopted within its framework do - the author is critical of his concept and believes that the idea needs to be refined. The first issue concerns the number of attributes: is one attribute within a given criterion reliable, or would it be useful to have several - how many? Are the attributes proposed by the author correctly selected or should they be modified - partially or entirely? What evaluation system should be adopted - the scale and values of evaluations? Should a homogeneous or diverse system of attribute measures be used within the criteria - relative or absolute metric? It should be remembered that due to the relational character of the indicator, the test (benchmarking) makes sense for at least two channels. This state of affairs is most appropriate for the omnichannel concept (more than one channel) - the mechanics of calculating the indicator automatically include theoretical omnichannel assumptions.

Certain combinations of attributes, e.g. product or price, are more frequently checked by consumers than other combinations. The pilot research carried out by the author on the indicator-based evaluation of the stock and price omni-channel in Tesco and Carrefour retail chains was received in a positive way [Domański, Łabenda, 2020]. Perhaps one should also introduce weights for individual criteria (pilot expert study) - assigning significance and hierarchy to attributes. In this case, the solution would evolve towards a simple multi-criteria weighted evaluation system.

Despite numerous dilemmas to be resolved, the unquestionable advantage of the presented concept is its universality. It offers the possibility of comparing the ominichannel offer in various detail-related sections: single product, product group, distributor, trade line. The concept is therefore very broad and comprehensive - not susceptible to limitations related to the type of good, intermediary or selected industry.

The state of scientific knowledge on omnichannel measurement and evaluation was based on articles from the Scopus abstract and citation database. Scopus can be treated as a research limitation related the knowledge of the subject of this article. Perhaps in other sources (e.g. Web of Science, Google Scholar) the state of knowledge is broader (more publications) and / or deeper (more detailed and precise information). It may be a form of breaking limitations, directions of future theoretical research.

The methodological approach adopted in the research part promotes the marketing approach to the topic. Perhaps, due to the origin of omnichannel as a concept on the border of marketing and logistics, one should look for a logistic approach to the subject. It is all the more interesting and innovative as it is only since 2017 that the Supply Chain Operations Reference (SCOR) Model (APICS, 2017), which is globally the most recognized model in the field of logistics, in its latest 12th edition for the first time takes into account omnichannel conditions. The pro-logistic approach to the subject can be treated as breaking (marketing) constraints, the direction of future practical research.

The ability to measure and evaluate the degree of omnichannel is very important, e.g. for Customer Relationship Management (CRM) systems. Monitoring consumer activity in relation to the level of the offer in individual channels is an important tool for distributors to construct a commercial strategy adequate to the market needs and expectations.

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REFERENCES

Acquila-Natale E., Chaparro-Peláez J., 2020. The long road to omni-channel retailing: An assessment of channel integration levels across fashion and apparel retailers, European Journal of International Management, 14 (6), 1049-1069, http://doi.org/10.1504/EJIM.2020.110562

Adivar B., Hüseyinoğlu I.Ö.Y., Christopher M., 2019. A quantitative performance management framework for assessing omnichannel retail supply chains, Journal of Retailing and Consumer Services, 48, 257-269, http://doi.org/10.1016/j.jretconser.2019.02.024

Ailawadi K.L. Farris P.W., 2017. Managing Multi- and Omni-Channel Distribution: Metrics and Research Directions, Journal of Retailing, 93 (1), 120-135, http://doi.org/10.1016/j.jretai.2016.12.003

APICS, 2017. Supply Chain Operations Reference Model SCOR, Version 12.0, APICS, Chicago USA, 1-1096.

Beloborodova A.L. Martynova O.V., 2016. Trends of online trading development in Russia, Journal of Economics and Economic Education Research, 17 (Special Issue 1), 9-15.

Bernon M., Cullen J., Gorst J., 2016. Online retail returns management: Integration within an omni-channel distribution context, International Journal of Physical Distribution and Logistics Management, 46 (6-7), 584-605, http://doi.org/10.1108/IJPDLM-01-2015-0010

Buldeo Rai H., Verlinde S., Macharis C., 2019. City logistics in an omnichannel environment. The case of Brussels, Case Studies on Transport Policy, 7 (2), 310-317, http://doi.org/10.1016/j.cstp.2019.02.002

Cakir G., Bezbradica M., Helfert M., 2019. The Shift from Financial to Non-financial Measures During Transition into Digital Retail – A Systematic Literature Review, Lecture Notes in Business Information Processing, 353, 189-200, http://doi.org/10.1007/978-3-030-20485-3_15

Cavender R.C., Kincade D.H., 2015. A luxury brand management framework built from historical review and case study analysis, International Journal of Retail and Distribution Management, 43 (10-11), 1083-1100, http://doi.org/10.1108/IJRDM-07-2014-0103

Chaparro-Peláez J., Acquila-Natale E., Hernández-García Á., Iglesias-Pradas S., 2020. The digital transformation of the retail electricity market in Spain, Energies, 13 (8), 2085, http://doi.org/10.3390/en13082085

Domański R., Łabenda M., 2020. Omnichannel of private label grocery products in Tesco and Carrefour retail chains on the Polish market, Ekonomski Vjesnik / Econviews – Review of Contemporary Business, Entrepreneurship and Economic Issues, XXXIII, 1/2020, 191-202.

Fisher M.L., Gallino S., Xu J.J., 2019. The Value of Rapid Delivery in Omnichannel Retailing, Journal of Marketing Research, 56 (5), 732-748, http://doi.org/10.1177/0022243719849940

Fuchs K., Vuckovac D., Ilic A., 2017. Towards interoperability in mobile coupons: Enabling cross retailer coupon validation, International Conference on Information and Communication Technology Convergence: ICT Convergence Technologies Leading the Fourth Industrial Revolution (ICTC 2017), 327-333, http://doi.org/10.1109/ICTC.2017.8190997

Hu Q., Xu B., 2019. Differential game analysis of optimal strategies and cooperation in omni-channel organic agricultural supply chain, Sustainability, 11 (3), 848, http://doi.org/10.3390/su11030848

Jiang Y., Liu L., Lim A., 2020. Optimal pricing decisions for an omni-channel supply chain with retail service, International Transactions in Operational Research, 27 (6), 2927-2948, http://doi.org/10.1111/itor.12784

Jin M., Li G., Cheng T.C.E., 2018. Buy online and pick up in-store: Design of the service area, European Journal of Operational Research, 268 (2), 613-623, http://doi.org/10.1016/j.ejor.2018.02.002

Kim M.B., Jung S.W., Chi Y.D., Gim G.Y., 2018. A study on improvement of algorithm for measuring similarity of consumer movement paths in shopping mall, International Journal of Advanced Science and Technology, 116, 49-58, http://doi.org/10.14257/ijast.2018.116.05

Klein J.F., Zhang Y., Falk T., Aspara J., Luo X., 2020. Customer journey analyses in digital media: exploring the impact of cross-media exposure on customers' purchase decisions, Journal of Service Management, 31 (3), 489-508, http://doi.org/10.1108/JOSM-11-2018-0360

Leung K.H., Mo D.Y., Ho G.T.S., Wu C.H., Huang G.Q., 2020. Modelling near-real-time order arrival demand in e-commerce context: a machine learning predictive methodology, Industrial Management and Data Systems, 120 (6), 1149-1174, http://doi.org/10.1108/IMDS-12-2019-0646

Liu J., Xu Q., 2020. Joint decision on pricing andordering foromnichannel BOPS retailers: Considering online returns, Sustainability, 12 (4), 1539, http://doi.org/10.3390/su12041539

Liu X., Lan H., Song G., 2018. An evaluation model of omni-channel retail logistics service integration level, ACM International Conference Proceeding Series, 80-85, http://doi.org/10.1145/3288155.3288187

Ma S., 2017. Fast or free shipping options in online & Omni-channel retail? The mediating role of uncertainty on satisfaction & purchase intentions, International Journal of Logistics Management, 28 (4), 1099-1122, http://doi.org/10.1108/IJLM-05-2016-0130

MacCarthy B.L., Zhang L., Muyldermans L., 2019. Best Performance Frontiers for Buy-Online-Pickup-in-Store order fulfillment, International Journal of Production Economics, 211, 251-264, http://doi.org/10.1016/j.ijpe.2019.01.037

Martino G., Fera M., Iannone R., Miranda S., 2017. Proposal of a multi-method decision support system for the fashion retail industry, Lecture Notes in Electrical Engineering, 413, 187-199, http://doi.org/10.1007/978-3-319-48511-9_16

Nguyen N.M.H., Borusiak B., 2021. Using UTAUT2 model to examine the determinants of omnichannel technology acceptance by consumers. LogForum,2,5, http://doi.org/10.17270/J.LOG.2021.580

Park J., Kim R.B., 2019. The effects of integrated information & service, institutional mechanism and need for cognition (NFC) on consumer omnichannel adoption behavior, Asia Pacific Journal of Marketing and Logistics, 1-29, http://doi.org/10.1108/APJML-06-2018-0209

Patti C.H., van Dessel M.M., Hartley S.W., 2020. Reimagining customer service through journey mapping and measurement, European Journal of Marketing, 54 (10), 2387-2417, http://doi.org/10.1108/EJM-07-2019-0556

Pereira M.M., Frazzon E.M., 2020. A data-driven approach to adaptive synchronization of demand and supply in omni-channel retail supply chains, International Journal of Information Management, 102165, http://doi.org/10.1016/j.ijinfomgt.2020.102165

Radzevičė J., Banytė J., 2020. Driving Factors of Consumer Irrationality in Omnichannel Consumer Behaviour, Smart Innovation, Systems and Technologies, 167, 146-155, http://doi.org/10.1007/978-981-15-1564-4_15

Rigby D.K., 2011. The Future of Shopping, Harvard Business Review, 89, 65-76.

Rivero Gutiérrez L., Samino García R., 2020. Omnichannel Strategy and Consumer Behavior in Distribution Channels: Trends in the Ophthalmology Sector, Frontiers in Psychology, 11, 1142, http://doi.org/10.3389/fpsyg.2020.01142

Roy A., Sénécal S., Léger P.-M., Demolin B., Bigras É., Gagne J., 2020. Measuring Users' Psychophysiological Experience in Non-linear Omnichannel Environment, Lecture Notes in Computer Science including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics (LNCS), 762-779, http://doi.org/10.1007/978-3-030-60114-0_50

Ryu M.H., Cho Y., Lee D., 2019. Should small-scale online retailers diversify distribution channels into offline channels? Focused on the clothing and fashion industry, Journal of Retailing and Consumer Services, 47, 74-77, http://doi.org/10.1016/j.jretconser.2018.09.014

Tao Z., Zhang Z., Wang X., Shi Y., 2018. Simulation Analysis of Omni-channel Strategy Based on System Dynamics: A Case Study of Company X, IOP Conference Series: Materials Science and Engineering, 439 (3), 032039, http://doi.org/10.1088/1757-899X/439/3/032039

Wojciechowski H., Łukasz Hadaś Ł., 2020. Ranking of opportunities for implementing the omnichannel concept, LogForum,2,4, http://doi.org/10.17270/J.LOG.2020.381

Valentini S., Neslin S.A., Montaguti E., 2020. Identifying omnichannel deal prone segments, their antecedents, and their consequences, Journal of Retailing, 96 (3), 310-327, http://doi.org/10.1016/j.jretai.2020.01.003

Yu B., Chen X., Cao M., 2019. Omni-channel Retail Symbiosis Model and Its Empirical Analysis, 5th International Conference on Systems and Informatics (ICSAI), 8599338, http://doi.org/10.1109/ICSAI.2018.8599338

Zhang J., Onal S., Das R., Helminsky A., Das S., 2019. Fulfilment time performance of online retailers – an empirical analysis, International Journal of Retail and Distribution Management, 47 (5), pp. 493-510, http://doi.org/10.1108/IJRDM-10-2017-0237

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ORIGINAL PAPER

A LOGISTIC OPTIMIZATION FOR THE VEHICLE ROUTING PROBLEM THROUGH A CASE STUDY IN THE FOOD INDUSTRY

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ABSTRACT. **Background:** In this study, the food delivery problem faced by a food company is discussed. There are seven different regions where the company serves food and a certain number of customers in each region. The time of requesting food for each customer varies according to the shift situation. This type of problem is referred to as a vehicle routing problem with time windows in the literature and the main aim of the study is to minimize the total travel distance of the vehicles. The second aim is to determine which vehicle will follow which route in the region by using the least amount of vehicle according to the desired mealtime.

Methods: In this study, genetic algorithm methodology is used for the solution of the problem. Metaheuristic algorithms are used for problems that contain multiple combinations and cannot be solved in a reasonable time. Thus in this study, a solution to this problem in a reasonable time is obtained by using the genetic algorithm method. The advantage of this method is to find the most appropriate solution by trying possible solutions with a certain number of populations.

Results: Different population sizes are considered in the study. 1000 iterations are made for each population. According to the genetic algorithm results, the best result is obtained in the lowest population size. The total distance has been shortened by about 14% with this method. Besides, the number of vehicles in each region and which vehicle will serve to whom has also been determined. This study, which is a real-life application, has provided serious profitability to the food company even from this region alone. Besides, there have been improvements at different rates in each of the seven regions. Customers' ability to receive service at any time has maximized customer satisfaction and increased the ability to work in the long term.

Conclusions: The method and results used in the study were positive for the food company. However, the metaheuristic algorithm used in this study does not guarantee an optimal result. Therefore, mathematical models or simulation models can be considered in terms of future studies. Besides, in addition to the time windows problem, the pickup problem can also be taken into account and different solution proposals can be developed.

Key words: vehicle routing problem, time windows, optimization, metaheuristic algorithm, genetic algorithm.

INTRODUCTION

Companies can be advantageous over their competitors only by increasing the added value of their products and services by delivering these services to their customers faster. In other words, companies have to better control their product prices, costs, and productivity to gain an advantage over their competitors. Companies should also increase customer service satisfaction by preventing total delays with a well-planned logistics distribution channel to be at the forefront in their sector [Subramanian et al. 2013].

Since the majority of the total logistics costs of companies arise from distribution costs, the effective and efficient use of distribution equipment and personnel has become an important area of interest for business managers. In this respect, finding the most suitable route for a vehicle reduce distribution costs and increase the quality of the service offered to customers. This subject

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is referred to as a vehicle routing problem (VRP) in the literature [Gendreau et al. 2008].

The problem of vehicle routing is a problem of drawing a route, starting from a single point that allows all points to be visited with the shortest time and lowest cost. For a multi-system, at least one manufacturer, one customer, one vehicle, and one distribution structure are required for vehicle routing. Multiple input variables constitute important parameters in determining the routes according to the goal value of the total system. Therefore, the routing problem is a difficult optimization problem to calculate the results under variable inputs [Adamski 2015].

In the literature, many methods have been developed to find solutions to VRPs. There are mathematical models in different studies in the literature. In cases where mathematical models are inadequate, it is possible to talk about a wide variety of algorithms developed using heuristic and metaheuristic methods.

Metaheuristic solutions constitute the tools used to find solutions to problems at appropriate times. However, these methods obtain approximate values instead of finding the best solution value. Tabu search algorithm [Ting et al. 2017], variable neighborhood search [Todosijević et al. 2017], simulated annealing [Du et al. 2017], iterated local search [Uchoa et al. 2017], greedy randomized adaptive search procedure [Sörensen and Schittekat 2013], genetic algorithm [Hassanzadeh and Rasti-Barzoki 2017], memetic algorithm [Qi et al. 2015] and ant colony optimization [Du et al. 2017] are the most commonly used metaheuristic techniques.

Heuristic methods are iterative solution methods that consist of an intelligent combination of heuristic algorithms with different properties to find the best results in the solution area. Time-oriented nearest-neighbor heuristic [Hsu et al. 2007], iterative route construction and improvement algorithm [Figliozzi 2010], continuous forecasting model [Saberi and Verbas 2012], deterministic local search [Felipe et al. 2014], fuzzy inference algorithm [Jovanovic et al. 2014], heterogeneous adaptive neighbor search [Koç et al. 2014], evolutionary local search [Zhang et al. 2015], Clarke and Wright savings algorithm and density clustering algorithm [Erdoğan and Miller-Hooks 2012], lantime algorithm [Wen and Eglese 2015] and nearest neighbor algorithm [Suzuki and Kabir 2015] are some of the heuristic techniques used in vehicle routing problem.

There are many vehicle routing methodologies based on mathematical programming techniques. Mixed-integer linear programming [Gajanand and Narendan 2013], linear programming [Franceschetti et al. 2013], integer programming [Zhu et al. 2014], mixed-integer nonlinear programming [Glock and Kim 2015] and statistical method [Velázquez-Martínez et al. 2016].

Most of the above-mentioned studies are focused on the classical network design rather than specific vehicle routing problems with time windows. In this study, firstly we are focusing on the real-life problem considering multi-vehicle routing of daily delivery for lunch meal that a company is encountered. Secondly, time windows constraint is considered since each customer needs their lunch at different times. These objectives are considered using a genetic algorithm which is a mostly used method for NP-hard problems.

The remainder of the paper is organized as follows. Section 2 provides brief information about vehicle routing problems. The genetic algorithm which is used in this study is provided in Section 3. The proposed vehicle routing problem and application results are detailed in Section 4. Section 5 presents the conclusion and future research directions.

VEHICLE ROUTING PROBLEM

VRP was first introduced to the literature in 1959 by Dantzig and Ramser. In these studies, the authors focused on the problem of gasoline distribution to gas stations and established the first mathematical programming model to solve the problem. Later in 1964, Clark and Wright proposed an intuitive solution to the problem, but after this study, interest in VRP has grown even more in the literature. VRP is one of the optimization problems on which most methods are developed [Dantzig and Ramser 1959].

VRP is finding the best route a vehicle should follow to reduce transportation costs and increase customer service. According to another definition; VRP is the problem of designing optimum distribution/collection routes of vehicles assigned to serve geographically dispersed customers from one or more warehouses. VRP is the heart of distribution management. The simplest form of VRP is called Classical VRP [Khouadjia et al. 2012]. In Classic VRP:

1. Each city is visited only once.
2. Each vehicle starts and ends its route in the same warehouse.
3. There are restrictions on the number and configuration of routes.

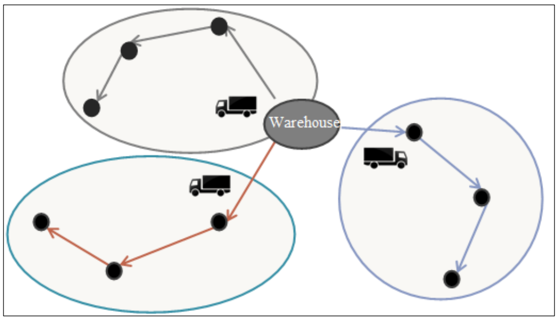
Constraints other than these basic constraints vary according to the nature of the problem. The problem of distribution of consumer goods from factories to retailers is a good and easy-to-understand example problem for VRP. Factories are supply centers, and customers are demand centers.

The VRP is a widely known integer programming problem that falls into the class of NP-hard problems where the computational power required to solve the problem increases exponentially with the size of the problem. In such problems, it is aimed to find approximate results to reach the right result quickly. This task is usually accomplished using a variety of metaheuristic methods that try to understand the nature of the problem. In this study, the genetic algorithm metaheuristic which is frequently used in the solution of NP-hard problems is used.

In the literature, VRP problems are classified according to many basic types. Most important ones; capacity-constrained, distance-constrained, time windows, distribution, and pickup VRPs. Subtypes of each basic type with additional constraints and different features are also included in the literature. The VRP type that is considered in this study is the time window distribution for multiple-vehicle delivery VRP. Brief information about this problem is given in the following section.

MULTIPLE-VEHICLE DELIVERY ROUTING PROBLEM WITH TIME WINDOWS

In this method, the needs of the customers in the network are tried to be met by using a large number of vehicles. After the demands of the customers are loaded in the network by the vehicle capacities, the vehicles reach the points on the determined route at the same time, meet the demands and return to the warehouse again. The difference between multi-vehicle vehicle routing and single-vehicle routing is that it requires as many vehicles as the number of routes in the network. This method meets the demands faster than other methods. Each transport request must be served within a predetermined time window (this constraint is called a time window). For this purpose, it is valid in cases where time constraints are important. The solution to the problem requires assigning the transportation demands to the vehicles and finding the route for each vehicle that minimizes the total cost [Laporte, 2009]. In this study, the multi-vehicle routing problem is discussed and an example of this problem type is provided in Figure 1.



Source: Khouadjia et al. 2012

Fig. 1. Multi-Vehicle Routing Problem

GENETIC ALGORITHM

The Genetic Algorithm (GA) involves the application of selection, crossover, and mutation processes to a population of individuals. Following the application of these procedures, a new population is created. The old population and the new population are exchanged for each other and each individual has its regulated value. The newly formed population is selected according to this regulated value and more compatible populations are tried to be formed in each newly created population.

GAs are particularly used in the areas of optimization, automated, mechanical learning, finance, marketing, vehicle routing, scheduling, assembly/disassembly line balancing, plant layout, and system reliability. The basic characteristics of GAs can be listed as follows [Zames et al. 1981];

- Poor solutions tend to disappear while good solutions tend to be used to create better solutions as the population evolves from generation to generation.
- They scan not the whole solution space only part of it.
- They reach a possible solution in a shorter time by doing an active search.
- They do not stick to local best solutions by simultaneously examining a population of solutions.

GAs first creates an initial population of individuals coded by the notation specified in the solution steps. Each chromosome in the initial population represents a possible solution to the problem. Each chromosome has a conformity value indicating the quality of the solution it encodes. The basic working logic of GAs is based on the proliferation of chromosomes with better conformity values, just like in the evolutionary process.

Selection is the process of selecting individuals of a new generation from the existing population according to the selection method chosen. The crossover operator is one of the substantial parameters that affect the performance of the GAs. Crossover creates new offspring by manipulating selected genes in the parent. Following the crossover operation, some of the chromosomes are mutated to increase the diversity of the chromosomes in the generation. The purpose of this process is to identify changes within the population. During the mutation process, the number of genes on the chromosome remains constant.

USE OF GENETIC ALGORITHM IN VRP

In this section, an application related to VRP has been made. The problem definition, the design phase of GA, and the results obtained are given in detail in the following sub-sections.

Problem Definition

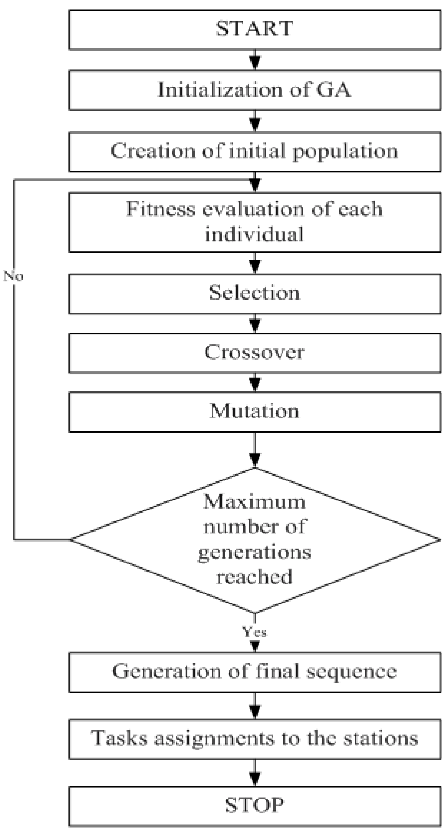
Several numerical network designs related to the VRPs are developed in the relevant literature to improve the near-optimal route for vehicles as discussed in the introduction section.

This study focused on the delivery of lunch meal food of a Food Company (FC) to various retailers in a variety of locations using the general type of vehicles. The focused problem can be described as a variant of VRP because of different service times. FC is located to the near of city center and has served 71 customers. Customer distance to the FC and the region of the vehicles are shown in Appendix-I. 7 regions and thus 7 routes are considered for this study. The customers need the foods at specific times. Minimization of the route cost increases Company's profitability. Thus, the first objective of this study is to minimize the total distances for all vehicles.

As it can be figured out from the problem, there may many different delivery options due to the nature of the problem. As an example, 11 customers are included in Region 1 means 11 different combination of the delivery route is possible for Route-1 vehicles. This combination is different for each region. To cope with the best delivery for each route, a genetic algorithm solution is provided in the following section. Thus, the second objective of this study is to find out which vehicle will serve which customer.

Design of the Genetic Algorithm

The definition of the GA was detailed in section 3. In this section, the design phase of the genetic algorithm used in the study is given. The flow diagram of this algorithm is provided in figure 2.



Source: Zames et al. 1981

Fig. 2. Flowchart of GA

The solutions in GAs are encoded as chromosomes based on the features of the problem. Chromosomes are usually constructed by using alphabets, integers, binary digits, or other characters. The structure of a chromosome for Route-1 is given in Figure 3. This chromosome involves the permutation of customer numbers and represents a possible delivery route.

9	**8**	**6**	**7**	**3**	**11**	**1**	**10**	**2**	**5**	**4**

Source: own work

Fig. 3. Structure of a chromosome for Route-1

The objective function of this study is to find the shortest routes for each region. While these routes are determined, each route can only be served by one vehicle and the route of the vehicles must start and end in the warehouse. However, the number of vehicles can be increased according to the desired mealtime. With the objective function, it is aimed to reduce costs by saving time, and it is aimed to ensure the highest level of customer satisfaction by meeting the demands of the customers on time. As mentioned before, customers want their meals at a certain time. In this direction, the genetic algorithm performance criteria selected for the solution were tested with different replications, and the best solution was reached, and how the genetic algorithm criteria affect the solution was revealed. It was stated in the study that there are 7 different routes. While explaining the solution method, instead of showing the solution separately for each route, only the solution for route 1 is shown. However, the findings obtained for all routes are given in Table 5 at the end of the study.

The data of 11 customers that FC distributes on Route-1 are given in the tables below. The distance matrix of the customers is given in Table 1 as km. The time interval values that customers want to receive service are given in Table 2. The travel times of the customers to each other are given in Table 3. The service time of the vehicles is fixed and 10 minutes for each customer. Accordingly, with MATLAB R15a, the data were encoded using Windows 10, 8GB RAM, 2.7 GHz (i5) computer, and the steps of the genetic algorithm were applied. The results obtained were presented in the next section.

Results of the genetic algorithm

The stages of the genetic algorithm were previously given in Figure 1. In the coding stage, permutation coding is used, single-point crossover for the crossover operator, and the mutation of two neighboring genes for mutation was applied. The sum of the distances is taken into account for the fitness function. The roulette wheel method, which is frequently used in the genetic algorithm, has been chosen in chromosome selection. Population size was considered as 10, 30, and 50 in the study. 1000 iterations were made for each population and this number was taken into account as the stopping criterion. The values obtained for all population sizes after running the program are given in Table 4.

Table 4 shows the results of the study. 1000 iterations were made for each population. The shortest distance obtained was 57.4 km with 10 population sizes. The shortest route length was seen after the 246th iteration in the algorithm running 1000 iterations.

The value did not change in subsequent iterations. The graph of this iteration is given in Figure 4. The most suitable route for this population is 1-2-6-5-11-9-10-8-7-3-4. The population size was increased in the second stage. It was observed that the total distance also increased despite the increasing population size. This value was seen after 84th iterations and did not change until 1000 iterations. Finally, the algorithm has been tested for a population size of 50 and it has been observed that the total distance increases again. As a result, the shortest path was obtained in the smallest population size and after 246th iterations. An improvement of approximately 14% was seen with the genetic algorithm as the total distance

Table 1. The distances of the customers on Route-1 to each other

Distance (km)	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
C_1	0	2	2	4	5	3	4	5	2	3	1
C_2	2	0	4	4	1	5	5	1	4	3	2
C_3	2	4	0	1	1	2	5	3	4	2	4
C_4	4	4	1	0	4	3	4	1	2	5	2
C_5	5	1	1	4	0	1	2	6	2	2	3
C_6	3	5	2	3	1	0	5	4	5	2	3
C_7	4	5	5	4	2	5	0	1	4	5	3
C_8	5	1	3	1	6	4	1	0	2	3	5
C_9	2	4	4	2	2	5	4	2	0	2	5
C_{10}	3	3	2	5	2	2	5	3	2	0	1
C_{11}	1	2	4	2	3	3	3	5	5	1	0

Source: own work

Table 2. Time intervals that customers on Route-1 want the service time

Service time	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
Start	08:00	09:45	11:00	12:00	11:30	10:00	10:30	9:30	08:00	08:30	12:00
End	11:45	12:15	13:15	13:00	13:30	10:30	11:40	10:30	12:45	12:30	13:15

Source: own work

Table 3. Travel times of customers on Route-1 relative to each other

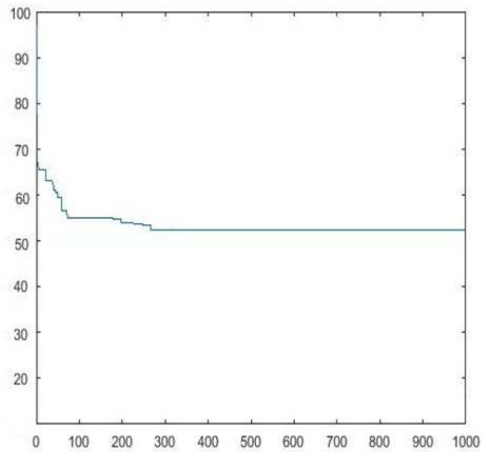
Duration (min)	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
C_1	0	5	5	10	12	7	10	12	5	7	3
C_2	5	0	10	10	3	12	12	3	10	7	5
C_3	5	10	0	3	3	5	12	7	10	5	10
C_4	10	10	3	0	10	7	10	3	5	12	5
C_5	12	3	3	10	0	3	5	14	5	5	7
C_6	7	12	5	7	3	0	12	10	12	5	7
C_7	10	12	12	10	5	12	0	3	10	12	7
C_8	12	3	7	3	14	10	3	0	4	7	12
C_9	5	10	10	5	5	12	10	4	0	4	12
C_{10}	7	7	5	12	5	5	12	7	4	0	3
C_{11}	3	5	10	5	7	7	7	12	12	3	0

Source: own work

Table 4. Results of the genetic algorithm for Route-1

Population size	10	30	50
Iteration number	1000	1000	1000
Mutation rate	0.8	0.9	0.01
Crossover rate	0.2	0.05	0.5
Total shortest distance (km)	57.4	65.3	74.9
Suitable route	1-2-6-5-11-9-10-8-7-3-4	1-10-8-5-4-9-2-6-7-3-11	9-8-6-7-3-11-1-10-2-5-4
Convergence iteration number	246	84	48

Source: own work



Source: own work

Fig. 4. Convergence graph for Route-1.

In the study, the shortest path calculation for a FC is shown for Route-1. As seen in Appendix-I, there are 7 different routes in total in the study. Using the same steps for each route, a solution was found with the genetic algorithm. The shortest route and improvement rates for all routes are given in Table 5.

In the study, in addition to the route calculation for 7 different routes, how many vehicles should be for each route and which vehicle will serve which customers were added as constraints. Accordingly, an additional vehicle for each route has been added to the system. Only one vehicle service can be continued on the last route. Table 6 shows which vehicle will serve which customers for each route.

Table 5. Shortest route and recovery rates for all routes

Route	Previous total distance (km)	After total distance (km)	Delivery order within the route	Improvement rate (%)
Route-1	65.4	57.4	1-2-6-5-11-9-10-8-7-3-4	13.9
Route-2	53.3	46.3	9-12-1-3-5-8-2-11-4-10-7-6	15.1
Route-3	10.9	9.8	4-10-3-13-5-12-6-1-11-2-8-7-9	11.3
Route-4	64.8	54.1	4-6-5-1-2-3-8-7	19.8
Route-5	160.6	146.6	4-2-7-11-13-8-10-5-15-6-12-3-9-1-14	9.6
Route-6	21.2	17.3	5-7-2-8-6-1-3-4-9	22.4
Route-7	12.4	10.7	2-3-1	16.4

Source: own work

Table 6. The customer that the vehicles will serve

Routes	Vehicles	Customers	Living time
Route-1	1	1-2-6-5-11	08:00
	2	9-10-8-7-3-4	08:00
Route-2	1	9-12-1-3-5-8	08:00
	2	2-11-4-10-7-6	08:00
Route-3	1	4-10-3-13-5-12-6	09:45
	2	1-11-2-8-7-9	08:45
Route-4	1	4-6-5-1	11:30
	2	2-3-8-7	09:00
Route-5	1	4-2-7-11-13-8-10-5-15	08:45
	2	6-12-3-9-1-14	09:30
Route-6	1	5-7-2-8-6	10:50
	2	1-3-4-9	08:30
Route-7	1	2-3-1	09:00

Source: own work

APPENDIX-I

C	S	F	D (km)	R	C	S	F	D (km)	R
C_1	08:00	11:45	29,6		C_1	09:45	11:30	19,7	
C_2	09:45	12:15	32,2		C_2	08:00	12:00	23,1	
C_3	11:00	13:15	33,1		C_3	11:00	12:00	23	
C_4	12:00	13:00	32,5		C_4	09:30	11:00	20,5	
C_5	11:30	13:30	31,3		C_5	11:30	12:30	19,8	
C_6	10:00	10:30	25,3	R_1	C_6	12:00	13:30	20,1	
C_7	10:30	11:40	26,1		C_7	11:45	12:45	19,6	R_2
C_8	09:30	10:30	29,2		C_8	12:30	13:30	19,7	
C_9	08:00	12:45	29,9		C_9	08:30	10:00	23,1	
C_{10}	08:30	12:30	29,8		C_{10}	09:45	10:30	18,9	
C_{11}	12:00	13:15	34,8		C_{11}	08:45	10:00	23,3	
C_1	08:45	10:00	1,1		C_{12}	09:00	11:00	19,5	
C_2	11:00	12:00	0,65		C_1	12:00	13:00	28,2	
C_3	11:15	12:30	2,1		C_2	11:30	12:30	25,7	
C_4	09:45	11:00	0,35		C_3	11:45	12:30	48	
C_5	12:00	13:30	0,55		C_4	09:00	10:30	38,8	R_4
C_6	12:30	13:30	3,5		C_5	11:30	12:30	39,9	
C_7	12:00	13:00	3,6	R_3	C_6	11:00	13:00	44,8	
C_8	11:15	12:30	4,5		C_7	12:30	13:30	24,3	
C_9	12:30	13:30	0,9		C_8	12:00	12:45	20,3	
C_{10}	10:00	11:30	0,95		C_1	11:30	13:00	24,3	
C_{11}	09:30	11:00	2,7		C_2	09:30	11:00	17,9	
C_{12}	12:15	13:30	0,2		C_3	10:15	11:30	18,3	
C_{13}	11:45	12:45	1,5		C_4	08:45	09:45	19,6	
C_1	08:30	11:00	5		C_5	11:45	13:00	20,1	
C_2	11:45	12:30	10,4		C_6	09:30	11:00	18,5	
C_3	10:30	13:00	5,7		C_7	09:45	12:0	18,8	
C_4	11:30	13:30	6,5		C_8	11:00	12:00	19,5	R_5
C_5	10:50	12:30	5,5	R_6	C_9	10:30	11:30	20,6	
C_6	12:30	13:30	5,3		C_{10}	11:30	13:00	23,6	
C_7	11:30	13:00	12		C_{11}	10:15	11:00	19,7	
C_8	12:00	13:30	14,5		C_{12}	09:45	11:00	25,8	
C_9	11:45	12:30	13,3		C_{13}	10:30	11:30	17,9	
C_1	09:30	11:00	14,4		C_{14}	12:00	13:30	20,1	
C_2	10:00	11:30	17,3	R_7	C_{15}	12:30	13:30	22,1	
C_3	09:00	10:00	15,3						

C: Customer, S: Service Start, F: Service Finish, D: Customer distance to the FC, R: Delivery region/route.

CONCLUSIVE REMARKS

Transportation has an important share in the activities in the field of logistics. Improvements to be made on the duration and cost of transportation positively affect the total logistics activities. Planning the vehicles most appropriately can complicate the problem and turn it into a problem that cannot be solved in a reasonable time. For the solution of these and similar problems, it is tried to obtain a solution in a reasonable time with metaheuristic algorithms.

In this study, the VRP for a food company is discussed. Currently, this business serves 7 different regions. Every customer in each region requests meals at different times. Therefore, the business wants to know which customer will provide the most appropriate service with which vehicle. Genetic algorithm, one of the metaheuristic algorithms, was used in the study to solve this problem. With this algorithm, different numbers of populations were repeated for certain times, and the shortest total distance was found. However, the same method was used to determine which vehicle will serve on which route. In the study, it was observed that significant improvements were made compared to the current situation. Accordingly, the findings obtained in the study positively affected the profitability of the company because of shorter delivery distances. Moreover, increased customer satisfaction can also be considered as a positive effect for long-term profitability. The metaheuristic algorithm used in the study does not give the most optimal result due to the nature of the problem.

Therefore, mathematical models or simulation algorithms can be considered as future studies.

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REFERENCES

Adamski A., 2015. Routing problems based on HILS system platform, LogForum, 11(1). http://doi.org/10.17270/J.LOG.2015.1.8

Campbell A.M., Savelsbergh M., 2005. Decision support for consumer direct grocery initiatives, Transportation Sciences, 39 (3), 313-327. http://doi.org/10.1287/trsc.1040.0105

Dantzig G.B., Ramser J.H., 1959. The truck dispatching problem. Management Science, 6(1), 80–91, http://doi.org/10.1287/mnsc.6.1.80.

Du J., Li X., Yu L., Dan R., Zhou J., 2017. Multi-depot vehicle routing problem for hazardous materials transportation: A fuzzy bilevel programming. Information Sciences, 399, 201–218, http://doi.org/10.1016/j.ins.2017.02.011.

Erdoğan S., Miller-Hooks E., 2012. A green vehicle routing problem. Transportation Research Part E: Logistics and Transportation Review, 48(1), 100-114. http://doi.org/10.1016/j.tre.2011.08.001

Felipe Á., Ortuño M.T., Righini G., Tirado G., 2014. A heuristic approach for the green vehicle routing problem with multiple technologies and partial recharges, Transportation Research Part E: Logistics and Transportation Review, 71, 111-128. http://doi.org/10.1016/j.tre.2014.09.003

Figliozzi M., 2010. Vehicle routing problem for emissions minimization. Transportation Research Record: Journal of the Transportation Research Board, (2197), 1-7. http://doi.org/10.3141/2197-01

Franceschetti A., Honhon D., Van Woensel T., Bektaş T., Laporte G., 2013. The time-dependent pollution-routing problem. Transportation Research Part B: Methodological, 56, 265-293.

Gendreau M., Iori M., Laporte G., Martello S., 2008. A Tabu search heuristic for the vehicle routing problem with two-dimensional loading constraints, Networks: An International Journal, 51(1), 4-18. http://doi.org/10.1002/net.20192

Gajanand M.S., Narendran T.T., 2013. Green route planning to reduce the environmental impact of distribution, International Journal of Logistics Research and Applications, 16(5), 410-432. http://doi.org/10.1080/13675567.2013.831400

Glock C.H., Kim T., 2015. Coordinating a supply chain with a heterogeneous vehicle fleet under greenhouse gas emissions, The International Journal of Logistics Management, 26(3), 494-516. http://doi.org/10.1108/IJLM-09-2013-0107

Govindan K., Jafarian A., Khodaverdi R., Devika K., 2014. Two-echelon multiple vehicle location-routing problem with time windows for optimization of sustainable supply chain network of perishable food, International journal of production economics, 152, 9-28. http://doi.org/10.1016/j.ijpe.2013.12.028

Hasani A., Zegordi S.H., Nikbakhsh E., 2012. Robust closed-loop supply chain network design for perishable goods in agile manufacturing under uncertainty, International journal of production research, 50 (16), 4649-4669. http://doi.org/10.1080/00207543.2011.625051

Hassanzadeh A., Rasti-Barzoki M. 2017. Minimizing total resource consumption and total tardiness penalty in a resource allocation supply chain scheduling and vehicle routing problem. Applied Soft Computing Journal, 58, 307–323, https://doi.org/10. 1016/j.asoc.2017.05.010.

Hsu C.I., Hung S.F., Li H.C., 2007. Vehicle routing problem with time-windows for perishable food delivery, Journal of Food Engineering, 80(2), 465-475. http://doi.org/10.1016/j.jfoodeng.2006.05.029

Jovanović A.D., Pamučar, D.S., Pejčić-Tarle S., 2014. Green vehicle routing in urban zones–A neuro-fuzzy approach, Expert Systems with Applications, 41(7), 3189-3203. http://doi.org/10.1016/j.eswa.2013.11.015

Khouadjia M.R., Sarasola B., Alba E., Jourdan L., Talbi E.G. 2012. A comparative study between dynamic adapted PSO and VNS for the vehicle routing problem with dynamic requests, Applied Soft Computing Journal, 12(4), 1426–1439. http://doi.org/10.1016/j.asoc.2011.10.023

Koç Ç., Bektaş T., Jabali O., Laporte G. 2014. The fleet size and mix pollution-routing problem, Transportation Research Part B: Methodological, 70, 239-254.

Laporte G., 2009, Fifty years of vehicle routing, Transportation science, 43(4), 408-416. http://doi.org/10.1287/trsc.1090.0301

Osvald A., Stirn L.Z., 2008. A vehicle routing algorithm for the distribution of fresh vegetables and similar perishable food, Journal of Food Engineering, 85 (2), 285-295. http://doi.org/10.1016/j.jfoodeng.2007.07.008

Prindezis N., Kiranoudis C.T., Marinos-Kouris D., 2003. A business-to-business fleet management service provider for central food market enterprises, Journal of Food Engineering, 60 (2), 203-210. http://doi.org/10.1016/S0260-8774(03)00041-4

Qi Y., Hou Z., Li H., Huang J., Li X., 2015. A decomposition based memetic algorithm for multi-objective vehicle routing problem with time windows, Computers & Operations Research, 62(3), 61–77, http://doi.org/10.1016/j.cor.2015.04.009.

Saberi M., Verbas İ.Ö., 2012. Continuous approximation model for the vehicle routing problem for emissions minimization at the strategic level, Journal of Transportation Engineering, 138(11), 1368-1376.

Schmid V., Doerner K.F., Hartl R.F., Savelsbergh M.W.P., Stoecher W., 2009. A hybrid solution approach for ready-mixed concrete delivery, Transportation Sciences, 43 (1), 70-85. http://doi.org/10.1287/trsc.1080.0249

Sorensen K., Schittekat P., 2013. Statistical analysis of distance-based path relinking for the capacitated vehicle routing problem, Computers and Operations Research, 40(12), 3197–3205, https://doi.org/10.1016/j.cor.2013.02.005.

Subramanian A., Uchoa E., Ochi L.S., 2013. A hybrid algorithm for a class of vehicle routing problems, Computers & Operations Research, 40(10), 2519–2531. http://doi.org/10.1016/j.cor.2013.01.013

Suzuki Y., Kabir, Q.S., 2015. Green Vehicle Routing for Small Motor Carriers, Transportation Journal, 54(2), 186-212. http://doi.org/10.5325/transportationj.54.2.0186

Ting C.K., Liao X.L., Huang Y.H., Liaw R.T. 2017. Multi-vehicle selective pickup and delivery using metaheuristic algorithms. Information Sciences, 406–407, 146–169, http://doi.org/10.1016/j.ins.2017.04.001.

Todosijević R., Hanafi S., Urošević D., Jarboui B., Gendron B., 2017. A general variable neighborhood search for the swap-body vehicle routing problem. Computers & Operations Research, 78, 468–479, http://doi.org/10.1016/j.cor.2016.01.016.

Tarantilis C.D., Kiranoudis C.T., 2001. A meta-heuristic algorithm for the Efficient distribution of perishable foods, Journal of Food Engineering, 50 (1), 1-9. http://doi.org/10.1016/S0260-8774(00)00187-4

Tarantilis C.D., Kiranoudis C.T., 2002. Distribution of fresh meat, Journal of Food Engineering, 51 (1), 85-91. http://doi.org/10.1016/S0260-8774(01)00040-1

Uchoa E., Pecin D., Pessoa A., Poggi M., Vidal T., Subramanian A. 2017. New benchmark instances for the Capacitated Vehicle Routing Problem, European Journal of Operational Research, 257(3), 845–858, http://doi.org/10.1016/j.ejor.2016.08. 012.

Velázquez-Martínez J.C., Fransoo J.C., Blanco E.E., Valenzuela-Ocaña K.B., 2016, A new statistical method of assigning vehicles to delivery areas for CO2 emissions reduction. Transportation Research Part D: Transport and Environment, 43, 133-144. http://doi.org/10.1016/j.trd.2015.12.009

Ying W., Ying Y.L., 2012. Optimization model of refrigerated food transportation. In: Proceedings of International Conference of Service Systems and Service Management, Beijing, 220-224. http://doi.org/10.1109/ICSSSM.2012.6252224.

Wen L., Eglese R. 2015. Minimum cost VRP with time-dependent speed data and congestion charge. Computers & Operations Research, 56, 41-50. http://doi.org/10.1016/j.cor.2014.10.007

Zhang Z., Wei L., Lim A. 2015. An evolutionary local search for the capacitated vehicle routing problem minimizing fuel consumption under three-dimensional loading constraints, Transportation Research Part B: Methodological, 82, 20-35. http://doi.org/10.1016/j.trb.2015.10.001

Zames G., Ajlouni N.M., Ajlouni N.M., Ajlouni N.M., Holland J. H., Hills W.D., Goldberg D.E., 1981. Genetic algorithms in search, optimization and machine learning. Information Technology Journal, 3(1), 301-302.

Zhu X., Garcia-Diaz A., Jin M., Zhang Y., 2014. Vehicle fuel consumption minimization in routing over-dimensioned and overweight trucks in capacitated transportation networks, Journal of Cleaner Production, 85, 331-336. http://doi.org/10.1016/j.jclepro.2013.10.036

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ORIGINAL PAPER

UPSKILLING AND RESKILLING REQUIREMENT IN LOGISTICS AND SUPPLY CHAIN INDUSTRY FOR THE FOURTH INDUSTRIAL REVOLUTION

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ABSTRACT. **Background:** For years, the logistics and supply chain industries have been optimized to reduce cost, minimize the carried inventories and increase the efficiency of assets utilization. Besides that, the impact of industrial revolution 4.0 (IR 4.0) has queried for more new skills for a more demanding job scope. In particular, many traditional operation methods have been gradually replaced by automation-based operation. Hence the requirement for upskilling and reskilling became appealing. The present paper discusses the role of upskilling and reskilling during IR 4.0, a method to implement upskilling and reskilling training, the role of the Human Resource Development Fund (HRDF), as well as the challenges faced during the implementation of reskilling and upskilling in the logistics industries.

Methods: Inductive reasoning is employed in the paper, which is backed up by a study of related scholarly journal papers to uncover the Malaysian upskilling and reskilling requirement in the logistics industry during IR 4.0from both intrinsic and extrinsic lenses.

Results: The paper claims that changing the workplace and workforce, increase employees competitiveness and cost-effectiveness in long term is the main importance of upskilling and reskilling. Nevertheless, firms cannot disregard the needs for technical and human skills as well as the HRDF initiatives. These include the creation of a digital culture with the right training and development to uphold the local experts.

Conclusions: Despite the paper's qualitative approach, the findings will provide a clearer understanding of the upskilling and reskilling requirements for IR 4.0, as well as a foundation for future study. This paper proposes an alternative strategy to diversify the economy and enter IR 4.0 for a developing country that is dependent on a non-renewable source.

Key words: upskilling, reskilling, IR 4.0, logistics management, supply chain management.

INTRODUCTION

The term "IR 4.0" refers to a new phase of the industrial revolution that emphasises interconnectedness, automation, machine learning, and real-time data. If Industry 3.0 was concerned with the automation of single equipment and operations, IR 4.0 is associated with the end-to-end digitisation of all physical objects and their transformation into digital ecosystems with supply chain partners [Morgan 2019]. IR 4.0, also known as the internet of things (IoT) or smart manufacturing, combines physical production and processes with smart digital technology, machine learning, and big data to give manufacturing and supply chain management companies a more holistic and connected world. In brief, many activities that once involved humans can now be completed by automation and digitization. Employees have to adapt to such technological changes; for instance, they need to learn how to employ big data and machine learning to cater for technological advancement. Despite that, the majority of Malaysian employment is still relying on semi-skilled employees, while the proportion of skilled employees in Malaysia is at about 28 percent. This number definitely has

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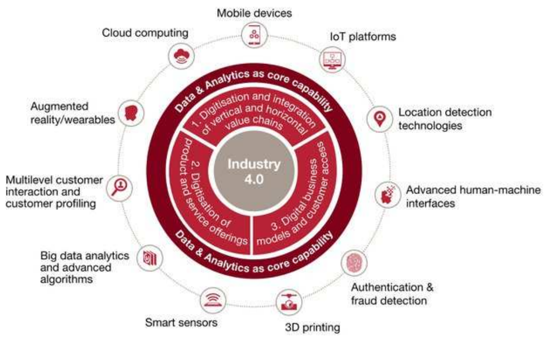
to be improved to cater for IR 4.0 development [John 2020].

Five main innovations are projected to have a major effect on logistics and supply chains and are currently at various levels of preparation and implementation across business sectors: IoT, artificial intelligence, autonomous robotics, enterprise wearables, and additive manufacturing [World Economic Forum 2017]. A wide variety of these innovations are now influencing manufacturing processes, logistics, and supply chains. Consumer expectations for goods, factory operations and footprints, and industrial supply chain management are all being reshaped to unparalleled degrees and at the greater speed [Wahab et al. 2020]. Thus, industry experts and leaders believed that IR 4.0 such as automated robots, autonomous systems, and additive manufacturing would revolutionize conventional methods of generating value.

In general view, IR 4.0 is driven by three main elements that are (i) digitisation and integration of vertical and horizontal value chains; (ii) digitisation of product and service offerings; and (iii) digital business models and customer access [Geissbauer et al. 2016]. IR 4.0 digitizes and incorporates operations vertically through the whole organization, starting with product production and ordering and continuing across processing, logistics, and operation. Meanwhile, horizontal integration extends beyond corporate processes to include all core supply chain players, from suppliers to end consumers. It encompasses systems ranging from track and trace technology to real-time automated preparation and execution. The second element which emphasized product digitisation involves both the addition of existing products, such as the addition of smart sensors or contact systems that can be used for data processing software and the development of new digitised products that rely on fully automated solutions [John 2020]. The last element focused on providing disruptive digital solutions such as complete, data-driven services and integrated platform solutions. Figure 1 presents IR 4.0 framework and contributing digital technologies.



Source: Geissbauer et al. 2016

Fig. 1. IR 4.0 framework and contributing digital technologies

IR 4.0 innovations are changing just not the logistics and supply chain environment, but also the world of work. According to a study conducted by Bank Negara Malaysia in 2018, 54 percent of Malaysian employees will be automated in the next 10 to 20 years. In order to adapt to these unavoidable shifts in the workplace, talent upskilling to keep up with digitalization trends is becoming more important than ever [Ramasamy 2018]. In 2020, Randstad Malaysia has carried out an online study with Malaysians to learn about the local workforce's attitudes toward the labour market as well as the difficulties and experiences of job seekers so far. The study's findings revealed that 91 percent of respondents plan to re-skill and upskill themselves, 55 percent are doing so to prepare for how robotics and digitisation will impact their future, 21 percent are looking to improve their occupation or sector that they work in, and 13 percent are afraid of losing their current job due to redundancy. Digital capabilities are critical for moving forward in IR 4.0. Although every business and organization are heading toward digitalization, they all face the same challenge: the need for connectivity and real-time insights through operations, collaborators, goods, and individuals [Randstad Malaysia 2020].

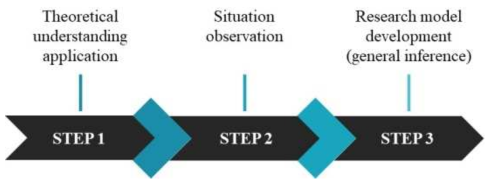
UPSKILLING & RESKILLING OVERVIEW

Cambridge dictionary defined the 'reskilling' as the procedure that learns a new skill that enables people to do a different job or give guidance to other people to do a different job; meanwhile, 'upskilling' refers to the procedure of learning a new skill or training employees with new skills. Upskilling and reskilling are important during IR 4.0 as most businesses have undergone a significant shift towards digitalization. For instance, IR 4.0 brings the revolution of technology and change the job scope/job profile more towards the internet base or automation base [Sima et al. 2020]. In fact, some of the conventional jobs will turn redundant. Hence, the knowledge and the skill of the employees need to be updated and always explore the new thing in order to stay competitive in the current working environment and for the future career life. The area to reskill and upskill during IR 4.0 may include but not limited to big data analysis, the IoT, app and web-based operation, machine learning, and cloud computing.

To minimise such technological change accompanied by a shortage of talent, mass unemployment and increased inequality, the companies (employers) must hold reskilling and upskilling training to the existing employees. In this regard, the government has the responsibility to cultivate awareness of reskilling advantages, training opportunities, as well as encourage employers to re-train their employees [McKee and Gauch 2020]. In Malaysia, various efforts have been done by the government to assist people in upskilling and reskilling. Back in the year 2015, the Malaysian Federal Budget already announced an employment insurance scheme that will help the employees that are retrenched by the company to do the reskilling and upskilling as reported by the Malaysian Trade Union Congress (MTUC). Alike, the MTUC hopes to help various departments such as the Department of Trade Unions Affairs and Labour Department doing the reskilling and upskilling for the employees in order to prepare for the future of work in the context of IR 4.0 [MTUC, 2018]. In recent years, the Ministry of Human Resource (MoH) indicated that the Manpower Department Training Institutes (ILJTM) will provide training to assist the employees to upskill, reskill and obtain relevant qualifications that enable them to benefit their career or reskilled for another job [Sivanandam 2019]. The training is expected to assist the Malaysian to face current and future job demand.

METHODOLOGY

In this study, an inductive reasoning approach was used to determine the upskilling and reskilling requirements in the logistics industry during IR 4.0. Since inductive analysis is seldom used in logistics studies, they suggest that more inductive research be conducted so that the findings may create a common and comprehensive understanding [Kovács and Spens 2005]. Instead of using an idealisation method, as suggested by Ketokivi and Mantere [2010], this study employed an empirical and theoretical contextualisation reasoning approach. An empirical contextualization is carried out with the help of contextual and reliable evidence obtained from previous empirical data. The findings of this study were derived from a relevant definition, which was then applied to the relevant theoretical discourse in terms of theoretical contextualization. Due to the shortcomings of the idealisation method, as well as a lack of analysis and familiarity with the logistics industry's upskilling and reskilling requirements during IR 4.0, a contextualisation approach was developed using specific upskilling and reskilling, logistics industry, and IR 4.0 literature.



Source: Kovács and Spens 2005

Fig. 2. Inductive reasoning process

THE IMPORTANCE OF UPSKILLING AND RESKILLING FOR IR 4.0

Reskilling and upskilling are important to increase company productivity. Research done by Mgiba [2019] indicated that upgrading the existing skill or learning a new skill and increase the knowledge will benefit the individual to be successful in the current working industry or moving to a new position. Moreover, the author also stated that reskilling and upskilling can help the sales and marketing personnel to put more attention on the customer and market, more agile and can be more flexible when facing the changes. In fact, reskilling and upskilling will help to maintain the company sustainability and reduce the hiring cost. The company sustainability can be ensured since the employees who have gone through the reskilling and upskilling training able to match the current business need.

Conduct the upskilling and reskilling training also enable the company to show their concern on the employees' career and their future and to make sure their skill would not turn obsolete. By adopting reskilling and upskilling in the workplace, it will increase motivation, enhance the employee experience, and encourage a higher level of loyalty. The company whether can conduct the training in technical skill and soft skill in order to enhance their ability to work under pressure work and built a strong relationship to the colleague or client. Moreover, learning the different skills bring opportunities for the organizations as well as employees to do better performance and stay throughout the long journey [Nayak 2018]. The importance of upskilling and reskilling towards IR 4.0 from various specific perspective are discussed below:

A Changing Workplace and Workforce

With the implementation of IR4.0, most organizations are attempting to carry out digital transformation in their workplace. The application of advanced technology in the market, such as artificial intelligence, nanotechnology, quantum computing, synthetic biology, and robotics, is regarded as the beginning of IR 4.0 and will gradually overtake manufacturing technologies developed over the last sixty years [Ghobakhloo 2018, Morgan 2019]. Based on the analysis done by the World Economic Forum, the majority of employers' re-skill and upskill work still concentrated on a small number of existing high-skilled and high-value employees. However, to truly meet the challenge of formulating a successful employee strategy for IR 4.0, industry leaders need to view the human capital investment as an asset rather than a liability [World Economic Forum 2018].

Increase Employees Competitiveness

The company should provide reskilling and upskilling support to its workforce to ensure its competitiveness in this industry. Adopting reskilling and upskilling in the workplace can boost morale, improve the employee experience, and foster a higher degree of loyalty. Furthermore, learning new skills allows the management and employees of a company to improve their work productivity and remain on the job for a longer period [Nayak 2018]. Almost 70 percent of employees said that the training provided by their companies has resulted in brighter professional opportunities in their relevant fields, and 60 percent of employees accepted that enjoyment at work is linked to job learning and development opportunity.

Cost-Effective in Long Term

According to Eshna [2019], if the company replace the salaried employees, it will cost about 6 to 9 months of salary for recruitment. For example, if a company intend to fire an employee who earns about 60,000 per year and recruit the new one, it will cost about 30,000 to 45,000 for recruiting and training. This percentage will be higher based on the educated level and senior-level position. Although the companies still must put more time and money in reskilling and upskilling training, the gained skills always lead to cost-saving in the long run. Moreover, the costs in hiring a new employee involve recruiting, advertising, training, interviewing and so on. Therefore, conduct reskilling and upskilling will reduce the cost of hiring and invest the money in the right place. This will lead to an increase in future productivity level and future profits.

REQUIREMENTS AND INITIATIVES FOR UPSKILLING AND RESKILLING

Requirements for technical and human skills

Physical engineering, biotechnology, and emerging innovations, such as artificial intelligence (AI), Internet of Things (IoT), big data analytics (BDA), automation, cloud technology, virtual reality, and high-speed mobile Internet, are driving the IR 4.0 (Butt, 2020). These technologies, especially automation and AI, have changed and disrupted the way businesses work, and they are also having a significant impact on how businesses interact with employees in order to enhance efficiency, quality, and safety [Ling and Wahab 2020, Rotatori et al. 2020].

Despite the upbeat outlook, technological advancement has resulted in the abolition of certain job functions and the development of new ones. As a result, in order to stay competitive, businesses must persevere and implement effective training programmes for upskilling and reskilling their current employees [McKinsey Global Institute 2020, Nier et al. 2020]. Current employees must be educated and exposed to the new skills that are needed as a result of the companies' adoption of new technology. Technical skills and human skills are two skill sets that businesses should develop in their employees. According to Kipper [2021], employees with technical skills or hard skills are capable of analysing data, developing software, and detecting system issues, improving security, and maintaining it. Due to a lack of experts, especially in AI and automation programming, IR 4.0 has led businesses to recruit external talent to train and equip employees with the required technical skills to simulate a real work environment [World Economic Forum 2018]. Human skills, on the other hand, are an important component of IR 4.0 [Oztemel and Gursev 2018]. Despite the fact that machines have taken over the majority of logistics operations, human involvement is still needed because human skills such as critical thinking, emotional intelligence, leadership, empathy, and initiative cannot be replaced by technology. Analytical and problem-solving abilities, as well as adaptability, versatility, creativity, and the ability to work multidisciplinary, are the skills that will keep employees important to the company even as AI and automation overtake their job functions [Rotatori et al. 2020].

Most employees have both technological and human abilities, and they are both inborn in them. However, the arrival of IR 4.0 necessitates upskilling and reskilling. To resolve the current situation, businesses play a critical role in determining the requisite skills based on the various techniques that an organisation employs in order to advance employees' skills to the next stage [Kipper 2021]. Since each employee has unique characteristics and abilities, the human resources unit of a company should be in charge of identifying and implementing the necessary upskilling and reskilling programmes in order to fulfil and utilise employees' hidden abilities. Fostering these abilities is critical in assisting employees in becoming more secure in the age of IR 4.0 and being prepared for the technological ability set requirement transition [Butt 2020].

In the IR 4.0 environment, previous research on technical and human skills identified these two skills as critical skills that needed employees to promote upskilling and reskilling. However, given that young and experienced employees have different sets of skills based on their job experiences, it is not suitable for all employees. Younger employees are more open to learning new skills and knowledge, particularly when it comes to technology adoption. Experienced employees, on the other hand, have a difficult time learning a new skill, especially when it comes to technology adoption. Similarly, experienced employees with valuable expertise can find their skills becoming increasingly obsolete. This could result in a lack of participation on both sides [Oztemel and Gursev 2018]. To address this issue, businesses should conduct an ability gap review. It is a mechanism in which an organisation is responsible for identifying the skills gap between what is required and what is available in the IR 4.0 setting in order to maintain company development and performance. The analysis can be carried out by proper knowledge exchange management and knowledge skills, which are essential to ensure that information is transmitted smoothly [Bahar et al. 2020]. In the same way, this analysis can be done on two levels: organisational or departmental level and individual level. An assessment of integrated abilities at the organisational or departmental level is used to determine a team's capability in completing a project or meeting expected potential business objectives. On the other hand, at the individual level, it is an assessment of a specific employee's abilities in relation to the present and potential demands of their job functions. It can be decided by a performance assessment and interview for current skills, but it can be determined by consideration of the company's mission and priorities for future skills. This skill gap review can be done internally or by an outside consultant, and it's a great way to evaluate the employees' abilities for reskilling and upskilling [Doherty and Stephens 2021].

Evidently, a business may use competency management software (CMS) to monitor employee competencies, conduct online training, and map out the skillset required for each employee. According to Wahab et al. [2021], when employees are assigned a new job role without the necessary skills due to a lack of company support, it can be a risk to the company, particularly in the manufacturing, construction industries, and healthcare. CMS assists the company in forecasting potential risk, allowing the appropriate department within the organisation to take the required steps to prevent any potential issues. This form of software can also be set up so that employees can see appropriate training and optional skills. It allows employees to increase their worth as employees by upskilling and rescaling. Most significantly, CMS can be used to forecast potential ability requirements by making upskilling and reskilling as a routine company procedure [Bohlouli et al. 2017].

Initiatives funded by the Human Resource Development Fund (HRDF)

The Human Resources Development Fund (HRDF) was established in 1993 to provide various training and development programmes for employees throughout the country in order to upskill and reskill their skills in order to meet current business needs and strategies, especially in the era of IR 4.0 It is important to improve employees' skills in order for them to be more competitive and valuable in the job market [Azizan et al. 2021]. HRDF is committed to achieving its vision of being the country's leading authority on human capital growth by providing learning and human resource development through funding, skills enhancement training, evaluations, promotional programmes, and education. The HRDF is a pool of funds made up of HRD levies raised from manufacturing and service sector employers. HRDF requires any employer to register to ensure the employees' welfare is defended. HRDF is the entity under the MoH that is in charge of training the existing and future workforce to help Malaysia become a high-income economy. When an employer fails to comply, they will be fined RM10,000 in the situation where they attempt to delay or ignore the monthly grant request [HRDF 2021].

Malaysia's government has mandated the establishment of the HRDF. As a result, businesses that fall into the government's designated category must participate in this initiative. The HRDF invests directly in numerous upskilling and capacity-building programmes for all industries, as well as technical training courses, in order to expand the country's skilled workforce [Azizan et al. 2021]. The ultimate aim is to bind employees together and train them for potential industrial demands (i.e., IR 4.0). The HRDF offers a variety of skill-building programmes that support employees. For example, HRDF is responsible for providing resource-rich information sharing and, as a result, creating a skill development atmosphere for employees across the country in order to create a professional and resourceful workforce [Man 2020].

As a result, HRDF will continue to be a key player in efforts to provide appropriate training for Malaysian employers and employees as they prepare for the arrival of IR 4.0. The use of emerging technology has reshaped the future of jobs since the introduction of IR 4.0 in 2011. This is because automation and AI have reduced the need for employees to perform repetitive tasks, resulting in higher company productivity and, as a result, a slowing economy [Man 2020]. HRDF is emphasising the requisite training set to equip employees with the right skills and resources needed by businesses in meeting the IR 4.0 environment, as the use of automation and digital technology grows. According to a survey conducted by the World Economic Forum in 2018, IR 4.0 will develop new work roles that will involve new skills, as well as change the way employees conduct themselves in day-to-day operations. As a result, HRDF takes the lead in ensuring that local employees are adequately trained by supplying and educating them with a set of training aimed at reducing their reliance on manual labour [HRDF 2021].

To date, HRDF has developed the Industrial Skills Framework (IndSF) to identify and analyse the appropriate upskilling and reskilling programmes that employers and employees need in order to prepare for IR 4.0. HRDF is currently assisting the country in achieving IR 4.0 by providing training and funding to ensure the growth of high-impact human resource initiatives. The HRDF's strategic map initiative was created to enable more employers to train their employees to deal with the digital age [John et al. 2020]. Adequate upskilling and reskilling training is critical, particularly in the private sector, to ensure that employees are prepared to work in the IR 4.0 environment. Without a doubt, HRDF has worked with a variety of stakeholders, including the Ministry of Higher Education, industries, and the private sector, to create more dynamic upskilling and reskilling training programmes for employees to keep their skills up to date. For example, the HRDF sectorial training committee was in charge of establishing the IndSF and advising on the relevant training and activities that the industry considered necessary to meet the IR 4.0. As a result, both the private and public sectors in Malaysia must recognise the importance of skill creation for their employees in order to remain competitive [HRDF 2021].

Similarly, HRDF offered training and development for recent graduates in an attempt to better prepare them with the necessary skill sets to reach the job market [Doherty and Stephens 2021]. In 2016, the Graduates Enhancement Programme for Employability 2.0 (GENERATE 2.0) was launched with the aim of increasing graduate employability by providing them with industry-required skill sets. HRDF also supports disabled people, housewives, and seniors through other programmes. Among the initiatives include, OKU Talent Enhancement Programme (OTEP), Housewives Enhancement and Reactivate Talent Scheme (HEARTS), and National Dual Training System (SLDN) [HRDF 2021].

HRDF has been recognised as Malaysia's leading training service provider, offering more than 15 different types of IR 4.0-related training and development services, including cloud computing, BDA, IoT, cybersecurity, vertical integration, robotic automation courses, and digitalization. Similarly, HRDF is funding training and development initiatives to prepare for the IR 4.0 climate. HRDF, for example, has set aside RM203 million for computer and data professional training and advancement, gender empowerment, data science leadership, and the provision of essential technical skills in information and communications technology [HRDF 2021].

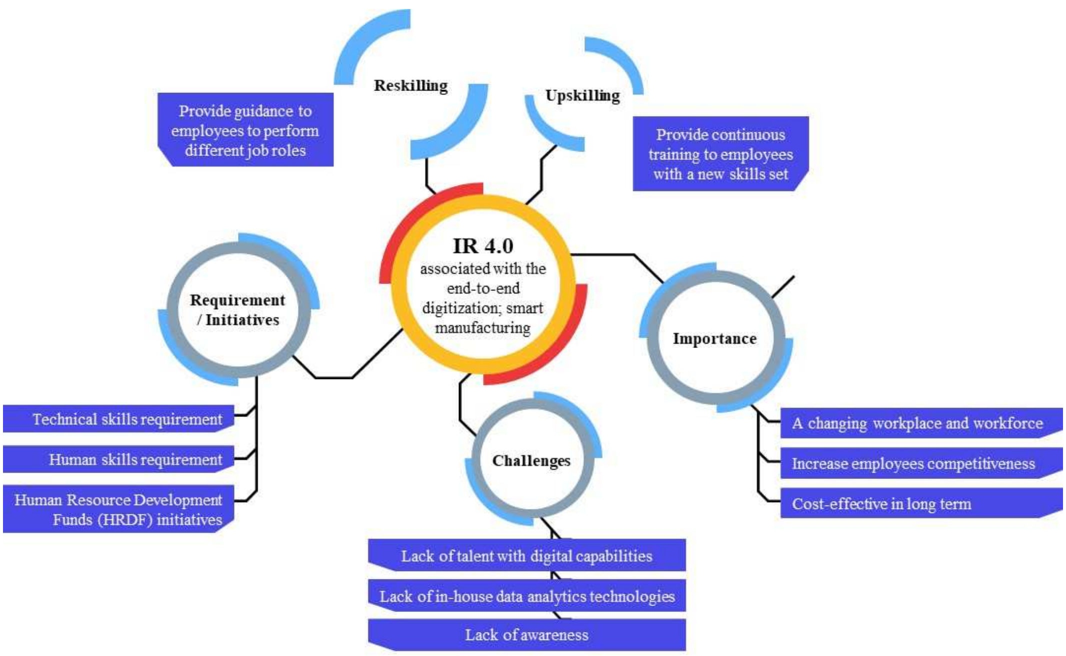
Malaysia is expected to be among the top 20 high-income developing countries in the world by 2050. To achieve this, approximately 43 percent of local employees must be professional employees. At this time, the nation only has 28 percent of qualified employees [John et al. 2020]. With the advent of IR 4.0, Malaysian businesses must be better positioned to achieve a qualified workforce of 35 to 40 percent in order to achieve the status of a developed economy by 2050. Hence, employers must ensure that their employees are reskilled, upskilled, and multi-skilled in order for them to be ready to face and adapt to the IR 4.0 world. Employers must also be dynamic and go above and beyond in training their employees for the IR 4.0 climate in order to stay competitive.

CHALLENGES IN UPSKILLING AND RESKILLING FOR IR 4.0

IR 4.0 has far-reaching consequences for the way an organization organizes itself and its distribution model. Companies will need talent with the capabilities to exploit emerging innovations as they become more widely embraced. Companies must ensure that their employees appreciate how the company is transforming and how they can participate in it. With technical advances emerging at a growing pace, companies are finding it extremely difficult to locate talent with the necessary competencies. According to Geissbauer et al. [2016], the most complex difficulties is the absence of digital culture and the right training. In fact, in the marketplace is a rising expertise gap between what businesses need and what talent can provide.

Next, the most significant obstacle in upskilling and reskilling is lack of expertise or competencies in the company's workforce. Aside from individual competencies, organizations must be ready to re-skilling their employees to be IR 4.0. For an instance, it is important to develop in-house data analytics technologies and expertise levels for increasing data analytics capabilities. External partners are also playing their role to support in upskilling and reskilling, such as providing technologies or training, as well plan to acquire outside companies by merge and acquisition [Bahar 2020].

Furthermore, experts and efficient data analytics are needed for data to be used to generate value. This is because data is the entry from a variety of sources in various formats, and there is a need to merge internal data with data from external sources. Thus, another hurdle needs to be faced by organizations. With too many entry points, businesses must take a robust, constructive approach to data protection and related issues, as well as strive to create digital confidence. Besides that, the rise of new ecosystems and the widespread use of data poses serious concerns about cybersecurity. More data collection and exchange touchpoints mean more possible points of entry for an attacker.



Source: original

Fig. 3. IR 4.0 reskilling and upskilling model

Companies would simply not be able to accomplish advanced digitisation without a significant number of efforts in upskilling and reskilling. Over the next five years, advanced deployment of IR 4.0 will become a 'qualifier to compete,' as well as a 'qualifier for financing'. Companies that have not kept up will not only struggle to retain market share but will also face higher capital financing costs. To summarise, Figure 3 depicts IR 4.0 as a basis, as well as the reskilling and upskilling requirement and initiatives, its importance and challenges of IR 4.0.

CONCLUSIONS

This study adopted inductive reasoning methods to assess the criteria and obstacles for upskilling and reskilling in the era of IR 4.0 within the logistics and supply chain industry. The paper met its objectives by describing three key aspects of the logistics industry's upskilling and reskilling requirements in the IR 4.0 era. Two upskilling and reskilling programmes were also highlighted as possible solutions for the logistics industry during IR 4.0. Additionally, a few challenges relating to upskilling and reskilling requirements are also being discussed.

The findings of this study can help practitioners, the private and public sectors, as well as academics, gain a better understanding. Although the focus area for this study focusing on the Malaysian context, the finding might also useful particularly for the emerging countries. It's because this research could serve as a foundation for potential upskilling and reskilling research in the logistics industry, as well as probably other industries, during IR 4.0. Since this study attempted a basic evaluation of upskilling and reskilling in the logistics industry during IR 4.0, practitioners would have a better understanding of the need for and value of upskilling and reskilling during IR 4.0. Furthermore, the issues raised here can prove to be useful information for top management in making more strategic and creative decisions

Nonetheless, more empirical evidence was required to prove the study's reliability and validity. Furthermore, since it is confined to the logistics sector, future research should take a quantitative approach and a more applied study should be conducted. Future research may include focus groups or panel interviews to produce more significant insights into the logistics industry's upskilling and reskilling expertise during IR 4.0. Despite its limitations, the study certainly added to our understanding of the logistics industry's upskilling and reskilling needs and challenges during IR 4.0. It is hoped that this research would add to the growing body of information in the upskilling and reskilling literature while also broadening the reach of logistics research.

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REFERENCES

Azizan N., Pangil F., Zin M.L.M., 2021. Human Capital Development in Malaysia: Issues and Challenges, Sergi, B.S., and Jaaffar, A.R. (Ed.) Modeling Economic Growth in Contemporary Malaysia (Entrepreneurship and Global Economic Growth), Emerald Publishing Limited, Bingley, 151-175. http://doi.org/10.1108/978-1-80043-806-420211013.

Bahar N., Wahab S.N., Rahman M., 2020. Impact of knowledge management capability on supply chain management and organizational practices in logistics industry, VINE Journal of Information and Knowledge Management Systems, ahead-of-print. http://doi.org/10.1108/VJIKMS-02-2020-0022.

Bohlouli M., Mittas N., Kakarontzas G., Theodosiou T., Angelis L., Fathi M., 2017.

Competence assessment as an expert system for human resource management: A mathematical approach. Expert Systems with Applications, 70, 83–102. http://doi.org/10.1016/j.eswa.2016.10.046.

Butt J., 2020. Exploring the Interrelationship between Additive Manufacturing and Industry 4.0. Designs, 4(2), 13. http://doi.org/10.3390/designs4020013

Doherty O., Stephens S., 2021. The skill needs of the manufacturing industry: can higher education keep up?, Education + Training, ahead-of-print. http://doi.org/10.1108/ET-05-2020-0134.

Eshna V., 2019. 5 Ways Upskilling Will Cut Costs and Boost Productivity at Your Company. Available on the Internet: https://bit.ly/3u7pgqU.

Geissbauer R., Vedso J., Schrauf S., 2016. Industry 4.0 Building the Digital Enterprise. Available on the Internet: https://pwc.to/3t89YB0.

Ghobakhloo M., 2018. The future of manufacturing industry: a strategic roadmap toward Industry 4.0. Journal of Manufacturing Technology Management, 29(6), 910-936.

HRDF 2021. Human Resource Development Fund. Available on the Internet: https://www.hrdf.com.my/employer/.

John K., Benjamin L., Katherine L. 2020, The Future of Work Across ASEAN: Policy Prerequisites for the Fourth Industrial Revolution. The Asia Foundation. Available on the Internet: http://hdl.handle.net/11540/11663.

Ketokivi M., Mantere S., 2010, Two strategies for inductive reasoning in organizational research. Academy of Management Review, 35(2), 315-333.

Kipper L.M., Iepsen S., Dal Forno A.J., Frozza R., Furstenau L., Agnes J., Cossul D., 2021. Scientific mapping to identify competencies required by industry 4.0. Technology in Society, 64. http://doi.org/10.1016/j.techsoc.2020.101454.

Kovács G., Spens K.M., 2005. Abductive reasoning in logistics research. International Journal of Physical Distribution & Logistics Management, 35(2), 132-144.

Ling E.K., Wahab S.N., 2020. Integrity of Food Supply Chain: Going beyond Food Safety and Food Quality. International Journal of Productivity and Quality Management, 29(2), 216-232.

Man M.M.K., 2020. Human Resource Development Requirements in Industrial Revolution 4.0, Turkmenoglu, M.A. and Cicek, B. (Ed.) Contemporary Global Issues in Human Resource Management, Emerald Publishing Limited, Bingley, 129-139. http://doi.org/10.1108/978-1-80043-392-220201011.

McKee S., Gauch D., 2020. Implications of Industry 4.0 on Skills Development." In: Panth B., Maclean R. (eds) Anticipating and Preparing for Emerging Skills and Jobs. Education in the Asia-Pacific Region: Issues, Concerns and Prospects, 55. Springer, Singapore. http://doi.org/10.1007/978-981-15-7018-6_34.

McKinsey Global Institute, 2020, Industry 4.0: Reimagining manufacturing operations after COVID-19. Singapore: McKinsey & Company.

Mgiba F., 2019. Merger, Upskilling, and Reskilling of the Sales – Marketing Personnel in the Fourth Industrial Revolution Environment: A Conceptual Paper. Global Journal of Management And Business Research: Marketing. 19(5), 12-23.

Morgan J., 2019. Will we work in twenty-first century capitalism? A critique of the fourth industrial revolution literature. Economy and Society, 1-28. http://doi.org/10.1080/03085147.2019.1620027.

MTUC 2015. Decision on employment insurance scheme to be announced soon. Malaysian Trades Union Congress. Available on the Internet: http://www.mtuc.org.my/decision-on-employment-insurance-scheme-to-be-announced-soon/.

MTUC, 2018. Yb Kula appropriate mohr to instill confidence in tripartism. Malaysian Trades Union Congress. Available on the Internet: http://www.mtuc.org.my/yb-kula-appropriate-mohr-to-instill-confidence-in-tripartism/.

Nayak S., Kumar, R.H., 2018. Exigency of Re-skilling for Organization and Employees Growth. International Journal of Business, Management and Allied Sciences. 5(S1), 65-67.

Nier R.D.J, Wahab S.N., Daud D., 2020. A Qualitative Case Study on the Use of Drone Technology for Stock Take Activity in a Third-Party Logistics Firm in Malaysia. IOP Conference Series: Materials Science and Engineering, 780(6), 062014. http://doi.org/10.1088/1757-899x/780/6/062014.

Oztemel E., Gursev S., 2018. Literature review of Industry 4.0 and related technologies. Journal of Intelligent Manufacturing. http://doi.org/10.1007/s10845-018-1433-8.

Ramasamy M., 2018. Up to 54% of current jobs will be affected by automation, says Kula. Available on the Internet: https://bit.ly/3aRExET.

Randstad Malaysia, 2020. 91% of respondents are motivated to upskill and re-skill in the next 12 months. Available on the Internet: https://bit.ly/3xCcbrH.

Rotatori D., Lee E.J., Sleeva S., 2020. The evolution of the workforce during the fourth industrial revolution. Human Resource Development International, 1-12. http://doi.org/10.1080/13678868.2020.1767453.

Sima V., Gheorghe I.G., Subić J., Nancu D., 2020. Influences of the Industry 4.0 Revolution on the Human Capital Development and Consumer Behavior: A Systematic Review. Sustainability, 12(10), 4035. http://doi.org/10.3390/su12104035.

Sivanandam, H., 2019. HR Ministry ready to upskill and reskill Malaysians, The Star. Available on the Internet: https://bit.ly/3uaiUXZ.

Wahab S.N., Bahar N., Radzi N.A.M., 2021. An Inquiry on Knowledge Management in Third-party Logistics Companies. International Journal of Business Innovation and Research, 24(1), 124-146.

Wahab S.N., Loo Y.M., Say C.S., 2020. Antecedents of Blockchain Technology Application among Malaysian Warehouse Industry. International Journal of Logistics Systems and Management, 37(3), 427-444.

World Economic Forum, 2017. Impact of Fourth Industrial Revolutions on Supply Chains. Switzerland.

World Economic Forum, 2018. The Future of Jobs Report 2018. Insight Report, Geneva, Switzerland.

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ORIGINAL PAPER

CHALLENGES IN THE IMPLEMENTATION OF AUTONOMOUS ROBOTS IN THE PROCESS OF FEEDING MATERIALS ON THE PRODUCTION LINE AS PART OF LOGISTICS 4.0

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ABSTRACT. **Background:** Along with the development of Industry 4.0, the concept of Logistics 4.0 is also developing in parallel. Some researchers emphasize that the fourth industrial revolution in the area of logistics concerns in particular warehouse services. New technologies related to automatic data identification and autonomous vehicles are increasingly appearing in warehouse processes. In particular, the implementation of autonomous vehicles in processes carried out so far by people generates significant challenges related to the proper preparation of the entire system, but also its coordination with processes carried out in the enterprise. The aim of the article is to present the results of the analysis of disturbances occurring in the first stage of the implementation of autonomous vehicles in the process of feeding material production lines in a surveyed company from the automotive industry.

Methods: The article presents the implementation assumptions for the use of autonomous robots in the process of materials feeding. The scope of the required safety analyzes was presented as well as the time measurements carried out regarding the implementation of the process of servicing power supplies for assembly lines. The research used direct observations in the assessed enterprise and unstructured interviews with persons responsible for the implementation.

Results: The results show the deviations from the adopted assumptions, both in the area of vehicle safety and the deviations in the time of material supply operations. It is worth noting that both positive and negative deviations from the adopted standard were recorded in the measurements. Based on the analyzes of the causes and effects of the deviations, guidelines have been developed for the changes to the functioning of autonomous vehicles.

Conclusions: The results of the presented research allowed to identify potential adverse events that may occur in the process of implementing autonomous solutions in logistics service processes. The basic rules for the implementation of autonomous solutions in logistic operations, which are carried out in anthropotechnical systems, were also indicated.

Key words: autonomous vehicles, logistics 4.0, disruptions.

INTRODUCTION

In recent years, a very intensive development of the concept of Industry 4.0 has been observed, which is referred to as the Fourth Industrial Revolution [Kagermann 2013]. This development is visible both in the practical sphere (more and more widespread implementation of solutions based on cyber-physical systems) and in the area of scientific research, which has been reviewed, among others in [Kosacka-Olejnik and Pitakaso 2019, Gajdzik et al. 2021]. In its original form, Industry 4.0 mainly concerned production processes and the creation of the so-called Smart Factory, which is equated with a smooth flow of information, ease of adaptation to a changing market environment, as well as a high level of data security [Odważny et al. 2018b]. Gajdzik et al. [2021] emphasize that Industry 4.0 is a strong combination of operational technology (OT) and information technology (IT) in production. However, the growing popularity of this concept caused the fourth revolution also in processes supporting

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production processes, such as logistics and maintenance. For this reason, the simultaneous development of Logistics 4.0 can be observed, which is now considered an integral part of Industry 4.0 [Kostrzewski et al. 2020]. The Logistics 4.0 is linked to such notations as Smart Services and Smart Products [Cyplik et al. 2019]. For this reason, as emphasized by Wawrla et al. [2019], the fourth industrial revolution in the area of logistics concerns in particular warehouse services. For this reason, new technologies related to automatic data identification and autonomous vehicles are increasingly appearing in warehouse processes.

The potential for the implementation of new technologies in the area of warehouse services is large due to the fact that these are routine operations, based on a certain pattern of conduct, which in the traditional system generates a high demand for man-hours of the staff. At the same time, in many cases these activities are simple, repetitive and do not require high competences. For this reason, in the face of the current demographic decline and the growing employee market, companies are looking for solutions that will allow them to eliminate the human factor in some operations. This is especially true for enterprises in the phase of intensive development. The planned increase in warehouse turnover and an increase in employee salary make the implementation of automatic solutions in logistics processes attractive. This is confirmed by the research presented, among others in [Čámská and Klečka 2020], in which the authors proved that enterprises can achieve higher profitability through the human labor replacement by machines (robots) and other new technologies.

However, the implementation of autonomous vehicles in processes carried out so far by people generates significant challenges related to the proper preparation of the entire system, but also its coordination with processes carried out in the enterprise. For this reason, the aim of the article is to present the results of the analysis of disruptions occurring in the first stage of the implementation of autonomous vehicles in the process of production line material feeding on the example of a project carried out in a selected company from the automotive industry. The structure of the article includes a literature review on Logistics 4.0 and the implementation of autonomous vehicles. Then the methodology and scope of the conducted research were discussed and the obtained results were presented. Based on the achieved results, final conclusions were formulated regarding the challenges of preparing the organization to implement solutions in the area of Logistics 4.0.

LOGISTICS 4.0. – LITERATURE REVIEW

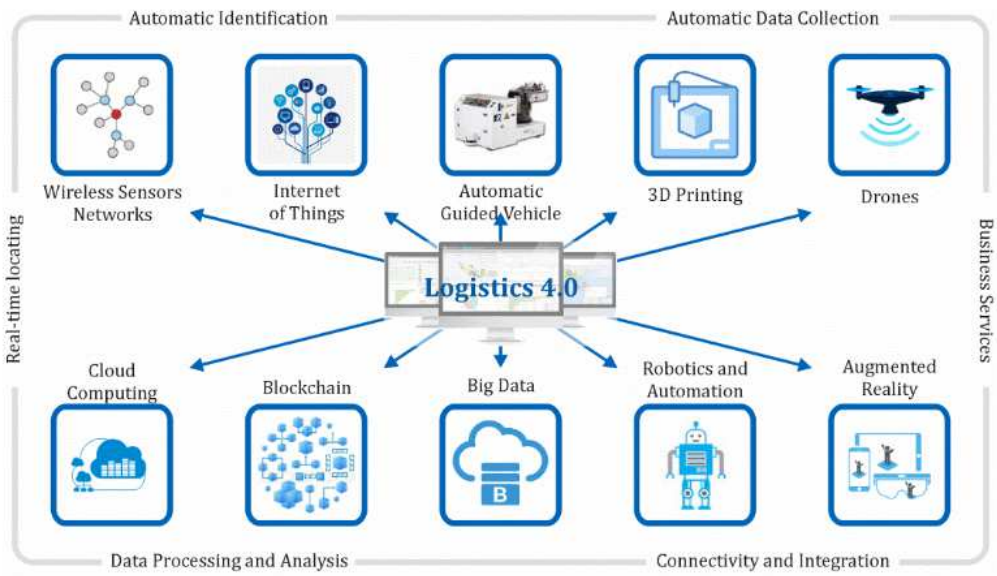
Internet access and the development of mobile devices and intelligent sensor technology enabled the intensive development of the Industry 4.0 concept [Gotz 2017]. Industry 4.0 is an overall term for technical innovations and value change organization concepts that revolutionize industrial production [Gracel et al. 2017]. One of its primary goals is enabling the communication and cooperation of people and machines with the systems of information and communication technology in real-time [Odważny et al. 2018a].

Industry 4.0 is based on an innovative technology system, called Technology 4.0. The key innovations of this system include [Gajdzik et al. 2021]:

1. a new communication system that connects the digital world with the real world and enables direct communication between devices, devices and people (through human-machine interfaces);
2. intelligent sensors with built-in systems of individual identification, data processing, and communication;
3. data processing in the cloud and simulation techniques for the operation of real objects in their virtual representations, based on data provided and processed in real-time;
4. a new generation of robots that enable active interaction with the environment and adaptation to changing conditions and requirements.

Digitization of production in the concept of Industry 4.0 requires the interconnectivity and integration of the adjoining internal and external procedural landscape in order to ensure efficient value creation. For this reason, it is also necessary to digitize the processes supporting the 4.0 production system. As noted by Schmidtke et al. [2018] it requires integration of existing logistic processes into the virtual level and linking them with internal and external production facilities and partners. This makes Logistics 4.0 an integral part of the Industry 4.0 concept [Kostrzewski et al. 2020]

Many authors define Logistics 4.0 as a collective term for technologies and concepts of value chain organization. The key element of this concept is the creation of a cyber-physical system supporting logistic processes. The term cyber-physical systems (CPS) refers to a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities [Baheti & Gill 2011]. Wang [Wang 2016] notes that within the logistics, CPS monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions and thanks to IoT, CPS communicate and cooperate with each other and humans in real-time. According to [Barreto et al. 2017] Logistics 4.0 can be seen as a supply network where all processes can communicate with each other, as well as with humans for enhancing their analytical potentialities throughout the supply chain. Optimization carried out within this network must be supported by intelligent systems, embedded in software and databases from which relevant information is provided and shared through the Internet of Things (IoT) systems, in order to achieve a major automation degree [Barreto et al.2017]. For this reason, Logistics 4.0 combines two aspects of material flows [Szymańska et al. 2017]: processual (supply chain processes are a subject of the Logistics 4.0 actions) and technical (tools and technologies that support internal processes in the supply chains). Therefore, an efficient Logistics 4.0 system must use the following technological applications [Baretto et al. 2017]: (1) Resource Planning, (2) Warehouse Management Systems, (3) Transportation Management Systems, (4) Intelligent Transportation Systems and (5) Information Security. The most important technological components used in Logistics 4.0 are shown in Figure 1.



Source: AtiGA 2020

Fig. 1. Components and technologies of Logistics 4.0

The development of Logistics 4.0 in production and logistics companies has caused changes in the current material flows in supply chains. The most important development trends in this area include [Glistau & Coello-Machado 2019]: (1) Cloud software, (2) Edge Computing, (3) Artificial Intelligence, (4) Big Data Analysis, (5) Blockchain technology, (6) Decentral organization and self-organization, (7) Networking, (8) Autonomous driving, (9) New professions and activities in logistics, (10) Infrastructure and smart infrastructure. The subject of the research presented in this article is the use of autonomous vehicles in logistics 4.0 systems. The studies described in [Wen et al. 2018] presented several areas in logistics that could be supported by autonomous swarm robotics, e.g. efficient transportation or green Logistics. These systems are also of particular importance in warehouse operations, and their implementation results primarily from economic benefits, which include [Bechtsis & Tsolakis 2018]:

- a capability to function on a 24/7 basis;
- a minimization of labor cost;
- a low maintenance cost;
- an enhanced accuracy in daily activities, and
- an improved safety at industrial facilities.

The most frequently used autonomous vehicles in Logistics 4.0 systems include Unmanned Aerial Systems (UAS) and Automatic Guided Vehicles (AGV). This article focuses on the use of Automatic Guided Vehicles in logistics processes. AGVs are unmanned vehicles based on sensor and video detection technologies, artificial intelligence, and other information and communication technologies. AGV vehicles that are used in logistic processes may be [Radivojević & Milosavljević 2019]: tractors for towing trailers, vehicles for unit loads, pallet trolleys, trolleys with additional forks, light load vehicles, assembly line vehicles, special vehicles, etc. These vehicles are used for traditionally demanding tasks; they enable automatic handling of freight and equipment. The application of AGVs in logistic processes decreases expenses and labor, increases reliability, productivity, safety and quality of work, reduces the risks of human errors and damaged, etc. [Kückelhaus & Chung 2018]. Some authors, however, also pay attention to the limitations associated with the use of AGVs. [Zhang et al. 2018] highlight three main problems with the use of AGV:

- The urgent tasks are unable to be dealt with because of the low flexibility of the AGVs.
- AGVs have to stop to avoid collisions due to the limited detecting distance.
- The workspace is seldom optimized in order to increase the number of vehicles operating in the limited area.

However, the currently identified limitations will be removed through intensive development, e.g. towards increasing vehicle intelligence [Zhang et al. 2018]. Thanks to this, according to the research [Kostrzewski et al. 2020], the use of AGV in Logistics 4.0 will represent future trends in less than the next 5 years. However, according to the consulting company ABI Research, the robots will become the so-called warehouse standard until 2025 [Kulikowska-Wielgus 2019]. Currently, it can be noted that in some systems, AGVs are used as basic devices, while in some logistic systems they supplement the existing cargo manipulation system [Jurczak 2019].

METHODOLOGY AND SCOPE OF RESEARCH

The aim of the research is to analyze the potential and risk associated with the use of AGV robots in logistics systems. According to the research presented in [Automatyka B2B 2019], AGV vehicles are most often used in warehouse logistics, as well as in production and intralogistics. From the point of view of the coordination of internal processes, the case of the use of robots in intralogistics is particularly interesting. Moving loads between the warehouse and the production area is exposed to more disruptions because delivery processes are carried out at the junction of two areas of the company's activity. For this reason, the material supply process on assembly lines in the intralogistics system of a manufacturer from the automotive sector was selected for the study.

The material supply system for the assembly stations concerned the operation of two assembly lines shown in Figure 2. Loop 1 is 420 m long, and loop 2 is 300 m long.

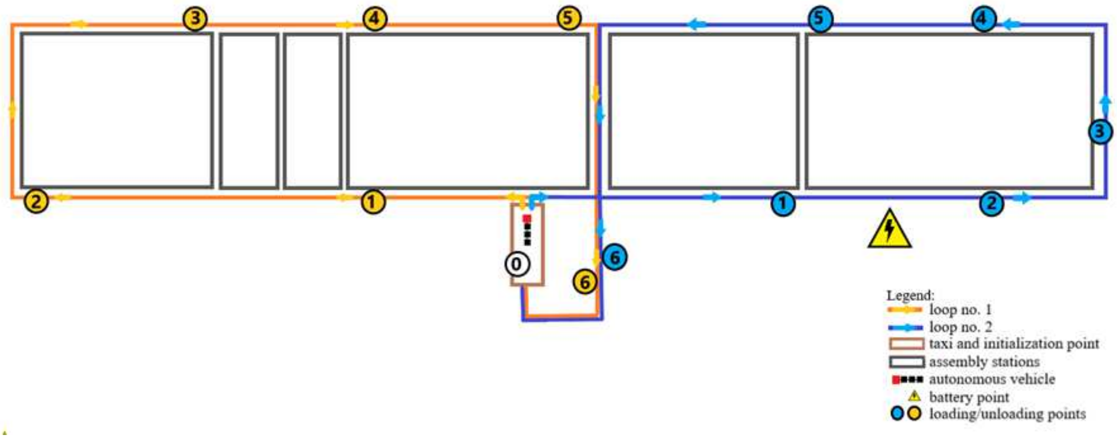


Fig. 2. Presentation of the assembly lines supported by the AGV system

The implementation of the system was carried out in accordance with the procedure described in [Poturaj & Lewandowski 2020]. This procedure includes 7 steps of the procedure presented in Figure 3. From the point of view of the conducted research, the "Implementation" stage is particularly important.

It is also worth noting that the research presented in [Automatyka B2B 2019] indicates that for AGV users, safety and reliability are of significant importance when implementing this solution (see Figure 4). Both of these elements are subject to specific monitoring during the implementation phase. For this reason, the results of these analyzes are presented in this article.

Research on the safety of use of AGV devices was carried out in cooperation with the Health and Safety Department. As part of the evaluation carried out, it was checked:

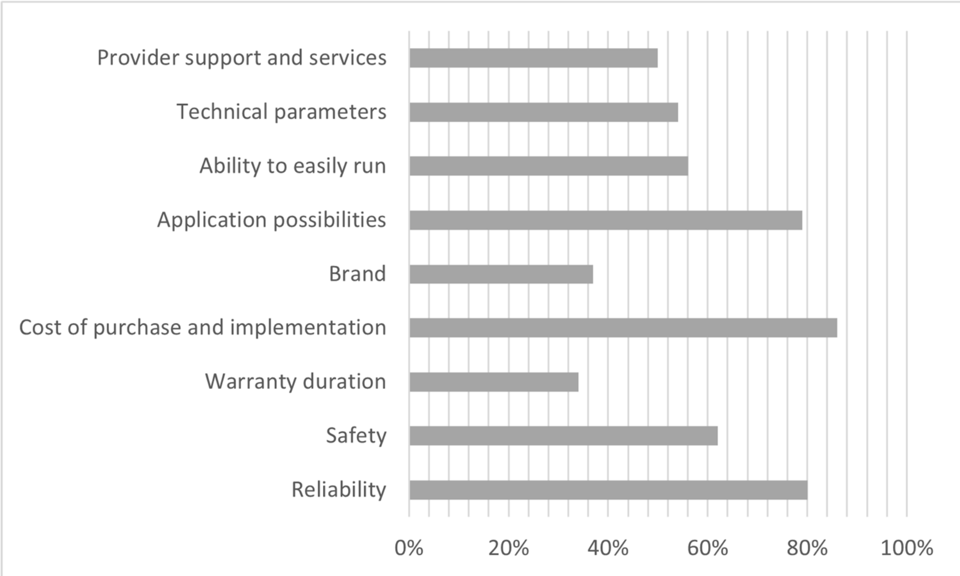
1. Vehicle equipment, including: warning lights related to the operating mode of the device; emergency stop system; laser curtain scanner for obstacle detection, LED light informing pedestrians about the approaching work
2. The applicable fields for dynamic deceleration and stopping of the device.
3. Functioning of the device in the event of loss of reference to the mapped path (the vehicle goes into error mode when the navigation laser is not able to measure a sufficient number of points).

The parameters of the device offered by the manufacturer were compared with the safety standards required by the organization and on this basis, the possibility of approving the vehicle for use was determined.

Reliability can be understood as the lack of failure of the device, but also as failure-free (correct) execution of the process. For this reason, as part of the research carried out in the first phase of implementation, the correctness of the mission of delivering components to the assembly stations was assessed. At the stage of testing the system, the failure rate of vehicles was assessed primarily from the safety point of view, as described above. With regard to the reliability assessment, the measurement concerned the time of vehicle travels and the completeness of the mission (delivery of materials to all planned assembly stations). The reliability analysis method is shown in the Figure 5.

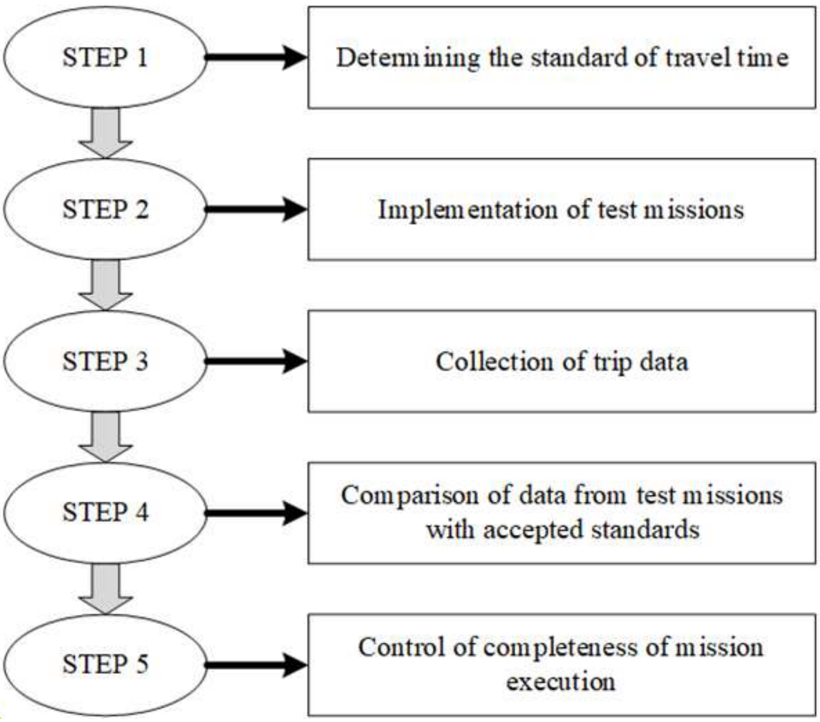
Source: Poturaj & Lewandowski 2020

Fig. 3. Implementation scheme



Source: Automatyka B2B 2019

Fig. 4. Criteria for the selection of AGV solutions by future users



Source: Automatyka B2B 2019

Fig. 5. Reliability analysis method

In the first step, the standard travel times of the device along each assembly line were determined. These standards were defined by the implementation team based on the adopted assumptions regarding the speed of vehicle movement and the average time of loading and unloading materials at the assembly station. The following times were assumed for both lines:

- Correct travel time - 15 - 20 minutes.
- Too short travel time - less than 15 minutes - means that the vehicle did not stop in all designated service zones.
- Too long travel time - more than 20 minutes - signals that the route was disturbed or the vehicle waited too long to be loaded or unloaded by assembly line workers.

The tests were carried out in two stages in accordance with the procedure presented in Figure 3. The first stage: "The vehicle moves under the supervision of the operator" was carried out in the period October 28 - October 30. The second stage: "The vehicle moves independently" was carried out in the period October 31 - November 3.

The data on travel times for each mission was collected from the Robot Manager system recorder that each vehicle is equipped with. The data collected in this way was analyzed in terms of meeting the standards adopted in step 1. Then, the completeness of the missions was checked.

For a detailed analysis of the time deviations recorded during the measurement, the following were used: (1) cause and effect analysis, (2) direct interviews with selected representatives of the warehouse zone and the assembly line, (3) the Ishikawa diagram.

RESULTS

In Logistics 4.0 systems, special emphasis is placed on security issues that must be guaranteed in connection with the cooperation of people and automated systems. Before starting the tests of the AGV vehicle in the real system, it was necessary to obtain the approval of the Health and Safety Department in the scope of including it in the processes carried out in the storage area and the assembly line. The Health and Safety Department actively participated in the 2nd stage of the implementation process – “System Planning". As a result, the selected device to be implemented in the enterprise complied with the approval conditions that were specified from the point of view of process implementation security. The vehicle is equipped with:

- Stack controller module - two warning lights (green and blue) controlled by the original truck system and two warning lights (orange and red) controlled by the automatic control system.
- Emergency stop button.
- Laser curtain scanner.

However, the standard equipment offered by the manufacturer did not meet the internal health and safety requirements regarding the visibility of the vehicle and reporting irregularities during the implementation of the mission, i.e. when moving in the storage and assembly area. For this reason, it was necessary to place additional signaling, located on each wagon. It has two colors - green and red. When the green part of the siren is on, it means that all elements are properly connected. Turning on the red lamp means that there are irregularities in the group consisting of a tractor and wagons.

The second area of research was the assessment of the reliability of delivery missions. To analyze the correctness of the missions performed, time measurements were taken in two stages, which are described in the Methodology section:

1. „The vehicle moves under the supervision of the operator "- the total number of test runs was: loop 1 - 46 missions, loop 2 - 30 missions.
2. „The vehicle moves independently "- the total number of test runs was: loop 1 - 70 missions, loop 2 - 47 missions.

Measurements were carried out separately for each of the serviced assembly lines. Therefore, Figures 6 (a) and 6 (b) show the share of individual travel times achieved in stage 1 - moving under the supervision of the operator, while in Figures 7 (a) and 7 (b) - in stage 2 during independent movement of the vehicle.

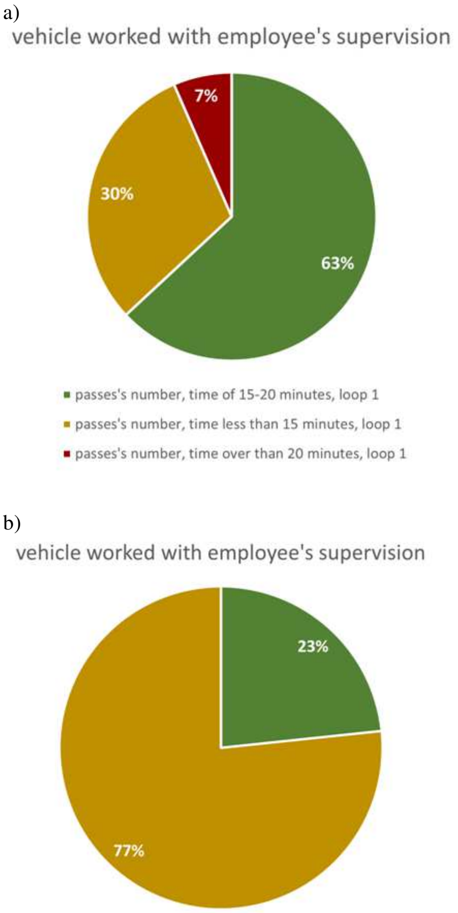


Fig. 6. The share of the individual times of vehicle movement under the supervision of the operator (a) on line 1 and (b) on line 2.

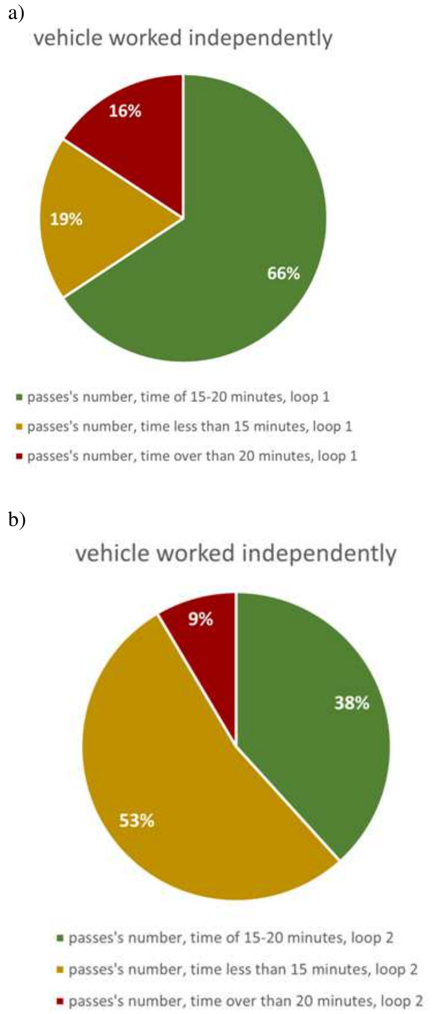
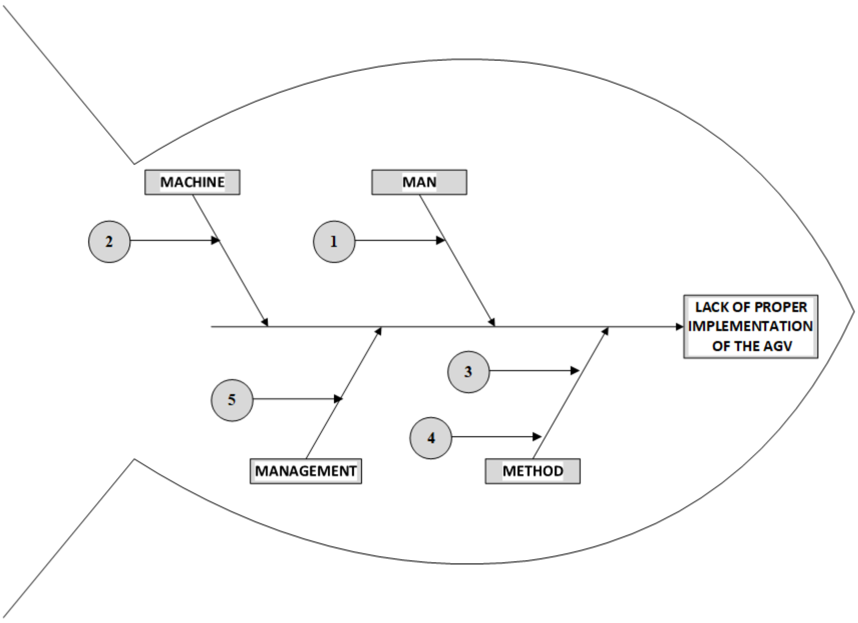


Fig. 7. The share of the individual times when the vehicle was traveling alone (a) on line 1 and (b) on line 2.

Measurement of the operation of the device under the supervision of a warehouse employee showed that for Loop 2, most of the completed runs were completed below the target of 15 minutes. Only 23% of the journeys were made in accordance with the assumption. At the same time, on the basis of observation carried out by the person supervising the operation of vehicles, it was found that only in part of the journeys there was a skipping of selected service zones. A detailed analysis has shown that the required travel times on loop 2 should be shorter than in the case of loop 1 (shorter route and fewer service zones).

The independent implementation of the mission by the vehicle increased the share of journeys exceeding 20 minutes. The cause-and-effect analysis proved that the source of the occurring delays is the prolonged stay of the vehicle in the service zones. The main cause of this situation is the duration of the unloading and loading operations of the vehicle by the assembly line operators. The conducted direct interviews proved that many employees, due to the use of personal protective equipment (e.g. ear muffs, glasses), do not always see the vehicle waiting for unloading. One of the reasons given was the lack of regularity of the train run (no fixed service hours). At the same time, the analysis of the vehicle departure times for each line showed that the train was leaving on line 2 more frequently than it was expected from the schedule. In-depth interviews with delivery operators revealed that the initially adopted delivery schedule for this line is insufficient. This makes it necessary to carry out additional deliveries beyond the designated tact.

The obtained results of the mission analysis should be considered statistically significant. For this reason, it was necessary to conduct additional analyzes that identified the reasons for the deviations from the adopted standard. All indicated disturbances recorded during the implementation phase were classified according to the Ishikawa diagram presented in Figure 8.



1 – Longtime of loading and unloading the vehicle by an assembly line worker
2 – Limited visibility of the vehicle
3 – Standard travel time incorrectly specified
4 – Incorrectly specified frequency of travel
5 – No fixed hours of service

Fig. 8. Ishikawa diagram for recorded adverse events during the implementation phase.

A well-conducted implementation phase allowed to identify significant disruptions in the implementation of the AGV system in the material supply process for the selected two assembly lines. Thanks to this, it was possible to supplement the vehicle's equipment with additional lighting elements and to change the schedule of journeys on both lines. In this way, the risks associated with the functioning of the anthropotechnical system in which autonomous vehicles must cooperate with people were limited.

CONCLUSIVE REMARKS

The implementation of automated solutions in logistics processes is playing an increasingly important role. This is the result of the development of the Logistics 4.0 concept, an increase in employee salary costs, and the progressive development of new technologies for this area. Autonomous vehicles that support warehouse operations and material supply systems in production are currently particularly popular.

The concept of Logistics 4.0 is a new trend that is currently developing as part of improving the functioning of individual cells as well as entire supply chains. On the basis of an increasing number of implementations, good practices are formulated that allow implementation companies and their clients to prepare better and better for this process. In this area, publications on potential adverse events and methods of risk assessment related to implementation are of particular importance. For this reason, the aim of the article was to analyze the potential disruptions occurring in the first phase of the implementation of autonomous vehicles. The significant contributions of the presented research include:

- Identification of adverse events related to the AGV implementation phase.
- Including in the analyzes not only the assessment of the functioning of the vehicle itself, but also its functioning in cooperation with the environment.

At the stage of choosing the right solution, the particular attention of decision-makers is focused on the costs of purchasing and implementing such a system. However, in the operation phase of autonomous devices, decision-makers focus their attention primarily on the safety and reliability of these vehicles in the anthropotechnical system. For this reason, the testing phase should include at least 2 stages of the assessment of the operation of these devices: (1) work with human supervision and (2) independent operation of the vehicle. Particular emphasis should be placed on the first stage of device performance evaluation. The operator's supervision over the device should concern not only the correctness of the delivery mission carried out by it, but also its functioning in the anthropotechnical system. Thanks to the operator's report on the completed mission, it is possible to assess the correct functioning of the vehicle and delivery reliability in the logistics process, as well as its cooperation with the operating environment.

Simulation tests can provide better preparation for the testing phase by eliminating potential hazards related to the operation of the device in an anthropotechnical system. By mapping the real system in the simulation model, various decision-making variants regarding future material supply and AGV operation can be analyzed. At the same time, the analysis of simulated flows will allow to identify potential undesirable events still in the virtual model phase. Thanks to this, it is possible to limit their occurrence in the real system before the start of the test phase.

The article presents the results of the test phase of a selected power supply system of assembly lines. The conducted analyzes indicate that even proper preparation of the system for operation, taking into account the safety and reliability aspects at an early stage of system design, does not guarantee success. Only the tests of the device's operation in real conditions show the potential threats that may occur in connection with the integration of the elements of the anthropotechnical system. For this reason, in the testing phase, not only the failure-free operation of the device itself should be assessed, but it is also necessary to observe its cooperation with the environment. It should also be remembered that introducing improvements / corrections after the test phase should not end the process of monitoring the functioning of the device. Due to the changing environmental conditions, wear of the AGV system components and human-vehicle cooperation, it is recommended to perform further systematic evaluation aimed at identifying potential hazards in the activities performed.

The research presented in the article is an introduction to the development of detailed risk analysis for adverse events related to the implementation of solutions in the Logistics 4.0 system. The analysis of adverse events was focused primarily on the process aspects related to the correctness of achieving the assumed goal for the delivery mission. However, in the next stages of research it is justified to carry out a risk analysis in accordance with the ISO 12100:2012 standard, which will allow for a comprehensive assessment of the risk posed by AGV machines in the logistics service environment.

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REFERENCES

Advanced Logistics or Logistics 4.0, 2020. AtiGA International Technological Alliance of Galicia. Available on the Internet: https://www.atiga.es/en/advanced-logistics-or-logistics-4-0/ (15/04/20210)

AutomatykaB2B, 2019. Roboty współpracujące i mobilne roboty AGV. Raport z rynku [Collaborative robots and mobile AGV robots. Report form market], Available on the Internet: https://automatykab2b.pl/raporty/51097-roboty-wspolpracujace-coboty-agv-raport-rynek (10/02/2021)

Baheti R., Gill H., 2011. Cyberphysical Systems, The Impact of Control Technology, 161-166. http://doi.org/10.1109/ICMECH.2019.8722929

Barreto L., Amaral A., Pereira T., 2017. Industry 4.0 implications in logistics: an overview, Procedia Manufacturing 13, 1245-1252. http://doi.org/10.1016/j.promfg.2017.09.045

Bechtsis D., Tsolakis N., 2018. Trends in Industrial Informatics and Supply Chain Management, International Journal of New Technology and Research, 4(10), 91-93. http://doi.org/10.31871/IJNTR.4.10.44

Čámská D., Klečka J., 2020. Cost development in logistics due to Industry 4.0, LogForum 16 (2), 219-227. http://doi.org/10.17270/J.LOG.2020.415

Cyplik P., Oleskow-Szlapka J., Tobola A., Adamczak M., 2019. Building a Model For Assessing The Maturity Of Polish Enterprises In Terms Of Logistics 4.0 Assumption, Business Logistics in Modern Management, Josip Juraj Strossmayer University of Osijek, Faculty of Economics, Croatia, 19, 105-120.

Gajdzik B., Grabowska S., Saniuk S., 2021. A Theoretical Framework for Industry 4.0 and Its Implementation with Selected Practical Schedules. http://doi.org/10.3390/en14040940

Glistau E., Coello-Machado N.I., 2019. Solutions and Trends in Logistics 4.0., Acta Technica Corviniensis, XII (4), 129 – 132.

Götz M., Gracel J., 2017. The Fourth-Generation Industry (Industry 4.0) – Challenges to Research in the International Context, Kwartalnik Naukowy Uczelni Vistula, 1(51), 217-235.

Gracel J., Stoch M., Biegańska A., 2017. Inżynierowie Przemysłu 4.0, Kraków – ASTOR Publishing.

Jurczak M., 2019. Logistyka 4.0 w praktyce. Jak wózki autonomiczne sprawdzają się w transporcie wewnętrznym? [Logistics 4.0 in practice. How can autonomous vehicles work in internal transport?], Trans.info. Available on the Internet: https://trans.info/pl/wozki-autonomiczne-w-transporcie-wewnetrznym-131662 (20/03/2021)

Kagermann H., Helbig J., Hellinger A., Wahlster W., 2013. Recommendations for implementing the strategic initiative Industrie 4.0: Securing the future of German manufacturing industry. Final report of the Industrie 4.0 Working Group, Forschungsunion. Available on the Internet: https://www.din.de/blob/76902/e8cac883f42bf28536e7e8165993f1fd/recommendations-forimplementing-industry-4-0-data.pdf (20/02/2021)

Kosacka-Olejnik M., Pitakaso R., 2019. Industry 4.0: State of the art and research implications, LogForum 15 (4), 475-485. http://doi.org/10.17270/J.LOG.2019.363

Kostrzewski M., Varjan P., Gnap J., 2020. Solutions Dedicated to Internal Logistics 4.0. In: Grzybowska K., Awasthi A., Sawhney R. (eds), Sustainable Logistics and Production in Industry 4.0. Eco-Production (Environmental Issues in Logistics and Manufacturing), Springer, Cham, 243-262. http://doi.org/10.1007/978-3-030-33369-0_14

Kückelhaus M., Chung G., 2018. Logistics Trend Radar, DHL Customer Solutions & Innovation, Germany. Available on the Internet: www.dhl.com (23/12/2018)

Kulikowska-Wielgus A., 2019. Do 2025 r. miliony robotów będą obsługiwać magazyny na całym świecie [By 2025, millions of robots will operate warehouses around the world], Trans.info. Available on the Internet: https://trans.info/pl/do-2025-r-miliony-robotow-beda-obslugiwac-magazyny-na-calym-swiecie-139138, (20/03/2021)

Odważny F., Szymańska O., Cyplik P., 2018. Smart Factory: The requirements for implementation of the Industry 4.0 Solutions in FMCG Environment – Case Study, LogForum 14 (2), 257-267. http://doi.org/10.17270/J.LOG.2018.253

Odważny F., Wojtkowiak D., Cyplik P., Adamczak M., 2018. Smart Factory within sustainable development and green growth concepts, LogForum 14 (4), 467-477. http://doi.org/10.17270/J.LOG.2018.301

Poturaj H., Lewandowski T., 2020. Procedura identyfikacji otoczenia w fazie projektowania systemu transportu wewnętrznego z wykorzystaniem pojazdów AGV [Guidelines which are used in environment identification during design phase of AGV system project in internal transport], Journal of Translogistics, 6(1), 201-210.

Radivojević G., Milosavljević L, 2019. The Concept of Logistics 4.0, 4th Logistics International Conference, Belgrade, Serbia, 283-292.

Schmidtke N., Behrendt F., Thater L., Meixner S., 2018. Technical Potentials and Challenges within Internal Logistics 4.0, 4th IEEE International Conference on Logistics Operations Management (GOL), 1-10. http://doi.org/10.1109/GOL.2018.8378072.

Szymańska O., Cyplik P., Adamczak M., 2017. Logistics 4.0 A new paradigm or a set of solutions, Research in logistics and production, Poznan University of Technology Publishing House, 7(4), 299–310. http://doi.org/10.21008/j.2083-4950.2017.7.4.2

Wang K., Logistics 4.0 Solution. New Challenges and Opportunities, 2016. International Workshop of Advanced Manufacturing and Automation (IWAMA), 68 – 74. http://doi.org/10.2991/iwama-16.2016.13

Wen J., He L., Zhu F., 2018. Swarm Robotics Control and Communications: Imminent Challenges for Next Generation Smart Logistics, IEEE Communications Magazine, 56(7), 102-107, http://doi.org/10.1109/MCOM.2018.1700544.

Zhang Y., Zhu Z., Lv. J., 2018. CPS-based Smart Control Model for Shopfloor Material Handling, IEEE Transactions on Industrial Informatics 14 (4), 1764–1775. http://doi.org/10.1109/tii.2017.2759319.

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ORIGINAL PAPER

MODELLING THE DISTRIBUTION PERFORMANCE IN DAIRY INDUSTRY: A PREDICTIVE ANALYSIS

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ABSTRACT. **Background:** Predictive analysis is a vital element to operations management as it facilitates real-time decision making and advanced planning on both strategy and performance. This paper identifies predictors to measure distribution performance in the dairy industry and to establish their importance.

Methods: A distribution model is developed through exploratory structural equation modelling (SEM) techniques. The key performance predictors are marketing and distribution management, quality management, supply chain coordination, and brand management, which account for 71.5% of the variability in distribution performance.

Results and conclusion: The predictors help improving the distribution performance, specifically in quality, order fill rate, and food safety. The outcomes of this research can help dairy professionals in managing their distribution channels, improving traceability, on-time delivery, and shipment accuracy. Consequently, these factors can improve distribution performance. Four predictors are elicited from the data to estimate the distribution performance and the relative importance of predictors is also established.

Key words: distribution performance; food supply chain, dairy industry, structural equation modelling (SEM), predictive analysis.

INTRODUCTION

The food industry has a vital role in promoting our routine activities and is an essential global industry with significant economic growth and rural development in many countries. The volume of the dairy market alone is projected at 216 metric tonnes in 2017 globally. India has noticed significant growth in the dairy sector over the last three decades, and the Indian dairy sector aims to increase milk production by 9% annually by 2022 [Economic Times Report, New Delhi]. The structure of Indian dairy involves private dairies, cooperative societies, milk unions, etc. The dairy supply chain starts with procuring milk from farmers, transporting it to milk processing plants, where milk is processed, packaged, and further supplied to retailers and finally to end-consumers. Dairy cooperatives contribute a significant share of processed milk and other value-added milk products through milk unions at the district level, and milk unions safeguard the farmers from unfair trade actions. Although India is the leading producer of milk globally, there are several issues in the dairy supply chain, especially on the distribution side, and need to be unexplored. The food supply chain is more complex and challenging to manage, and it differs from other supply chains because of the importance of food quality, safety, and perishable nature. The food supply chain depicts the activities from procurement, production, distribution, and consumption [Mor et al., 2018]. Generally, the word distribution denotes the place and method of delivering products and services to the end-user incorporating logistical and other accompanying supports.

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Unlike other industries, the food industry has an exclusive role in the ever-developing economy as it is a universal means of human life and wellbeing. The food industry is developing faster, and this growth is escorted by many challenges such as globalization, regulation, and competition. Novel and evolving technologies present quicker, safer, and more intellectual means to plan, optimize, and manage the different interfaces of the food supply chain viz. procurement, processing, distribution, etc. The role of an effective distribution system in a supply chain is to make vehicle scheduling and routing decisions in addition to the determination of optimal quantities of a product for delivery to a particular point of sale [Hsiao et al., 2010]. Researchers addressed that a systemic approach leading to sustainable practices and effective logistics, packaging, and marketing strategies can leverage the competitiveness status of the industry. It has been shown that decentralization in distribution systems of the food sector leads to distortion of food quality [Glover et al., 2014; Chen et al., 2014]. Specifically, perishable products necessitate a unique supply chain configuration for proper scheduling and delivery of products, mainly to shorten lead times to reduce work-in-progress, inventory, and finally, food waste. Moreover, the concern related to food safety, traceability, and quality issues in perishable products needs special care for the supply chain planning to help better coordinate supply chain partners [Kumar et al., 2020; Leon-Bravo et al., 2019; Mor et al., 2019a; Thomas & Mahanty, 2021]. Thus, a framework is essential to cope with such challenges and to measure the distribution performance.

The effectiveness of the supply chain in the food processing sector is a major concern, mainly for the short shelf-life and safety aspects of food products. Uncertainties in the food supply chains may occur because of various reasons. Still, the key factors include ineffective procurement, poor information and traceability, logistics and operational inefficiencies, inefficient cold chain infrastructure, poor marketing and distribution practices, etc. These uncertainties directly affect the profitability food industry throughout the supply chain [Mor et al., 2020]. Managing distribution practices in the food industry is equally vital as the procurement and processing operations and is becoming an essential part of food supply chains. Sustainable distribution in the food industry, particularly dairy products, is possible through optimization methods, implementing agile information and coordination systems, different quantitative management techniques, etc. Researchers advocated that the modelling approaches in the food supply chain specifically consider the short lifecycle of food products and the product's perishability characteristics and the waste. Structural equation modelling (SEM) techniques are used for data analysis since the 1980s, for example, to identify the reliability and validity of manufacturing operations and assess SMEs' performance [Thirupathi and Vinodh, 2016]. SEM is applied to evaluate the structural interfaces and the interaction among measured variables and latent constructs. Researchers modelled a mixed structure through constraint programming to improve sustainable supply chain decisions. Thus, this paper aims to identify predictors of distribution in the dairy industry and establish their importance. A framework is developed using SEM methodology to assess the distribution practices [Sitek and Wikarek, 2015]. This paper's outcomes are envisioned to help dairy professionals manage their distribution practices, such as improving traceability, on-time delivery, shipment accuracy, etc. The paper is structured as follows. Section 2 demonstrates a comprehensive literature review. Section 3 introduces the problem formulation, and Section 4 presents research methods applied in this paper. Section 5 illustrates the data analysis and prediction model for measuring distribution performance. Section 6 offers the conclusions of the study and provides the future scope in this area.

LITERATURE REVIEW

Food supply chain and distribution practices

Effective distribution management is the key performance parameter in competitive markets. Distribution contributes about 20% of logistical costs or even more for commodity products and mainly plans to flow the products in minimum lead time and minimum cost. Studies present optimizing the vehicle routing to handle the problems of distribution and overall distribution costs of dairy food products [Nabhani and Shokri, 2009]. The challenges of distribution management are more complex, and the prolonged distribution channels lead to high costs and high delivery time. The spatial distribution of logistics activities, location features of distribution centers, and effective logistics management is a real problem facing distribution management in the dairy industry. Another way of managing distribution channels is the periodic analysis of decisions taken for distributing food items [Selim and Ozkarahan, 2008]. Traceability offers safer food supplies. The traceability of product quality & location is another key factor of distribution management where information technology like geographical-information-system helps maintain better traceability. The demand and supply equations over the multi-time period, multi-supplier, and region settings are considered to analyze uncertainties and balance supply chains [Kumar et al., 2011; Dong et al., 2001]. Singh et al. [2011] studied the role of info technology for perishable food products in unorganized sectors and revealed a considerable loss of fresh food items due to ineffective information systems. The distribution performance also depends on better coordination and quality management initiatives to achieve competitiveness in an organization [Okano et al., 2014]. Thus, distribution management is an inherent part of supply chain decisions incorporating different practices about distributing products to the end-consumer. The assessment of supply chain coordination systems in conjunction with the modernized distribution with innovative labelling, packaging, and automatic milk vending technology also effectively manages dairy products' distribution practices [Mor et al., 2019a]. Georgiadis et al. [2005] focused on associating the single-echelon models to ascertain the effective policies and constraints in different decision-making issues of food supply chains. The literature on different supply chain issues about the distribution practices and distribution networks is presented in Table 1.

Table 1. Literature on Distribution Practices

Focus	Source
Flow coordination and information sharing	Sahin and Robinson (2002)
Food safety in global supply chains	Nardi et al. (2020)
Supply chain coordination approaches	Lemma et al. (2015)
Food distribution management	Bumblauskas et al. (2020)
Vertical coordination	Abdul-Rahaman et al. (2020)
Production and distribution of food products	Ahumada and Villalobos (2011)
Agile supply-chain systems	Ngai et al. (2004)
Supply chain coordination systems	Zhang et al. (2020)
Barriers in dairy supply chain	Mor et al. (2018)
Production scheduling and distribution planning	Bilgen and Celebi (2013)
Framework for supply chain	Manzini et al. (2011)
Food supply chain integration	Ling and Wahab (2020)
Production-distribution planning in supply chain	Lee et al. (2002)
Hybrid modelling in supply chain	Safaei et al. (2010)
Logistics efficiency in urban distribution	Cagliano et al. (2017)
Sustainable performance in agri. supply chains	Kamble et al. (2020)
Uncertainty in dairy supply chains	Mishra and Shekhar (2011)
Sustainable food supply chain	Smith (2007)
SC Modelling for delivery of milk products	Huang et al. (2019)
Traceability in food supply chains	Behnke and Janssen (2020)
Supply chain coordination under information asymmetry	Vosooghidizaji et al. (2020)

SEM techniques

Vinodh and Joy [2012] explored the usage of interpretive modelling and SEM approaches to establish a structural interface among different enablers of sustainable processes. Hussey and Eagan [2007] assessed the performance of small and medium enterprises (SMEs) using SEM methodology and found significant results for environmental constraints in the developed model. Hou et al. [2014] studied the associations in sustainable processes and the components affecting behaviour changes. The research focused on assessing different manufacturing operations also favor the application of SEM methodologies for performance measurement. Eid [2009] studied world-class manufacturing dynamics through SEM to explore the associations among various variables. Kadipas and Pexioto [1999] worked on business strategies by applying the SEM tools and established the interfaces among different variables. The authors analyzed different parameters, such as quality, productivity, and performance. Lau et al. [2010] worked on total quality management and supply chain integration for product modularity and found the SEM approach very useful in assessing the interactions among supply chain enablers. Curkovic [2003] explored the green manufacturing model using SEM. Thus, SEM methodologies have vast applications for evaluating the supply chain performance of manufacturing and service sector organizations worldwide.

Problem Formulation

It is apparent from the literature review that the distribution practices have been explored in different sectors. Still, there exists no such model to quantify the distribution practices in the dairy industry. There is minimal empirical research that measures distribution performance in the dairy industry, particularly in the cooperative system. The literature necessitates an empirical framework to support the policy-makers towards effective distribution management. Hence, this research shields the gap by addressing an empirical analysis of distribution practices in the dairy industry. The following null hypotheses are established to measure the impact of predictors on distribution performance:

H01: 'Supply chain coordination' has no impact on the distribution performance of the dairy supply chain

H02: 'Quality management' has no impact on the distribution performance of the dairy supply chain

H03: 'Marketing and distribution management' has no impact on the distribution performance of the dairy supply chain

H04: 'Brand management' has no impact on the distribution performance of the dairy supply chain.

METHODS

A survey instrument has been developed to study the different distribution practices and further measure the distribution performance in the dairy industry (Figure 1). A survey questionnaire was established after the literature review and focus group discussion with academicians and professionals from the dairy industry. The first part of the questionnaire comprises 22 statements/items of distribution practices followed in the dairy industry and one item measuring overall distribution performance. The second part of the questionnaire encompasses the demographic data of respondents and the industry. The same questionnaire was developed online (Google Forms) to collect data from industries with a difficult approach and at odd locations, making the data collection process very fast and appropriate. The questionnaire is validated through a pilot study before launching [Robson (2002]. The pilot study involves five specialists from the dairy industry and academic experts in operations management, supply chain modelling, and performance assessment.

The dairy industries from northern India were considered to collect data. Approx. 71% of responses were collected through personal visits to the concerned industry, and the rest of the data were collected through online mode. The questionnaire is distributed to participants to get their views regarding different distribution issues, and through the snowball sampling approach [Nargundkar, 2004], the desired information is obtained from the dairy industry. The responses were acquired on a five-point Likert scale, where 1-strongly disagree, 5-strongly agree (Annexure-I). The participants' privacy was retained secret to facilitate the balanced responses [Saunders et al., 2009]. The responses were received from all ranks, i.e., managing directors, managers, executives, heads of departments, etc. Most responses were received from the executive and assistant/deputy manager rank employees, as shown in Figure 2.

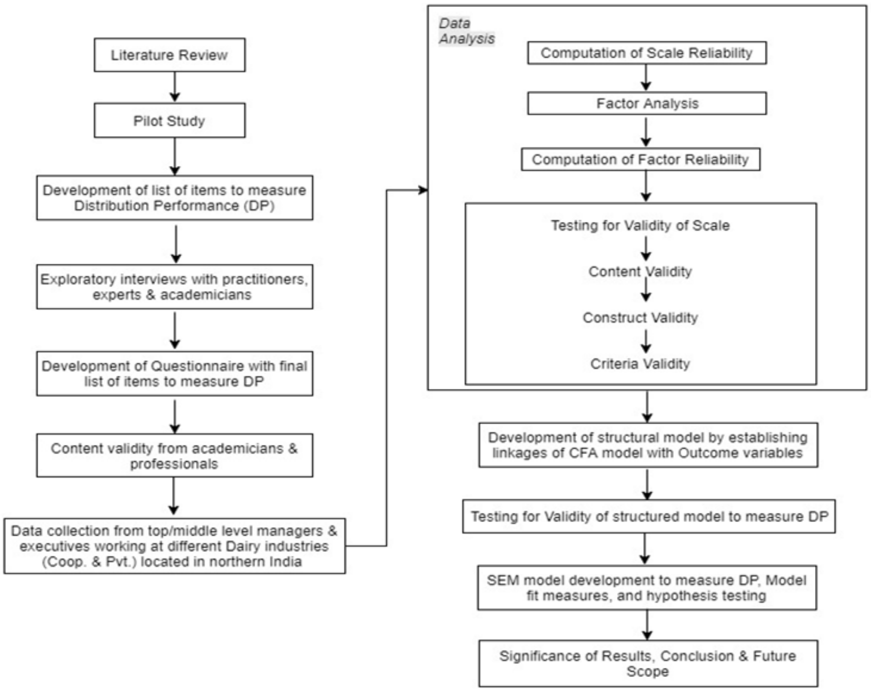

Fig. 1. Methodology

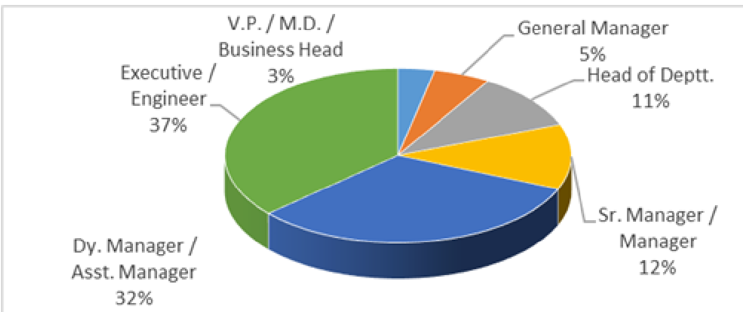

Fig. 2. Demographic distribution of responses

A total of 265 valid responses are carried forward for further examination. Since some of the queries to measure the distribution performance (DP) are selected from available literature and the rest from the pilot study; thus the developed survey instrument needs to be validated. The validation is performed via reliability analysis and exploratory factor analysis (EFA) method, and subsequent confirmatory factor analysis (CFA) process [Mor et al., 2019b], and a final SEM model to assess the distribution performance is developed by connecting the CFA model with outcome variables of the study.

DATA ANALYSIS

Reliability Analysis

The reliability of collected information is evaluated through Cronbach's alpha coefficient, which reveals the equivalence, homogeneity, and correlation of the statements. The reliability analysis is carried out by IBM SPSS v22 software, which indicates the Cronbach alpha coefficient value as 0.911; hence, depicting considerably high reliability of information [Cronin and Taylor, 1992, Mor et al., 2019b]. The reliability of each construct of the questionnaire is also assessed through Cronbach's alpha [Cronbach, 1951].

Exploratory Factor Analysis (EFA)

All 22 statements are selected for the EFA. Initially, the Bartlett test of Sphericity is applied to approve the relevance of factor analysis and measured by evaluating the correlation matrix of collected information. Simultaneously, the evaluation of sampling adequacy (N= 265) is referred by Kaiser-Meyer-Olkin (KMO) statistics, ranging between 0-1. The KMO value of >0.6 is assumed as considerable, and it is 0.897 here, which shows the aptness of factor analysis. The value of the Bartlett test of Sphericity and the KMO value given by SPSS v22 software is Chi-square 4532.115, df: 231, Sig.: 0.000. The results were significant, thus verifying the factor analysis (Hair et al., 2005). The EFA is performed using the principal component analysis (PCA) method with Kaiser Normalization (four Predictors) and the Varimax rotation procedure through the SPSS software. EFA is applied to shrink the info probed in 22 questions into a reduced set of new elements. This ensued in the extraction of four predictors, explaining about 71.5% of the total variance. The predictors explain 20.85, 18.73, 17.62, and 14.55 percent variance individually. All the predictor loadings are constant with the proposed structure of the EFA model (Table 2).

Table 2. Exploratory Factor Analysis

Pre-dictor No.	Statements (Name & Label)	Communality	Predictors				Mean	Standard Deviation	Overall Score of Predictor	
			F1	F2	F3	F4	Measurement on 5-point Likert Scale		Mean	Standard Deviation
	Supply Chain Coordination (F1)									
F1	DIS22 You perceive better inter-departmental supply chain coordination in dairy industry	0.82	0.83				4.36	0.86	4.01	0.94
	DIS21 The existing information systems help to strengthen the supply chain coordination in dairy industry	0.77	0.80				3.34	1.17		
	DIS24 You deploy cross-functional teams for better supply chain coordination	0.62	0.70				4.03	1.00		
	DIS20 Supply chain coordination system help in maintaining the shipment accuracy, high order-fill-rate, and on-time delivery of products in dairy industry	0.72	0.73				4.00	0.85		
	DIS25 Supply chain coordination system help for better traceability of vehicles deployed for distribution of products	0.56	0.65				4.24	0.97		
	DIS19 Better supply chain coordination leads to effective demand management in dairy industry	0.55	0.61				4.47	0.81		
	Quality Management (F2) You perceive wastage in the Distribution of dairy products due to following reasons:									
F2	DIS30new Unhygienic practices	0.86		0.92			3.65	1.43	3.41	1.39
	DIS28new Improper loading/unloading	0.82		0.90			3.45	1.32		
	DIS27new Poor cold chain infrastructure	0.79		0.85			3.48	1.42		
	DIS31new At retailer level due to unsold products	0.75		0.85			3.40	1.50		
	DIS29new Leakages during transportation	0.71		0.82			3.13	1.23		
	DIS26new Inappropriate storage system	0.69		0.79			3.35	1.46		
	Marketing & Distribution Management (F3)									
F3	DIS1 You perceive an adequate infrastructure to look after the logistics needs and it responds rapidly to demand fluctuations in dairy industry	0.74			0.85		3.82	0.92	3.85	0.97
	DIS16 You have implemented the RFID technology to have automated warehousing	0.84			0.85		3.90	0.98		
	DIS9 The logistics systems can accommodate to special or non-routine requests rapidly in dairy industry	0.55			0.69		4.11	0.93		
	DIS12 The level of marketing in rural areas is low as compared to peri-urban & urban in dairy industry	0.62			0.59		4.06	0.81		
	DIS35 You have installed the automatic milk vending machines in the region	0.64			0.69		3.15	1.29		
	DIS7 The distribution-planning schedule is highly effective in dairy industry	0.67			0.64		4.08	0.91		
	Brand Management (F4) Customers prefer to buy your products due to the following reasons:									
F4	DIS38 Long shelf-life of products	0.53				0.68	4.34	0.89	4.42	0.82
	DIS37 Close contact with Customers	0.84				0.84	4.42	0.78		
	DIS36 Better order-fill-rate	0.87				0.88	4.41	0.86		
	DIS33 Image for better product quality	0.78				0.83	4.51	0.75		
Reliability (Cronbach Alpha# value) of identified predictors			0.889	0.931	0.892	0.885				

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 5 iterations.
[*]Cutoff point for loadings is 99% significant and is calculated by 2.58/√n (Pitt et al., 1995), where n (=22) is the number of items in the scale. F1-F4 represents individual predictor.
α values ≥ 0.70 are adequate (Nunnally, 1978).

The extracted predictors are named as: 'Supply chain coordination, Quality management, Marketing and distribution management, and Brand management' in discussion with a group of professionals. The communalities depict the amount of variance of 22 items extracted by four predictors. All 22 items have the commonalities of above 0.5 value representing as significant. The predictor-item loadings signify the correlations among each item with the underlying predictors. All the items depict the loadings of above 0.55 value specifying as significant [Gandhi et al., 2018; Pitt et al., 1995]. Internal reliability is measured by Cronbach's alpha coefficients (Bagozzi and Yi, 1988). Reliability scores range from 88.5% to 93.1%; hence, acceptable [Nunnally, 1978].

Confirmatory Factor Analysis (CFA)

Confirmatory factor analysis is performed to further approve the EFA outcomes through testing the CFA model fit. The CFA model, having four individual predictors with their respective statements, has been run using SPSS AMOS v21 software, and the model fit is observed for each predictor [Bienstock et al., 1997]. Table 3 illustrates the key model fit indices of the individual predictor.

The results show that the goodness-of-fit indices (GFI) values are higher than 0.9, which approves the validation of individual predictors of the CFA model [Hair et al., 2005]. The CFA model with the four predictors and their respective statements is presented in Figure 3.

Table 3. Key Fit Indices for CFA model of Distribution practices

Predictors	$(\chi 2)$/df = CMIN/df	RMR	GFI	NFI	CFI	RMSEA
F1: Supply chain coordination	2.738	.036	.950	.955	.964	.056
F2: Quality management	1.399	.065	.907	.930	.936	.068
F3: Marketing & distribution management	2.790	.026	.955	.963	.972	.070
F4: Brand management	2.237	.047	.937	.949	.951	.059

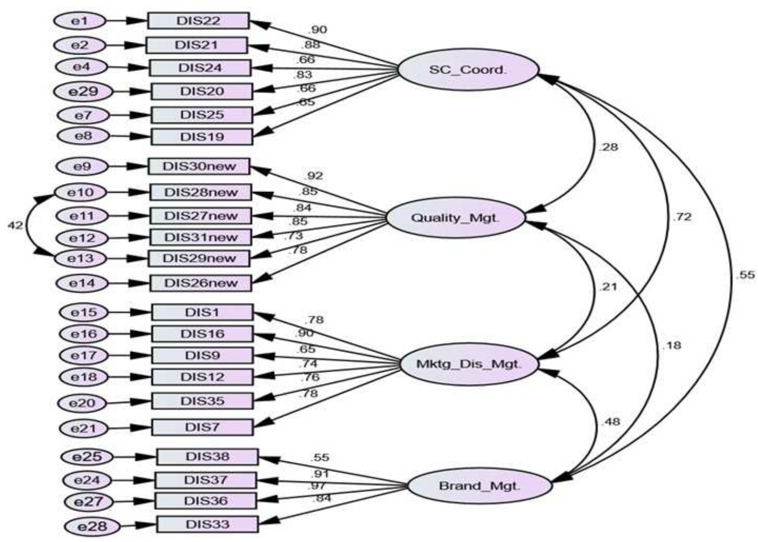

Fig. 3. CFA model of distribution practices

Model Fit

Various goodness-of-fit indices are attained by running the CFA model using AMOS v21 software. The Normed Chi-square value of the developed CFA model is 2.908, which signifies a good fit. Moreover, the values of Goodness-of-Fit Index (GFI), Normed-Fit-Index (NFI), and Comparative-Fit-Index (CFI) are 0.930, 0.974, and 0.913, respectively, and the root-mean-square error of approximation (RMSEA) value of 0.06 specifies a good fit, such that the model signifies an adequate fit [Tanaka, 1987].

Interpretation of Predictor Structure

The four predictors specify the leading distribution issues in the dairy industry. The total variance explained by the four predictors is 71.5%. The results propose that four predictors can significantly explain the distribution performance. The mean scores and standard deviations (SDs) of survey instrument items with their underlying predictors are also calculated (Table 2). The first predictor, labelled as 'Supply chain coordination', accounts for 20.85% of the total variance. Six items of this predictor with loadings from 0.61 to 0.83 and the second predictor is labelled as 'Quality management' and accounts for 18.73% of the total variance. Six items of this predictor with loadings from 0.79 to 0.92. The third predictor is labelled as 'Marketing and distribution management' and accounts for 17.62% of the total variance. The six items of this predictor with loadings from 0.505 to 0.782, and the fourth predictor is labelled as 'Brand management' and accounts for 14.55% of the total variance. The four items describing this predictor with loadings ranging from 0.59 to 0.85 are shown in Table 2.

Validity of Construct

The face validity evaluates by perceiving 'on-its-face' to confirm whether it seems like a good translation of the construct. The face validity assessment quality can be improved by making the construct more organized [Trochim, 2007]. The developed model provides a good reflection of distribution practices in the current analysis.

Content Validity

The items' content validity is measured after discussions with scholars and academicians and the literature review and the researchers' knowledge [Trochim, 2007]. Subsequent modifications of the survey instrument are confirmed by focus group discussion with dairy industry representatives. The developed model thus depicts good content validity.

Construct Validity

Construct validity is calculated in four steps, (i) Unit-dimensionality, (ii) Convergent Validity, (iii) Discriminant Validity, and (iv) Predictive Validity.

i. Uni-dimensionality: The developed CFA model illustrates the CFI value of 0.913, which suggests a strong uni-dimensionality, where CFI relates the model with a null model supposing that there is no relationship between different measures [Bollen and Ting, 1993].
ii. Convergent Validity: Convergent Validity evaluates the degree to which different methods of assessing a construct produce the same results, where a value of ≥0.55 of loadings in the CFA model proves strong convergent validity [Ahire et al., 1996]. The predictor loadings lie between 0.55 and 0.92 and depict a robust convergent validity in the current analysis.
iii. Discriminant Validity: Discriminant Validity evaluates the amount to which a construct and its indicators are dissimilar from another [Bagozzi et al., 1988]. The square root of average variance explained (AVE) for individual predictor is diagonal cells and the Correlation Coefficient of a predictor with the others in non-diagonal cells (Table 4). The discriminant validity has been judged using the 'StatToolPackage' proposed by Prof. James Gaskin. The value of the square root of AVE for individual predictors is higher than that predictor's correlation coefficient with others, proving the discriminant validity of the CFA model.
iv. Predictive Validity: Predictive validity is recognized if a standard external to the dimension is interrelated with the structure [Nunnally, 1978]. The predictive validity of four predictors is calculated by ascertaining the correlation of individual predictors with mean scores of items (being an external criterion) through Pearson correlation. All the correlation coefficients are substantial at the significance level of 0.05; hence, predictive validity is proved here (Table 5).

Table 4. Discriminant Validity for CFA model of Distribution practices

	SC_Coord.	Quality_ Mgt.	Mktg_Dis_Mgt.	Brand_Mgt.
SC_Coord.	**0.77**			
Quality_Mgt.	0.276***	**0.832**		
Mktg_Dis_Mgt.	0.723***	0.207**	**0.772**	
Brand_Mgt.	0.545***	0.176**	0.481***	**0.833**

The √AVE is represented in the diagonal cells and the correlation in other cells

Table 5. Correlation for CFA model of Distribution practices

Sr. No.	Predictors	Correlation with Distribution practices
1	Supply chain coordination	0.771*
2	Quality management	0.816*
3	Marketing & distribution management	0.648*
4	Brand management	0.723*

*Correlation is significant at the 0.05 level (2-tailed).

DISTRIBUTION MODEL

A distribution model is developed to measure the overall distribution performance by associating the CFA model with the three outcome variables. The outcome variables were nominated in consultation with professionals from the academics and dairy industry, as follows.

- DIS_out1: Order-fill-rate against daily demand fluctuations
- DIS_out2: On-time-delivery of products
- DIS_out3: Customer satisfaction

The final distribution model comprising the four predictors (with 22 statements) and three outcome variables define distribution performance in the dairy industry (Figure 4).

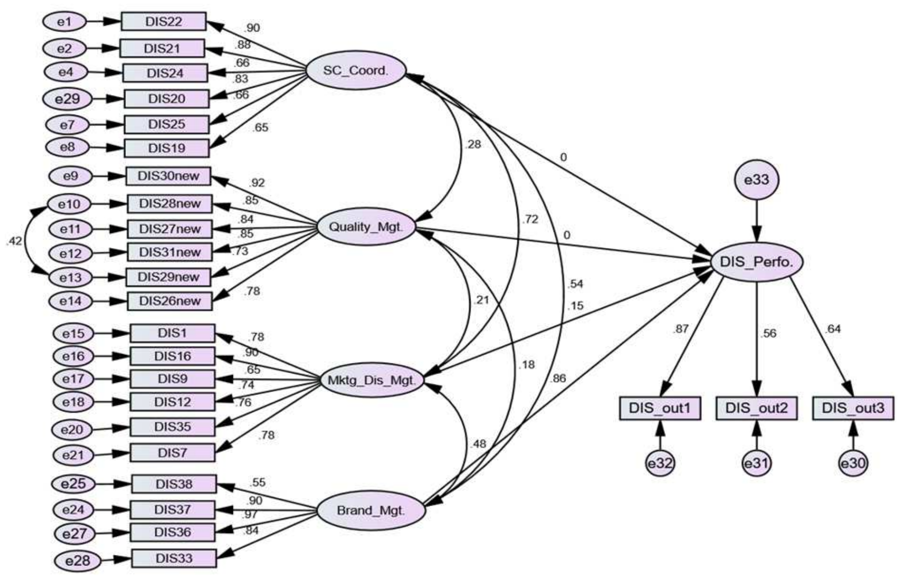

Fig. 4. Distribution model

Validity of Model

The validity of the SEM model is assessed in different steps as follows.

Discriminant Validity of Model: The discriminant validity is measured using 'AMOS Plugin,' and 'StatToolPackage', which depicts that all MSV values are lesser than AVE, values of AVE are >0.5, and critical ratio (CR) is greater than AVE. AVE's square root for individual predictor is better than the correlation coefficient of that predictor with others, which supports the discriminant validity of the model (Table 6). In reference to Hu et al. [1999], all values supported the model well, and hence, there are no validity problems in the distribution model.

Table 6. Discriminant Validity of Distribution model

	CR	AVE	MSV	MaxR(H)	SC_Coord.	Quality_Mgt.	Mktg_Dis_Mgt.	Brand_Mgt.
SC_Coord.	0.85	0.54	0.524	0.923	**0.715**			
Quality_Mgt.	0.89	0.59	0.076	0.942	0.276***	**0.771**		
Mktg_Dis_Mgt.	0.87	0.58	0.524	0.915	0.724***	0.207**	**0.717**	
Brand_Mgt.	0.92	0.7	0.294	0.966	0.542***	0.176**	0.479***	**0.838**

Source; Hu et al. (1999); Gaskin et al. (2016).

Model Fit Measures

The model fit measures were assessed using 'StatToolPackage', and obtained values are CMIN/DF: 2.631, CFI: 0.912, SRMR: 0.068, RMSEA: 0.079, and PClose: 0.061, and all values support the distribution model well (Hu et al., 1999) (Table 7).

Hence, the established SEM model is suitable for assessing the distribution performance in the dairy industry.

Table 7. Model Fit Measure for measuring Distribution performance

Measure	Estimate	Threshold	Interpretation
CMIN	694.486	--	--
DF	264	--	--
CMIN/DF	2.631	Between 1 and 3	Excellent
CFI	0.912	>0.95	Acceptable
SRMR	0.068	<0.08	Excellent
RMSEA	0.079	<0.06	Acceptable
PClose	0.061	>0.05	Acceptable

Source: Hu et al. (1999); Gaskin et al. (2016).

Hypotheses testing and relative importance of predictors

The key aim of SEM methods is to examine the validity of theoretical models by recognizing, estimating, and assessing the linear relationships among perceived and ignored variables. The models established in SEM are generally more optimistic and definitive than other approaches [Collis and Rosenblood, 1985; Cudeck and O'Dell, 1994]. Table 8 depicts the values of C.R. >1.96 (95% confidence) and p-values <0.05, thus, indicating as significant. The null hypotheses are rejected, and all predictors positively impact the dairy industry's distribution practices.

Table 8. SEM Model for measuring Distribution performance

Sr. No.	Outcome	Predictor	Estimate	S.E.	C.R.	p Value	Status	Order of importance
1	Distribution Performance	Supply chain coordination	0.293	0.061	3.110	***	Significant	3
2		Quality management	0.300	0.052	4.321	***	Significant	2
3		Marketing & distribution management	0.321	0.068	4.760	***	Significant	1
4		Brand management	0.208	0.070	3.127	***	Significant	4

Statistical significance is shown by *** $p < 0.05$

The standardized coefficient beta results signify the importance of each item incorporated in this study, Table 8 [Parasauraman et al., 1988]. These results depict the inference of the inclusive regression model ($p<0.00$), with 71.5% of the variance in distribution practices described by the different items. The predictors of distribution practices are shown in order of their significance based on the β coefficient. It shows that the greater the standardized β coefficient, the more the predictor supports explaining the dependent variable. The predictor 'Marketing and distribution management' emerges to be the most imperative, followed by others, i.e., quality management, supply chain coordination, brand management. Therefore, all four predictors describe the distribution performance considerably here.

CONCLUSIONS

This research investigates the sustainable distribution practices of the dairy industry both theoretically and the empirical validation of the outcomes. A total of 22 items of distribution practices are selected for factor analysis based on a comprehensive literature review and pilot study, summarized the items into four predictors viz. supply chain coordination, quality management, marketing and distribution management, and brand management. The mean score of quality management, and marketing and distribution management indicates the key improvement areas. The relative importance of predictors is indicated through standardized beta value, and marketing and distribution management are vital ($\beta= 0.321$), followed by quality management, supply chain coordination, and brand management. The final distribution model is developed after confirming the reliability (Cronbach's alpha) and the validity of the CFA model (loadings ≥ 0.6), discriminant validity (AVE >0.5), and predictive validity (correlation constant positive at 0.05 level) of the model. The hypothesis testing outcome advocates that all four predictors positively impact distribution performance in the dairy industry. The SEM model is verified for discriminant validity and model fit indices and found acceptable for measuring the distribution performance.

It is concluded that an effective information system results in improved coordination and traceability. The cold chain and automated milk handling management help improve the sustainable distribution performance of the dairy industry. Effective product marketing into rural areas and agile logistics systems also play an important role in achieving marketing goals. The predictors explored in this study can help dairy professionals towards effective distribution management. Further, predictive analysis is a vital element to ensure compliance with risk & safety factors, and in the food industry, it is mission-critical to achieve optimal distribution performance. Future studies in this context may be conducted to validate the survey instrument and empirically assess the proposed model in alternate settings. The dairy supply chain interfaces, i.e., procurement, processing, etc., can also be revealed using applied SEM methodology. However, some case studies and other methods may also be used to collect more intuitive results, and the procedure may be tested in other perishable food processing industries.

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REFERENCES

Ahire S.L., Golhar DY, Waller M.A., 1996. Development and validation of TQM implementation constructs. Decision Sciences 27(1): 23-56. http://doi.org/10.1111/j.1540-5915.1996.tb00842.x

Ahumada O., Villalobos J.R., 2011. A tactical model for planning the production and distribution of fresh produce. Annals of

Operations Research 190(1): 339-358. http://doi.org/10.1007/s10479-009-0614-4

Bagozzi R., Yi Y., 1988. On the evaluation of structural equation models. Journal of Academy and Marketing Science 16(1): 74-94. http://doi.org/10.1007/BF02723327

Behnke K., Janssen M.F., 2020. Boundary conditions for traceability in food supply chains using blockchain technology. International Journal of Information Management, 52, 101969. http://doi.org/10.1016/j.ijinfomgt.2019.05.025

Bilgen B., Aelebi Y., 2013. Integrated production scheduling and distribution planning in dairy supply chain by hybrid modelling. Annals of Operations Research, 211(1), 55-82. http://doi.org/10.1007/s10479-013-1415-3

Bollen K., Ting K., 1993. Confirmatory tetrad analysis. Sociological Methodology, 147-175. http://doi.org/10.2307/271009

Bumblauskas D., Mann A., Dugan B., Rittmer J., 2020. A blockchain use case in food distribution: Do you know where your food has been? Int. Journal of Information Management, 52, 102008. http://doi.org/10.1016/j.ijinfomgt.2019.09.004

Cagliano A.C., De Marco A., Mangano G., Zenezini G., 2017. Levers of logistics service providers efficiency in urban distribution. Operations Management Research, 10(3-4): 104-117. http://doi.org/10.1007/s12063-017-0125-4

Collis B.A., Rosenblood L.K., 1985. The problem of inflated significance when testing individual correlations from a correlation matrix. Journal for Research in Mathematics Education 16, 52-55. http://doi.org/10.5951/jresematheduc.16.1.0052

Cronin J.J., Taylor S.A., 1992. Measuring service quality: a re-examination and extension. Journal of Marketing 6, 55-68. http://doi.org/10.1177/002224299205600304

Cronbach L.J., 1951. Coefficient alpha and internal structure of tests. Psychometrika 16(2): 297-334. http://doi.org/10.1007/BF02310555

Cudeck R., Odell L.L., 1994. Applications of standard error estimates in unrestricted factor analysis: Significance tests for factor loadings and correlations. Psychological Bulletin, 115(3): 475-487. http://doi.org/10.1037/0033-2909.115.3.475

Curkovic S., 2003. Environmentally responsible manufacturing: The development and validation of a measurement model. Journal of Operations Research, 146(2),130-155. http://doi.org/10.1016/S0377-2217(02)00182-0

Dong K., Xu Y., 2001. Towards better coordination of the supply chain. Transportation Research Part E: Logistics and Transportation Review 37(1): 35-54. http://doi.org/10.1016/S1366-5545(00)00010-7

Economic Times Report, New Delhi, 2018. Milk production to grow at 9 per cent annually by 2022 from 6 per cent now: Radha Mohan Singh. Retrieved from: https://economictimes.indiatimes.com/news/economy/agriculture/milk-production-to-grow-at-9-per-cent-annually-by-2022-from-6-per-cent-now-radha-mohan-singh/articleshow/64418219.cms?from=mdr.

Eid R., 2009. Factors affecting the success of world class manufacturing implementation in less developed countries: the case of Egypt. Journal of Manufacturing Technology Management, 20(7): 989-1008. http://doi.org/10.1108/17410380910984249

Fornell C., Larcker D.F., 1981. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research 18(1): 39-50. http://doi.org/10.1177/002224378101800104

Gandhi S., Sachdeva A., Gupta A., 2018. Developing a scale to measure employee service quality in Indian SMEs. Management Science Letters, 8(5): 455-474. http://doi.org/10.5267/j.msl.2018.3.005

Gaskin J, Lim J., 2016. Master Validity Tool. AMOS Plugin, Gaskination's StatWiki.

Glover J.L., Daniels D.C., Dainty A.J., 2014. An institutional theory perspective on sustainable practices across dairy supply chain. International Journal of Production Economics, 152: 102-111. http://doi.org/10.1016/j.ijpe.2013.12.027

Georgiadis P., Vlachos D., Iakovou E., 2005. A system dynamics modeling framework for the strategic supply chain management of food chains. Journal of Food Engineering, 70(3), 351-364. http://doi.org/10.1016/j.jfoodeng.2004.06.030

Hair J.F., Anderson R.E., Tatham R.L., Black W.C., 2005. Multivariate Data Analysis, 5th Ed. Pearson Education, New Delhi, India.

Huang K., Wu, K.F., Ardiansyah, M.N., 2019. A stochastic dairy transportation problem considering collection and delivery phases. Transportation Research Part E: Logistics and Transportation Review, 129, 325-338. http://doi.org/10.1016/j.tre.2018.01.018

Manzini R., Accorsi R., 2013. The new conceptual framework for food supply chain assessment. Journal of food engineering, 115(2), 251-263. http://doi.org/10.1016/j.jfoodeng.2012.10.026

Hou D., Al-Tabbaa A., Chen H., Mamic I., 2014. Factor analysis and structural equation modelling of sustainable behaviour in contaminated land remediation. J. Cleaner Production 84: 439-449. http://doi.org/10.1016/j.jclepro.2014.01.054

Hsiao H.I., Van der Vorst J.G.A., Kemp R.G.M., Omta O., 2010. Developing a decisionâ€ making framework for levels of logistics outsourcing in food supply chain networks. International Journal of Physical Distribution and Logistics Management, 40(5), 395-414. http://doi.org/10.1108/09600031011052840

Hu L., Bentler P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives, SEM 6(1): 1-55. http://doi.org/10.1080/10705519909540118

Hussey D.M., Eagan P.D., 2007. Using structural equation modelling to test environmental performance in small and medium-sized manufacturers: can SEM help SMEs? Journal of Cleaner Production 15(4): 303-312. http://doi.org/10.1016/j.jclepro.2005.12.002

Kadipas N., Pexioto M.B., 1999. Global manufacturing practices: An empirical evaluation. Industrial Management & Data Systems, 99(3): 101-108.

Kamble S.S., Gunasekaran A., Gawankar S.A., 2020. Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. International Journal of Production Economics, 219, 179-194. http://doi.org/10.1016/j.ijpe.2019.05.022

Kumar A., Mishra A.K., Saroj S., Sonkar V.K., Thapa G., Joshi P.K., 2020. Food safety measures and food security of smallholder dairy farmers: Empirical evidence from Bihar, India. Agribusiness. http://doi.org/10.1002/agr.21643.

Kumar A., Staal S.J., Singh D.K., 2011. Smallholder dairy farmersâ€™ access to modern milk marketing chain in India. Agricultural Economics Research Review, 24: 243-253. http://doi.org/10.22004/ag.econ.118232

Lau K.W., Yam C.M., Tang P.Y., 2010. Supply chain design and product modularity. International Journal of Operations & Production Management, 30(1): 20-56.

Lee Y.H., Kim S.H., Moon C., 2002. Production-distribution planning in supply chain by using a hybrid approach. Production Planning and Control 13(1): 35-46. http://doi.org/10.1080/09537280110061566

Lemma H., Singh R., Kaur N., 2015. Determinants of supply chain coordination of milk and dairy industries in Ethiopia: a case of Addis Ababa and its surroundings. SpringerPlus 4: 1-12. http://doi.org/10.1186/s40064-015-1287-x

Ling E.K., Wahab S.N., 2020. Integrity of food supply chain: going beyond food safety and food quality. International Journal of Productivity and Quality Management, 29(2): 216-232. http://doi.org/10.1504/IJPQM.2020.105963

Len-Bravo V., Caniato F., Caridi M., 2019. Sustainability in multiple stages of the food supply chain in Italy: practices, performance and reputation. Operations Management Research, 12(1-2): 40-61. http://doi.org/10.1007/s12063-018-0136-9

Abdulai Rahaman A., Abdulai A., 2020. Vertical coordination mechanisms and farm performance amongst smallholder rice farmers in northern Ghana. Agribusiness, 36(2), 259-280. http://doi.org/10.1002/agr.21628

Mishra P.K., Shekhar B.R., 2011. Impact of risks and uncertainties on supply chain: a dairy industry perspective. Journal of Management Research 3(2): 1-18. http://doi.org/10.5296/jmr.v3i2.651

Mor R.S., Bhardwaj A., Singh S., Arora V., 2020. Exploring the factors affecting supply chain performance in Dairy industry using exploratory factor analysis technique. International Journal of Industrial and Systems Engineering, 36(2), 248-265. http://doi.org/10.1504/IJISE.2020.110277

Mor R.S., Jaiswal S., Singh S., Bhardwaj A., 2019a. Demand Forecasting of the Short-Lifecycle Dairy Products, In: Chahal H., Jyoti J., Wirtz J. (eds.), Understanding the Role of Business Analytics. Springer, Singapore. http://doi.org/10.1007/978-981-13-1334-9_6.

Mor R.S., Bhardwaj A., Singh S., Nema P.K., 2019b. Framework for measuring the performance of production operations in dairy industry, In: Managing operations throughout global supply chains. http://doi.org/10.4018/978-1-5225-8157-4.ch002 , IGI Global.

Mor R.S., Bhardwaj A., Singh S., 2018. Benchmarking the interactions among barriers of dairy supply chain: An ISM approach. International Journal for Quality Research, 12(2): 385-404. http://doi.org/10.18421/IJQR12.02-06

Nabhani F., Shokri A., 2009. Reducing the delivery lead time in a food distribution SME through the implementation of six sigma methodology. Journal of Manufacturing Technology Management 20(7): 957-974. http://doi.org/10.1108/17410380910984221

Nardi V.A.M., Auler D.P., Teixeira R., 2020. Food safety in global supply chains: A literature review. Journal of Food Science, 85(4), 883-891. http://doi.org/10.1111/1750-3841.14999

Nargundkar R., 2004. Marketing Research: Test and Cases, 2nd Ed., Tata McGraw Hills Pvt. Ltd: New Delhi, India.

Ngai E.W.T., Cheng T.C.E., Ho S.S.M., 2004. Critical success factors of web-based supply-chain management systems: an exploratory study. Production Planning & Control, 15(6): 622-630. http://doi.org/10.1080/09537280412331283928

Nunnally J.C., 1978. Psychometric Theory, 2nd Ed. New York: McGraw Hill.

Okano M.T., Vendrametto O., Santos O.S., 2014. How to improve dairy production in Brazil through indicators for the economic development of milk chain. Modern Economy 5: 663-669. http://doi.org/10.4236/me.2014.56062

Pitt L.F., Watson R.T., Kavan C.B., 1995. Service quality: A measure of information systems effectiveness. MIS Quarterly, 19, 173-187. http://doi.org/10.2307/249687

Robson C., 2002. Real World Research, 2nd Ed. Oxford: Blackwell.

Sahin F., Robinson E.P., 2002. Flow coordination and information sharing in supply chains: review, implications, and directions for future research. Decision Sciences 33(4): 505-536. http://doi.org/10.1111/j.1540-5915.2002.tb01654.x

Saunders M., Lewis P., Thornhill A., 2009. Research Methods for Business Students, 5th Ed. Essex: Person Education.

Safaei A.S., Husseini M., Farahani R.Z., Jolai F., Ghodsypour S.H., 2010. Integrated multi-site production distribution planning in supply chain by hybrid modelling. International Journal of Production Research 48(14): 4043-4069. http://doi.org/10.1080/00207540902791777

Selim H., Ozkarahan I., 2008. A supply chain distribution network design model: an interactive fuzzy goal programming-based solution approach. Int. J. Advance Manufacture & Technology 36, 401-418. http://doi.org/10.1007/s00170-006-0842-6

Singh N., Javadekar P., 2011. Supply chain management of perishable food products: a strategy to achieve competitive advantage through knowledge management. Indian J. of Marketing 41(10).

Sitek P., Wikarek J., 2015. A hybrid framework for the modelling and optimisation of decision problems in sustainable supply chain management. Int. J. Production Research 53(21): 6611-6628. http://doi.org/10.1080/00207543.2015.1005762

Smith B.G., 2007. Developing sustainable food supply chains. Philosophical Transactions of the Royal. Society B: Biological Sciences 363(1492): 849-861. http://doi.org/10.1098/rstb.2007.2187

Tanaka J.S., 1987. How big is big enough? Sample size and goodness of fit in structural equation models with latent variables. Child Development, 58(1): 134-146. http://doi.org/10.2307/1130296

Thirupathi R.M., Vinodh S., 2016. Application of interpretive structural modelling and structural equation modelling for analysis of sustainable manufacturing factors in Indian automotive component sector. International Journal of Production Research 54(22): 6661-6682. http://doi.org/10.1080/00207543.2015.1126372

Thomas A.V., Mahanty B., 2018. Dynamic assessment of control system designs of information shared supply chain network experiencing supplier disruption. Operational Research, 21, 425-451, http://doi.org/10.1007/s12351-018-0435-9.

Trochim W.M., 2007. Research Methods, Biztantra, New Delhi.

Vinodh S., Joy D., 2012. Structural equation modelling of lean manufacturing practices. International Journal of Production Research 50(6): 1598-1607. http://doi.org/10.1080/00207543.2011.560203

Vosooghidizaji M., Taghipour A., Canel-Depitre B., 2020. Supply chain coordination under information asymmetry: a review. International Journal of Production Research, 58(6): 1805-1834. http://doi.org/10.1080/00207543.2019.1685702

Zhang X., Yousaf H.A.U., 2020. Green supply chain coordination considering government intervention, green investment, and customer green preferences in the petroleum industry. Journal of Cleaner Production, 246, 118984. http://doi.org/10.1016/j.jclepro.2019.118984

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ORIGINAL PAPER

ESTIMATING THE POTENTIAL OF A WARNING SYSTEM PREVENTING ROAD ACCIDENTS AT PEDESTRIAN CROSSINGS

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ABSTRACT. **Background:** The safety of pedestrians is one of the main traffic safety issues today and despite measures being applied, the number of pedestrian deaths in traffic is not changing. According to the Pareto Rule, 80% of consequences come from 20% of the causes and here the question arises whether we have already used these 20% of the most efficient measures. Todaythe European Union (EU) puts big hopes are on contemporary technologies, such as Advanced Emergency Braking Systems (AEB) and cooperative intelligent transport systems (C-ITS). This decade, we can expect smarter vehicles with automatic brakes, and smarter infrastructure which can communicate with vehicles. Along this other profits technological development provides new opportunities for improving pedestrian safety. One of the most promising solutions is deployment of C-ITS systems at uncontrolled crossings. It would monitor the situation and warn the road users of potential dangers as well as make the vehicles brake automatically. However, before making large investments into this field, one has to be sure that this approach will work. The aim of this paper is to describe typical vehicle-pedestrian crash scenarios and to estimate whether a C-ITS warning system is able to prevent them. Research estimates the potential of this system and provides insights to its must-have features.

Methods: To understand the situations in which the warning system should function, researchers carried out traffic conflict studies at uncontrolled crossings with traffic filmed in both winter and summer. They determined and described serious conflicts and, based on their scenarios, classified them into three types. Then, researchers selected the most critical conflict of each type and analysed whether warning signals can be provided to the vehicle and the driver early enough to prevent collisions. For these purposes, researchers used a modelling software for traffic accident investigation. To access the efficiency of the C-ITS warning system, researchers estimated the probability of preventing collisions and used the efficiency parameters of classical traffic calming measures.

Results: The C-ITS warning system has good potential in preventing vehicle-pedestrian collisions at uncontrolled pedestrian crossings. It is remarkable and very promising that it would be able to prevent all types of conflicts analysed in the scope of this study by warning AEB-equipped vehicles. Warning the driver would be also effective, but the system work will largely depend on the quality of warning signals. An effective C-ITS warning system should be capable of predicting the trajectories and acceleration of road users as well as calculating the stopping distance of vehicles based on the coefficient of static friction. Study showed that in some cases, the system will have to give false positive alarms, but the fewer such alarms will be given, the more efficient the system will be. A disturbing or annoying C-ITS warning system cannot be considered effective.

Conclusions: Road accident statistics contain general data about vehicle-pedestrian collisions at uncontrolled crossing, but there is few information about behavioral patterns leading to accidents. Based on large-scaled traffic studies, researchers were able to determine these patterns and described how road users act when being involved in a dangerous situation. This knowledge helped to model typical vehicle-pedestrian collisions as well as their possible scenarios. Researchers used the conflict models totest the C-ITS warning system and to understand its efficiency. The study results were implementedin a prototype that has been developed in Estonia and is being tested it in real traffic conditions of a smart city in the scope of the Finnish-Estonian project "FinEst Twins".The next steps are to analyze the test resultsand to conduct research to understand how to warn drivers (and pedestrians) most effectively.

Key words: AEB, C-ITS, traffic conflict, traffic study, uncontrolled pedestrian crossing.

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INTRODUCTION

The safety of pedestrians and other vulnerable road users is one of the main traffic safety issues today. Modern vehicles offer a high level of protection to drivers and passengers, but pedestrians and cyclists are left with significantly lower chances to survive in a road accident. In Europe, 22% of all road fatalities are pedestrians [European Commission 2018].

Analysis of 16 years' long trends in the behaviour of road users indicated that pedestrian safety is the most crucial problem in road safety in Estonia [Ess and Antov 2017]. According to the Estonian Road Administration, 24.6% of traffic accidents registered in Estonia in 2011–2019 were vehicle-pedestrian collisions and 40.4% of them occurred at uncontrolled pedestrian crossings. Half of all the vehicle-pedestrian collisions happened in Tallinn.

Pedestrian safety is an important topic not only for Estonia, but for the entire EU. Figures show that the decrease in the number of vehicle-pedestrian crashes (as well as other crashes) stagnated in 2012 [European Commission 2019a], which made the achievement of Vision Zero targets for 2020 impossible. To overcome these difficulties, the EU puts big hopes on modern technologies, such as AEB, which can decelerate and stop the vehicle automatically, and C-ITS, which allows vehicles to communicate with each other, with the road infrastructure, and with other road users [European Commission 2019b]. From 2015, all new heavy-duty vehicles are equipped with AEB [European Commission 2016] and from 2022, all vehicles, including passenger cars, will also be equipped with AEB [Regulation (EU) 2018/858]. Euro NCAP has already included AEB systems to their tests, but it must be mentioned that these tests are done in almost ideal conditions – dry road, no precipitation, visibility at least 1 km [European New Car Assessment Programme 2017].

In real-life situations on uncontrolled pedestrian crossings, the efficiency of AEB is limited by the performance of the sensors of vehicles (radar, lidar, camera) and by the fact that they cannot 'see' behind the obstacles. However, a smart pedestrian crossing (SPC) can be applied. This is a C-ITS system that monitors the surroundings of pedestrian crossings from multiple locations and detects potential danger much earlier than the sensor of a vehicle. The system could warn both the vehicles and the drivers of potential danger. The AEB could use the signal received from the SPC as a trigger for automatic braking. This article aims at estimating the potential of such an SPC for preventing vehicle-pedestrian crashes at uncontrolled pedestrian crossings. For this purpose, researchers determine typical conflict situations at uncontrolled crossings in Tallinn, using a modelling software to 'convert' them to collisions and estimate whether a smart C-ITS device could prevent them or not.

TRAFFIC CONFLICTS AND SIMULATION

Crashes in traffic result from many objective factors operating together and in safety studies, it is essential to estimate the cause-effect relationship of a crash on a time scale [Elvik et al. 2009]. Crash reports from police databases do not provide precise information for analysis, but this can be done by means of traffic conflict studies. These studies assume that there are sufficient similarities between actual accidents and 'almost accidents' of the same type [Polders and Brijs 2018]. Traffic conflicts are observational situations in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged [Svensson 1998]. Traffic conflict studies measure the number of conflicts and their severity, validate with traffic crash data, classify them, and find out precursors to crashes [Tarko 2012].

Conflicts are determined by means of special parameters or indicators which help to estimate the severity of a critical situation. The most common parameter in such studies is the time to collision (TTC) and its variations. TTC is the time until a collision between the vehicles would occur if they continued on their present course at their present rates [Laureshyn et al. 2016]. During the conflict, the TTC value varies over time, and therefore, a proper evaluation requires a continuous monitoring with the identification of the critical value. Usually, this is the lowest TTC value in the interaction – the minimal time to collision (TTCmin). As a rule, time TTCmin under 1.5 s is considered critical. However, for conflicts between vehicles and vulnerable road users, the proximity to a collision is only one dimension of its severity; the potential consequences (nearness to a serious personal injury) should be also taken into account [Polders and Brijs 2018]. These consequences can be estimated in relation to impact speed and a probability of death or injury [Astarita et al. 2019].

TTC can be used only if the trajectories of the road users are crossing and therefore do not take into account potentially dangerous 'near misses'. For this reason, some studies use a variation of TTC, placing emphasis on the second (later) road user. The respective conflict parameter is called T2. It shows the expected arrival time of the second road user to the potential collision point. T2 can be calculated also in the case of a non-collision course, which is an advantage compared to TTC [Laureshyn et al. 2016]. One more conflict parameter used in some studies is the deceleration to safety time. It shows the nearness to a collision through the minimal necessary deceleration for a driver to avoid the collision [Hupfer 1997]. Some parameters take into account not only deceleration, but also the potential impact speed, i.e. the speed at the moment of the collision supposing a braking deceleration [Johnsson et al. 2018].

Traditionally, traffic conflict studies were carried out using trained observers in the field. As this approach involves a risk of missing or misjudging conflicts without providing an option to look through them again, video recordings of the sites are often collected. However, a manual analysis of the video footage is often very time-consuming. Researchers have thus developed video analysis software for the automated tracking of road users to identify traffic conflicts automatically to reduce the time spent on analysing the video footage. The tool is a so-called watchdog system that detects events that should be investigated further while discarding the parts of the video with no activity of interest [Madsen and Lahrmann 2017]. One example of such software is Road User Behaviour Analysis (or RUBA) developed at Aalborg University. The performance of such systems depends on weather and light conditions, occlusion, shadows, and complex traffic scenes with multiple road user groups sharing the same space. Hence, a human-in-the-loop is therefore still necessary [Madsen and Lahrmann 2017]. To calculate conflict parameters (TTC and others), researchers use software which allows the extraction of road user positions frame by frame and calculating their speeds, accelerations, and a number of surrogate indicators of safety, such as TTC. An example of such software is the video analysis tool T-Analyst developed by the University of Lund [Bulla-Cruz 2020].

Classical conflict studies investigate the cause-effect relationship of a crash, but do not consider possible scenarios provoked by errors of conflicting road users and crash consequences. This can be done by means of microsimulation, which is a traffic simulation approach to reproduce all dynamic interactions among vehicles in fine detail. The state-of-the-art microsimulation converts conflicts traffic conflicts to crashes, simulates potential human errors and crash consequences [Astarita et al. 2019].

DEVELOPED METHODOLOGY

To assess the potential efficiency of SPCs in preventing vehicle-pedestrian collisions, a large-scale traffic conflict study was held. Traffic at uncontrolled crossings was filmed with high-resolution cameras and the video material was analysed to detect serious vehicle-pedestrian conflicts. Observation places have been selected according to crash statistics and these were the most dangerous crossings in Tallinn. The selection following criteria was:

- number of vehicle-pedestrian collisions in 2012–2018: not less than three;

- no significant changes in traffic management from 2012;
- different types of crossings (number of lanes, refuge island);
- suitability for camera placement (a pole or building near the crossing where it is possible to place the camera).

As a result, for the purposes of the study, ten uncontrolled crossings of the following types have been selected:

- three crossings on 1 + 1 roads without a refuge island;
- four crossings on 2 + 2 roads with a refuge island;
- three crossings with 3 lanes in one direction with a refuge island.

The traffic study consisted of two parts – the pilot study (held in winter 2017–2018) and the main study (held in summer 2018). The pilot study revealed several issues with cameras and batteries. Action cameras with power banks were used, but this approach did not justify itself, as the workload of changing power banks and memory cards did not correspond to the number of conflicts detected. During the main study, researchers used upgraded systems, which consisted of a security camera with a Wi-Fi connection and a vehicle battery stored in a box placed on the street pole. Cameras were placed at the height of approximately five metres and a Wi-Fi connection was used to tune the filming angle.

In each location, traffic was filmed for two weeks during the working days, making up 10 days for each location in total. The video material was analysed both using the semi-automatic software RUBA and by manual review performed by a team of trained staff. However, the share of semi-automatic analysis was very low due to the fact that the software produced too much 'noise' in the timestamps, because it was impossible to place cameras at a height that would provide a filming angle optimal for the software.

The research highlighted and described serious conflicts. In most cases, the severity of conflicts was determined by a team of researchers visually, taking into account nearness to serious injury for the pedestrian. In case of doubt, researchers proceeded from the possible impact speed – a conflict was classified as serious if the impact speed was 20 km/h or higher. This threshold was chosen because respective studies [Roséna et al. 2011] show that starting from this impact speed, the health risk for pedestrians starts increasing. The impact speed was calculated according to the formula below [Bosch automotive engineering 2007].

$$V_{impact} = V_{vehicle} - (TTC_{min} - t_r - t_a - 0{,}5 \cdot t_s) \cdot \varphi_x \cdot g \quad (1)$$

where:

t_r is reaction time (1 s)
t_a is response time (0,15 s for passenger cars)
t_s is pressure build-up time (0,36 s for passenger cars)
φ_x is coefficient on static friction
g is gravity constant

Parameters for the calculations were collected with the help of T-Analyst. This software allows combining orthophotos and a camera view to create a system of coordinates and calculate the speed of road users, TTC, T2, and other conflict parameters (see Figure 1). In case of 'near-misses' when there was no collision course and therefore it was impossible to calculate the TTC, researchers used T2 as the closest possible value to TTC.

Fig. 1. Determining conflict parameters with T-Analyst

All the serious conflicts determined were classified into types based on the similarity of their circumstances. For each conflict type, researchers determined the most serious conflict. This was done by means of TTC_{min} and impact speed as well as the risk of serious injuries. These conflicts were modelled using the PC-Crash software, which is used for traffic accident analyses. It allows animating pre-accident situations and 'see' it from different perspectives (see Figure 2). To create PC-Crash models, researchers used data retrieved from T-Analyst (the trajectories, speeds, and accelerations of road users). Conflicts were 'converted' to collisions using PC-Crash. Researchers investigated them and determined the timing of C-ITS warning signals. It was analysed whether the timing of warning signals is realistic and whether the driver could see the warnings and react in a proper manner (brake with maximum deceleration). After that, researchers added the reactions of typical road users to conflict models and analysed if they lead to additional hazards.

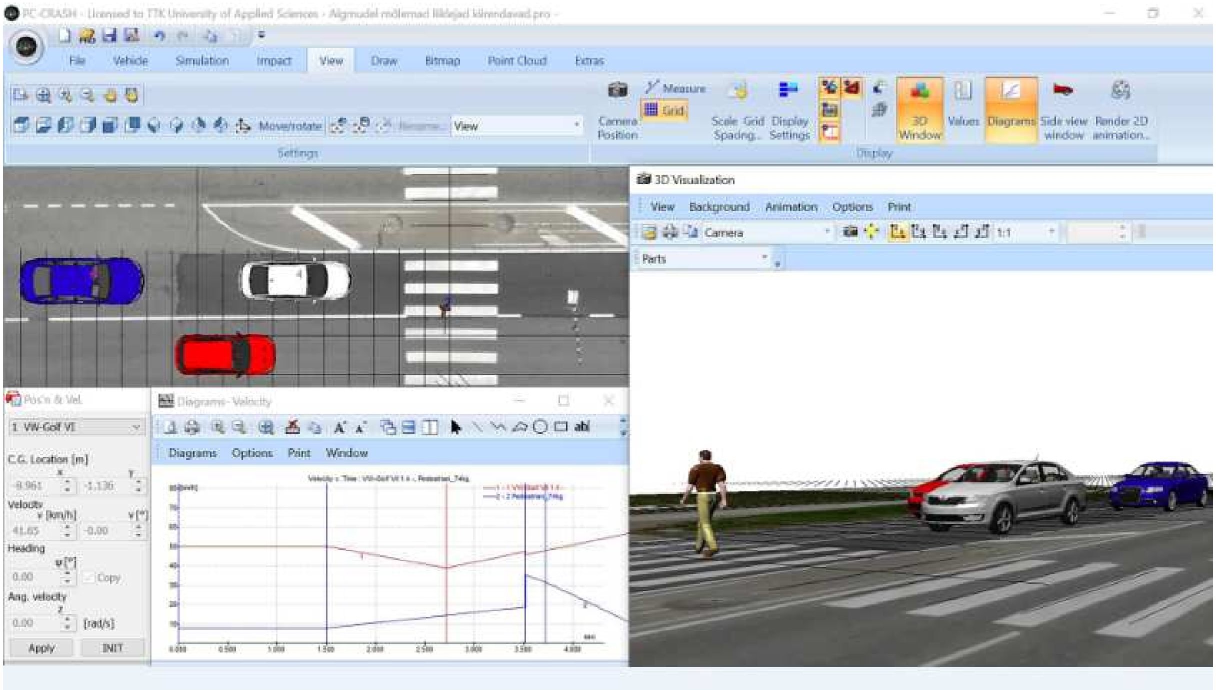


Fig. 2. Using PC-Crash to analyse traffic conflicts

THE STUDY

Conflict study

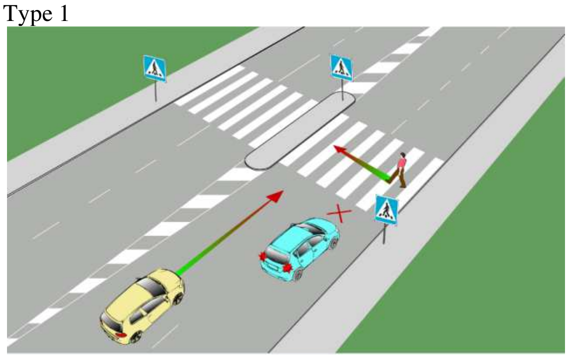
Researchers collected and analysed 1512 hours (approx. 2 months) of video material. A total of 283 hours were recorded during the pilot stage and 1229 hours during the main stage of the study. A total of 90 serious conflicts were determined. Sixteen of them were unclassified (conflicts with alarm vehicles, unusual pedestrian behaviour, vehicle-cyclist conflicts, etc). A total of 74 serious conflicts were selected for analysis. All of them took place at pedestrian crossings situated at multi-lane roads, as no serious conflicts were determined on 1 + 1 roads.

Serious conflicts were classified into three types (see also Figure 3):

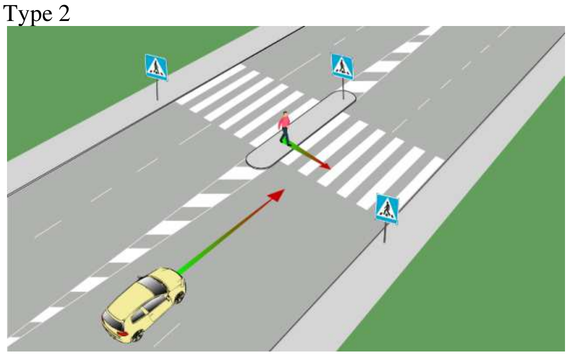
– one vehicle stops before the crossing while another vehicle in the next lane conflicts with the pedestrian (Type 1)
– a vehicle conflicts with a pedestrian who is about to step to the crosswalk from the sidewalk or refuge island (Type 2)
– a vehicle conflicts with a pedestrian who is already crossing the carriageway (Type 3)

The principal difference between Types 2 and 3 lies in the fact that for Type 2, the pedestrian has not yet started crossing the carriageway and the driver may hope that the pedestrian stops before the zebra. For Type 3, the pedestrian is already on the carriageway and the situation is potentially more dangerous.

Type 1



Type 2



Type 3

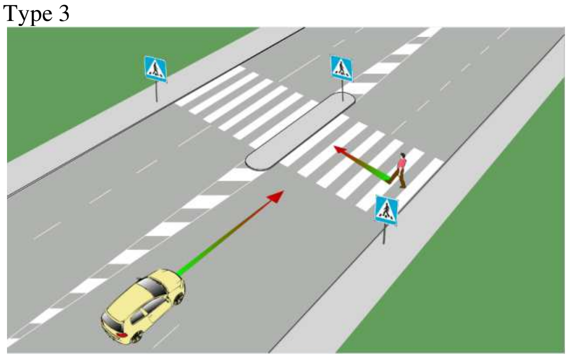


Fig. 3. Typical conflicts

It should be mentioned that between these types of conflicts there have been determined situations when a pedestrian was approaching both from the right and from the left. As it does not change the essence of the conflict, researchers ignored the direction of motion of pedestrians in their classification.

Half of serious conflicts correspond to the first type, one third to the third type, and the rest to the second type (see Figure 4). Much to our regret, due to strict personal data protection legislation, it was impossible to get detailed description of pedestrian accidents from the police, which made conflict validation with real crash data complicated. Researchers were provided only with superficial accident descriptions, which contained little to no detail. Researchers analysed the descriptions of 40 accidents which took place in 2012–2018 at the same multi-lane pedestrian crossings where the traffic conflict study has been conducted. Five vehicle-pedestrian collisions corresponded to the first type of conflicts, also five to the second, and two to the third type. Due to a lack of information, it was impossible to classify the remaining accidents, but analysis showed that conflicts of all three types ended with real traffic accidents.

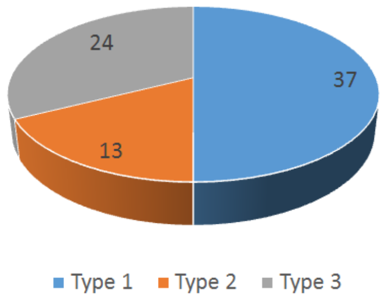


Fig. 4. Serious conflicts by types

Microsimulation and analysis

For every conflict type, researchers selected the most serious conflict and analysed it in T-Analyst and PC-Crash. Researchers used T-Analyst to determine road users' trajectories, speeds and accelerations as well as TTC_{min} and T2. Afterwards this data was imported to PC-Crash to create conflicts' models which were used to analyse capability of the SPC to prevent collision.

The type 1 conflict is presented on Figure 5. The vehicle initially moved at a speed of 36.4 km/h and the pedestrian at a speed of 7.9 km/h. This situation is interesting because of its dynamics. Analysis showed that the dense traffic flow caused visual distraction, so the driver and pedestrian saw each other at the very last moment. In a critical situation, the driver started decelerating while the pedestrian started running and jumped away from the approaching vehicle. TTC_{min} was 1.0 s.

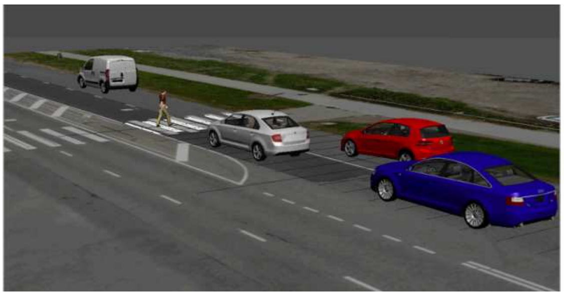


Fig. 5. Model of the type 1 conflict

In case of a collision, the vehicle would have hit the pedestrian at a speed of 34 km/h. Taking into account the speed and road conditions, the SPC should warn the driver at least 18 m before the crosswalk. This distance is relatively small, and one can admit that the driver would see the warning signal even when moving in a dense traffic flow. However, it should be taken into account that the driver does not see the pedestrian ahead and the question arises whether they react in an expected manner (brakes with maximum deceleration)?

In the case of an AEB system, the warning signal should be given at least 9 m before the crosswalk. Because of many moving objects hiding the pedestrian from the sensors of vehicles, the AEB system may not detect the pedestrian in time, especially in difficult conditions (precipitation, fog). For this type of conflicts, the vehicle would need additional input from the SPC.

The type 2 conflict is presented on Figure 6. The vehicle moved initially at a speed of 57.6 km/h (while the speed limit is 50 km/h) and the pedestrian at a speed of 5.4 km/h. It was snowing and the road was slippery. The conflict took place in the dark, but the road lighting was on and the crosswalk had additional illumination. There were no obstacles that could limit the driver's field of view. The driver assessed the situation incorrectly and when it was too late for braking, took the decision to accelerate and pass the crosswalk before the pedestrian. The pedestrian noticed the vehicle just before stepping to the carriageway from the refuge island. He stopped abruptly, slipped, and nearly fell down. $T2_{min}$ was 1.24 s.

Fig. 6. Model of the type 2 conflict

In case of a collision (for instance, if the pedestrian started accelerating), the vehicle would hit the pedestrian at a speed of 57.6 km/h. Taking into account the speed and road conditions, the SPC should warn the driver at least 41 m before the crosswalk. This raises a number of questions. Would the driver notice a warning signal located in front of the crossing? Would the speeding driver realise the danger and react to the warning signal, which is located so 40–50 m ahead? Would the driver take into account road conditions when braking? To sum up, there is certain doubt that warning the driver would have the expected effect in this situation.

In the case of the AEB system, the warning signal should be given at least 27 m before the crosswalk. In difficult weather conditions, the vehicle may not detect the pedestrian with its own sensors and may need additional input from the SPC.

The type 3 conflict is presented on Figure 7. The vehicle initially moved at a speed of 41.4 km/h and the pedestrian at a speed of 6.5 km/h. It was snowing and the road was slippery. The pedestrian moved along the road off the pavement (the trajectory is shown on Figure 7 with the blue line). He did not turn his head before crossing the road and because of his hood, he did not see the approaching vehicle in his peripheral vision. The driver started decelerating after the pedestrian had stepped to the crosswalk. Due to the late reaction, the car passed just in front of the pedestrian. $T2_{min}$ was 0.27 s.

Fig. 7. Model of the type 3 conflict

In case of a collision, the vehicle would have hit the pedestrian at a speed of 42.5 km/h. Taking into account the speed and road conditions, the SPC should warn the driver at least 26 m before the crosswalk. In the case of the AEB system, the warning signal should have been given at least 16 m before the crosswalk. In both cases, the warning should be given before the pedestrian changes direction to cross the road, i.e. before it is clear that he intends to step on the crosswalk. This case shows that in some situations, the SPC should give false positive warnings, especially in locations where the pavement is situated just next to the carriageway and the pedestrian can either cross the street or proceed walking parallel to it. Both for drivers and for AEB-equipped vehicles false positive signals would mean that sometimes they will have to brake ‘just in case’. However, this speed behaviour is typical for defensive driving style and many drivers are doing it in real traffic every day.

Coming back to the potential efficiency of SPC, in this situation, it is likely to prevent collision by warning the driver, as he or she sees the pedestrian, but postpones braking for the moment when it is too late. A warning signal would help to take a decision in time. It is important to note that in this particular case, one cannot expect the AEB to react in time without a warning signal from the SPC. As the pedestrian changes his direction suddenly and is very close to the crosswalk, the AEB will not consider him a conflicting object, before he actually turns and starts crossing. As a result, the vehicle will start decelerating later than needed. This means that the SPC should be ‘smart’ enough to predict the trajectories of pedestrians and to assess possible risks. It sets high standards to its software and processing power. Most probably the system should be based on machine learning, i.e. it should ‘learn’ the behaviour of road users from real traffic.

RESULTS

According to analysis performed withing microsimulation for all the situations studied, researchers answered the question ‘Would an SPC help to prevent a collision?’ Results are presented in Table 1.

Table 1. Ability for preventing collisions by type

Type of warning	Type 1	Type 2	Type 3
Warning the driver	likely	doubtful	likely
Warning the AEB-equipped vehicle	yes	yes	yes

Source: own work

Results show that the SPC will work most efficiently by warning AEB-equipped vehicles – they do not fail to react, and their pre-braking time is shorter. At the same time, in all the three situations studied, the AEB might need additional input, especially in case of visual distractions and difficult weather conditions. Warning the driver is assessed rather pessimistically, as with our current knowledge, we cannot be sure that the driver will react at the warning signal as expected. If we warn the driver, he or she might not notice the warning signal or react properly. At the other hand, conflict study showed that 53% of drivers involved in serious conflicts did not take any action. They might have assessed situation incorrectly or were distracted, so the warning signal might be useful. In this context, the efficiency of the SPC will highly depend on the efficiency of warning signals (first of all, on their type and location).

To sum up, from the cases studied, one can conclude that SPCs have a good potential to prevent typical vehicle-pedestrian crashes at uncontrolled crossings. Warning the vehicles has better potential than warning the drivers, because the efficiency of SPCs will largely depend on the quality of warning signals.

FEATURES TO PROVIDE EFFICIENCY OF THE SPC

In the scope of their study, researchers determined certain 'must have' features for an efficient SPC. First, an important feature for the SPC is calculating the stopping distances. If the road is dry and the vehicle's speed is 50 km/h, the SPC should warn the driver at least 30 m before the crossing, but in case of snow on the carriageway, 68 m before the crossing. The system should be smart enough to know the coefficient of static friction and to warn road users and vehicles in time.

Secondly, the SPC should predict road users' behavior. Analysis of traffic conflict showed that road users behave in different ways in pre-crash situations. The most common behavior for drivers is taking no action at all (53%); however, 1% start accelerating. The most common behavior for pedestrians is deceleration (74%), while 7% start accelerating. Researchers added the most typical behaviour patterns to traffic conflict models and checked if these patterns increase collision risks. Results are presented in Table 2. Impossible scenarios are marked with '-'.

Table 2. Potential probability for preventing collisions by type

Driver	Pedestrian	Type 1	Type 2	Type 3
Does nothing	Accelerates	No collision	Collision	Collision
Accelerates	Does nothing	Collision	No collision	High collision risk
Accelerates	Accelerates	Collision	High collision risk	Collision
Turns away	Does nothing	-	No collision	-
Turns away	Accelerates	-	No collision	-
Turns away and accelerates	Does nothing	-	No collision	-
Turns away and accelerates	Accelerates	-	No collision	-
Turns away and decelerates	Does nothing	-	No collision	-
Turns away and decelerates	Accelerates	-	High collision risk	-

Source: own work

Results show that in most cases, the acceleration of a conflicting road user leads to collision or high collision risk. Analysis of Type 3 conflict showed that the SPC should be capable to predict pedestrian's trajectory. At the same time modelling typical behaviour patterns of road users indicate that to prevent collisions effectively the SPC should also predict possible acceleration of the driver and the pedestrian.

In the third place, the SPC should be orientated not only to the vehicles, but also to the road users. The system will be most efficient for the AEB-equipped vehicles, but their share in traffic will be relatively low during the next decade. According to Estonian Transport Administration, the average age of a passenger car in Estonia is 12.9 years. The total number of passenger cars is approximately 910,000, while the number of annually sold new cars (which will be all AEB-equipped starting from 2022) is approximately 26,000. It means that the SPC should warn not only vehicles, but also drivers and its efficiency will largely depend on the warning signals. This topic needs additional research. It is important to understand which warning signals are most efficient for drivers and if it makes sense to warn pedestrians as well. One of the most important questions is where will road users look when they see (or hear) the warning? Is there a risk that they will pay attention only to the warning signal and fail to see the hazard?

How to measure efficiency of the SPC

A question arises how to estimate or measure efficiency of the SPC. This can be done by comparing number of collisions or traffic conflicts before and after implementing the SPC, but this approach will be very time-consuming. Both collisions and conflicts are rare events in traffic and getting a trustful sample size would be complicated, so alternative approach can be used.

In a broad sense, the SPC is a new generation traffic calming measure (TCM). Both the SPC and classic TCMs serve the same purpose – make drivers choose safe speeds – with the only difference being that classic TCMs do not 'understand' if there is a risk of collision or not. Therefore, when analysing the efficiency of the SPC, one can proceed from TCMs.

Ess and Antov proposed methodology to estimate the effectiveness of TCMs from the perspectives of vehicle speed and public acceptance [Ess and Antov 2016]. It assumes measuring speeds in certain locations in front and behind the TCM and calculating 85th percentile location speed and mean location speed. On the one hand, the choice of speed should guarantee traffic safety, but on the other hand, also smoothness of motion. In the context of the SPC, it means that the vehicle should reduce speed to the needed extent, but only if there is direct need for that. Warnings should not be given 'just in case' – the number of false positive signals forcing to brake should be as low as possible. The SPC is feasible to measure both speed parameters and share of false positive warnings automatically and use this data to improve its algorithms.

Public acceptance, i.e. road users' attitudes towards the TCM, is also taken into account – the better this attitude, the more efficient the TCM. Drivers and pedestrians should understand that the SPC is implemented not to disturb, but to help them. The better is their attitude towards the SPC, the more efficient it is. Public acceptance is estimated by means of survey.

Methodology described above can be used to estimate efficiency of the SPC, but also to compare different warning algorithms to improve road safety.

CONCLUSIONS

The general conclusion is that the SPC has good potential to prevent vehicle-pedestrian collisions at uncontrolled pedestrian crossings.It defenetly makes sense to invest money and time in research and development. The most effective is to warn AEB-equipped vehicles, as they react faster and brake automatically. Most importantly, in many situations, AEB will need input from the SPC and will not be able to prevent collision on its own. At the same time cooperation between AEB and C-ITS system would be able to prevent all types of conflicts analysed in the scope of this study.

Warning the drivers also has good potential, but much will depend on the quality of warning signals. Additional research is needed to understand how to warn drivers in the best way and whether it makes sense to warn the pedestrians along with the drivers. At the same time, it is important to warn not only the vehicles, but also the road users, as the share of AEB-equipped vehicles is rather small and will increase slowly.

To work efficiently, the SPC must be able to predict change in the speed and direction of road users as well as calculate the braking distance of vehicles according to the coefficient of static friction of the carriageway. False positive warnings are inevitable, but the number of such warnings should be as low as possible. The attitude of road users towards SPC should be positive, otherwise it cannot be considered effective.

The study results were used in working out the first prototype of the C-ITS warning system. At the moment of publication, it is being tested in Tallinn in the scope of Finnish-Estonian project "FinEst Twins", which aims at selecting smart city pilots with strong scientific, innovative and commercial potential for future studies [FinEst webpage]. The C-ITS prototype is equipped with cameras and sensors and uses narrow artificial intelligence algorithms to analyse the traffic situation and detect potential vehicle-pedestrian conflicts [Bercman Technologies webpage and webpage of the city of Tallinn]. The project will end last from 01.01.2020 to 31.08.2023.

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REFERENCES

Astarita V., Giofré V. P., 2019. From traffic conflict simulation to traffic crash simulation: Introducing traffic safety indicators based on the explicit simulation of potential driver errors, Simulation Modelling Practice and Theory. http://doi.org/10.1016/j.simpat.2019.03.003

Bercman Technologies webpage. Available on the Internet: https://www.bercman.com/spc (27/05/2021).

Bosch automotive engineering, 2007, 7th ed., Robert Bosch GmbH: 435, 438.

Bulla-Cruz L.A., Laureshyn A., Lyons L., 2020. Event-based road safety assessment: A novel approach towards risk microsimulation in roundabouts, Measurement. http://doi.org/10.1016/j.measurement.2020.108192

Elvik R., Vaa T., Hoye A., Sorensen M., 2009. The Handbook of Road Safety Measures (2nd ed.), Emerald Group Publishing.

Ess J., Antov D, 2016. Unified methodology for estimating efficiency of traffic calming measures – example of Estonia, The Baltic Journal of Road and Bridge Engineering 11(4): 259 – 265. http://doi.org/10.3846/bjrbe.2016.30.

Ess J., Antov D., 2017. Estonian traffic behaviour monitoring studies 2001–2016: overview and results, The Baltic Journal of Road and Bridge Engineering 12(3): 167–173. http://doi.org/10.3846/bjrbe.2017.20.

European Commission, 2016. Saving Lives: Boosting Car Safety in the EU Reporting on the monitoring and assessment of advanced vehicle safety features, their cost effectiveness and feasibility for the review of the regulations on general vehicle safety and on the protection of pedestrians and other vulnerable road users. Available on the Internet: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0787&from=EN (14/04/2021).

European Commission, 2018. Annual Accident Report. Available on the Internet: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2018.pdf (14/04/2021).

European Commission, 2019a. EU Road Safety Policy Framework 2021-2030 - Next steps towards "Vision Zero". Available on the Internet: https://ec.europa.eu/transport/sites/transport/files/legislation/swd20190283-roadsafety-vision-zero.pdf (14/04/2021).

European Commission, 2019b. Supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems. Available on the Internet: https://ec.europa.eu/transport/sites/transport/files/legislation/c20191789.pdf (14/04/2021).

European New Car Assessment Programme. 2017. Test Protocol – AEB VRU systems. Available on the Internet: https://cdn.euroncap.com/media/26997/euro-ncap-aeb-vru-test-protocol-v20.pdf (14/04/2021).

FinEst webpage. Available on the Internet: http://www.finesttwins.eu/projects (27/05/2021).

Johnsson C., Laureshyn A., De Ceunynck T., 2018. In search of surrogate safety indicators for vulnerable road users: a review of surrogate safety indicators, Transport Reviews 38(6): 765-785. http://doi.org/10.1080/01441647.2018.1442888.

Hupfer, C., 1997. Deceleration to Safety Time (DST) – a useful figure to evaluate traffic safety? 10th ICTCT Workshop, Lund.

Laureshyn A., Jonsson C., De Ceunynck T., Svensson Å., de Goede M., Saunier N., Włodarek P., van der Horst R., Daniels S., 2016. Review of current study methods for VRU safety – part 4, Project No. 635895

In-Depth understanding of accident causation for Vulnerable road users, Warsaw University of Technology. Available on the Internet: https://portal.research.lu.se/portal/files/39562440/InDeV_D2_1_Appx_4_Naturalistic_driving.pdf (14/04/2021).

Laureshyn A., De Ceunynckac T., Karlsson C., Svensson Å., Daniels S., 2017. In search of the severity dimension of traffic events: Extended Delta-V as a traffic conflict indicator, Accident Analysis & Prevention. http://doi.org/10.1016/j.aap.2016.09.026

Madsen T. K. O., Lahrmann H. S., 2017. Comparison of five bicycle facility designs in signalized intersections using traffic conflict studies, Transportation Research. Part F: Traffic Psychology and Behaviour 46(B): 438-450. http://doi.org/10.1016/j.trf.2016.05.008.

Polders, E., Brijs, T., 2018. How to analyse accident causation? A handbook with focus on vulnerable road users, Deliverable 6.3. Horizon 2020 EC Project, InDeV. Hasselt, Belgium, Hasselt University. Available on the Internet: http://www.intrasl.net/downloads/publicaciones/Handbook-InDeV.pdf (14/04/2021).

Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC. Available on the Internet: https://eur-lex.europa.eu/eli/reg/2018/858/oj (14/04/2021).

Roséna E., Stigsonb H., Sandera U., 2011. Literature review of pedestrian fatality risk as a function of car impact speed, Accident Analysis and Prevention 43: 25–33. http://doi.org/10.1016/j.aap.2010.04.003

Svensson, Å., 1998. A Method for Analysing the Traffic Process in a Safety Perspective, Bulletin 166. Dept. of Traffic Planning and Engineering, Lund University, Lund, Sweden.

Tarko P. A., 2012. Use of crash surrogates and exceedance statistics to estimate road safety, Accident Analysis and Prevention 45: 230– 240. http://doi.org/10.1016/j.aap.2011.07.008

The city of Tallinn webpage. Available on the Internet: https://www.tallinn.ee/eng/tallinnovation/Intelligent-traffic-signs (27/05/2021).

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ORIGINAL PAPER

EVALUATION OF SUSTAINABLE SUPPLIER PROBLEM: A HYBRID DECISION MAKING MODEL BASED ON SWARA-WASPAS

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ABSTRACT. **Background:** The fierce competitive advantage in the global market depends largely on the integration of all supply chain networks. This network facilitates the movement of information and materials through the suppliers and end customers with a focus on planning and managing. This integration can result in the meeting demands of customer orders being affected by the performance of the suppliers. As a result of this integration, it can be considered that the performance of the suppliers is important in fulfilling customer orders on time. Evaluating and selecting suppliers is greatly influencing the performance of the supply network.

Methods: Selecting the proper supplier is a multi-criteria decision-making problem which includes both quantitative and qualitative criteria. A two-stage decision making method is proposed in the study under sustainability dimension. First, SWARA method is used to determine the relative importance of criteria and than WASPAS method is used to evaluate and rank the given alternatives.

Results: A real-life case study is given for the selected approach. Also, sensitivity analysis is given. This selected alternative confirms the preferences of decision makers as it is a company that operates internationally and has a reputation and awareness in sustainability within its own country.

Conclusions: Due to the increase in awareness on sustainability and the resulting regulations, the issue of sustainability in supply chains and sustainable supplier selection has become an important issue for companies. It is aimed to examine the supplier selection of a company in an electronics sector on a "sustainable" basis, considering from economic, environmental and social aspects. In this study, which was carried out to fill the literature gap identified in this field and to propose a systematic approach to sustainable supplier selection, a hybrid method which consists of both SWARA and WASPAS method have been used to evaluate the suppliers under the sustainability dimensions. With the help of a hybrid model, decision makers can manage conflict management of individual challenges using an analytical process.

Keywords: sustainable supplier selection, multi-criteria decision-making, SWARA, WASPAS.

INTRODUCTION

Supply chain management, which involves all activities related to the transformation and flow of goods and services from suppliers to ultimate users, and which represents the integration of all activities of a company, today has been expanded to a sustainable supply chain management to meet market constraints and demands from various stakeholders, to comply environmental legislations and to perform better [Büyüközkan and Çiftçi 2011, Ghadimi et al. 2017]. The increasing awareness of sustainability both in business world and society as a whole, companies want to include this issue in their supply chain activities to meet the requirements of increasing environmental and social legislation and to be able to cope with pressures from different stakeholder groups [Carter and Easton 2011, Azadnia et al. 2015].

Sustainability can be described as keeping the ability to be continual while diversity and productivity are maintained. According to Brundtland Report, sustainability is known as meeting today's needs without compromising

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the ability of future generations to meet their own needs. Sustainability includes topics such as ensuring world-wide safety, satisfying fundamental human needs, conservation of non-renewable natural resources, understanding environmental impact on both developing and industrialized economies and so on [Carter and Rogers 2008]. Studies denote that companies with high levels of sustainability achieve significant competitive advantages [Hollos et al. 2011]. This forces companies to quickly adapt to the economic goals as well as the processes that will achieve green and social goals. Which is why, companies which have realized that increasing sustainability ratings could be possible by integrating sustainability into their supply chain activities, have begun to implement sustainable supply chain management by combining sustainable development and supply chain management concepts [Azandia et al. 2012]. Designing and implementing sustainable supply chains, an important parameter of sustainability, is a critical issue for companies in competitive markets. To get ahead of such issues, companies have to build a supply chain structure for their economic, environmental and social targets [Mavi et al. 2017]. A sustainable supply chain can be defined as the management of materials, information and cash flows taking into account the objectives of the economic, environmental and social dimensions of sustainable development, as well as the management of cooperation between companies through the supply chain [Büyüközkan and Çiftçi 2011, Amindoust et al. 2012].

Today, companies that evaluate suppliers in cost-based are more likely to lose their competitive edge. For this reason, enriching and developing the operations are important by adding environmental and social dimensions [Ghadimi et al. 2017].

Selection of the supplier is known as a strategic decision within the scope of the supply chain management and has an important role in boosting the overall performance [Azadi and Saen 2012, Azadnia et al. 2015, Hashim et al. 2017]. In supply chain management, suppliers are very influential in assuming a critical role in achieving their goals and in determining the suppliers to cooperate with in the success of a chain. Sustainable supplier selection is the traditional supplier selection, including environmental and social dimensions to assess the performance of suppliers and to select the most appropriate one [Tavana et al. 2017]. Traditionally, companies use criteria like price, quality, flexibility while measuring supplier's performance. Today, sustainability factors are known to have a vital role of a supply chain in the long-term success. Many organizations are now talking about environmental, social and economic concerns and measuring their suppliers' sustainability performance [Govindan et al. 2013, Mehregan et al. 2014]. Suppliers are very important for sustainable supply chains [Büyüközkan and Çiftçi 2011]. The ability to manage a sustainable supply chain effectively depends on the success of all players and processes in the chain in terms of sustainability [Ghadimi and Heavey 2014] and depends on the number and quality of suppliers and customers and the relationship between environmental, economic and social dimensions. These relationships demonstrate the importance of suppliers' sustainable performance [Büyüközkan and Çiftçi 2011].

Supplier selection problem is to make selection by evaluating the performance of many suppliers in order to increase the efficiency of the whole supply chain system. Selecting the proper supplier is a multi-criteria decision making (MCDM) problem that requires a balance between conflicting quantitative and qualitative criteria [Azadnia et al. 2012].

In this study for sustainable supplier selection, a two stage MCDM method is preferred. Because of the effectiveness of calculating subjective criteria weights [Alrasheedi et al. 2021], SWARA method is chosen to determine the relative importance of criteria. The WASPAS method is used to evaluate and rank the alternatives. The main reason for using SWARA and WASPAS methods together, is the ease of application of them. While the SWARA method allows fewer pair-wise comparisons compared against other methods, the application of the WASPAS method is much easier [Urosevic et al. 2017].

This paper aims of the sustainable supplier selection to determine the most appropriate one with high potential to meet the needs of the electronics sector. Also with this study, filling the literature gap and proposing a systematic approach to sustainable supplier selection are aimed. The remainder of this paper is organized as follows. In the second section, literature review of the most related studies was summarized. In third section, proposed Step-Wise Weight Assessment Ratio (SWARA) and Weighted Aggregated Sum Product Assessment (WASPAS) methods were described in depth for the sustainable supplier selection. The steps of the proposed models were applied to a real case study in an electronics sector and the results were presented in the fourth section. The paper was finalized with the fifth section where the conclusions and suggestions for future studies were presented.

LITERATURE REVIEW

Traditionally, supplier selection process is evaluated by different tangible and intangible criteria like price, quality, technical competence and delivery performance. Cooperating with suppliers in environmentally, socially and economically strong has a positive effect on supply chain performance. For this reason, many companies have begun to incorporate the environmental, social and economic dimensions of sustainability into their supplier selection processes. The problem of sustainable supplier selection can be considered as a traditional supplier selection problem in which environmental and social criteria are taken into account in order to select suppliers and monitor their performance. There are many approaches in the literature that address the problem of selecting sustainable suppliers. It is known that MCDM methods are used the most among these approaches [Hashim et al. 2017]. For this reason, it is important to consider the studies involving MCDM methods which have already been carried out in the selection of sustainable suppliers.

Table 1. Criteria used in some of selecting sustainable supplier studies

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Author(s)
✓	✓	✓													Tirkolaee et al. 2020
✓	✓	✓													Jain et al. 2020
✓	✓	✓													Stevic et al. 2020
✓	✓	✓													Liu et al. 2019
✓															Bai et al. 2019
	✓		✓	✓	✓	✓									Segura et al. 2019
		✓					✓	✓							Mohammed et al. 2019
✓	✓	✓													Phochanikorn and Tan 2019
✓	✓	✓													Stevic et al. 2019
	✓	✓							✓	✓					Rabieh et al. 2019
✓	✓	✓													Pishchulov et al. 2019
✓	✓	✓													Abdel-Baset et al. 2019
✓	✓	✓													Matici et al. 2019
✓	✓	✓													Memari et al. 2019
✓	✓	✓									✓	✓			Awasthi et al. 2018
		✓					✓	✓							Mohammed et al. 2018
✓	✓	✓													Lu et al. 2018
✓	✓	✓													Kannan 2018
✓	✓	✓													Goren 2018
✓	✓	✓													Cheraghalipour and Farsad 2018
✓	✓	✓													Luthra et al. 2017
✓	✓	✓													Ahmadi et al. 2017
✓	✓	✓													Tavana et al. 2017
✓	✓	✓											✓		Mavi et al. 2017
✓	✓	✓													Amindoust and Saghafinia 2017
✓	✓	✓												✓	Girubha et al. 2016
✓	✓	✓													Azadnia et al. 2015
✓	✓	✓													Ghadimi and Heavey 2014
✓	✓	✓													Govindan et al. 2013
✓	✓	✓													Amindoust et al. 2012
✓	✓	✓													Azadnia et al. 2012

To this end, in this study, some of studies using at least one of MCDM methods for sustainable supplier selection/evaluation and published in the journals indexed in Web of Science between 2010 and 2020, have been reviewed. The reason for choosing 2010 as the start date is that the SWARA method used in this study was first introduced in this year. Table 1 shows main dimensions under sustainability used in these studies. This table has been prepared according to the dimensions on the basis of authors since there is no standard definition of the criteria that have been. Abbreviations used in the title of the table are defined as follows: 1-Economic, 2-Environmental, 3-Social, 4-Food safety, 5-Logistic, 6-Product quality, 7-Commercial, 8-Conventional, 9-Green, 10- Cost economic, 11-Non-cost economic, 12-Quality of relationship, 13- Global risks, 14-Risk, 15-Business.

This study will be one of the rare studies using SWARA and WASPAS methods together to evaluate the most appropriate sustainable supplier for a company.

METHODOLOGY

Supplier selection can be determined as a complex MCDM problem that needs to address both quantitative and qualitative criteria while evaluating alternatives. As it is mentioned in Introduction section, there are many approaches used in sustainable supplier selection. A two-steps approach is preferred in this study. Firstly, criteria weights are calculated with SWARA method and then supplier alternatives are ranked using WASPAS method. The methods used in this study are described below.

Step-Wise Weight Assesment Ratio (SWARA) Method

The SWARA method has been often used recently, was first introduced by Kersuliene et al. [2010]. The SWARA method allows decision makers to choose their own preferences, based on the current environmental and economic situations. In addition, the role of decision makers is even more important in this method [Zolfani et al. 2013]. This method which intitles to decision makers to exclude the criteria that they think is insignificant, allows for each individual DM to create their own rankings for the criteria and weight them [Zolfani et al. 2018]. For these reasons, determining the decision makers is a critical activity.

With ease of application of SWARA many decision makers, working in different areas can easily get into contact with each other [Zolfani et al. 2013, Jamal et al. 2015]. SWARA method's viewpoint is different from other MCDM models. The most distinct difference of the SWARA method when compared to AHP and ANP methods is that the decision makers decide on their own on the priority of each criterion. This method, which can be easily used in unusual and complex situations, should be based on needs and circumstances [Khodadadi et al. 2017]. The SWARA method requires less pair-wise comparisons than the AHP method. This simplicity also describes the SWARA method as a more attractive and an easier method [Urosevic et al. 2017]. Also, in the SWARA method, there is no scale that DMs required to use, so they can express their opinions more freely.

Another advantage of this method is that the prioritization of some problems is base on the policies of companies or countries and that there is no need for any evaluation in sorting criteria [Zolfani et al. 2013]. But this method does not provide any structure to check the consistency of the comparisons. The steps of SWARA method are as follows [Khodadadi et al. 2017]:

Step 1: All criteria are sorted by importance using decision makers' opinions.

Step 2: Starting from the second criterion, the relative importance levels for each criterion are determined. The comparative importance of the average values of j is obtained as a relative importance in compliance with $(j-1)$. criterion. It's indicated by s_j.

Step 3: k_j coefficient is determined.

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \quad (1)$$

Step 4: w_j is recalculated.

$$w_j = \begin{cases} 1 & j = 1 \\ \frac{x_{j-1}}{k_j} & j > 1 \end{cases} \quad (2)$$

Step 5: The criteria weights are obtained.

$$q_j = \frac{w_j}{\sum_{k=1}^{n} w_j} \quad (3)$$

q_j is the relative weight of the criterion j and n is the number of criteria.

Weighted Aggregated Sum Product Assessment (WASPAS) Method

WASPAS method based on the combination of Weighted Sum Model (WSM) and Weighted Product Model (WPM) was developed by Zavadskas et al. in 2012. It has been proven that this combined method is better in terms of accuracy than the accuracy of individual methods [Zolfani et al., 2013]. This method's first phase is constructing a decision matrix, $X = [x_{ij}]_{mxn}$ where x_{ij} is the evaluation value of the i^{th} alternative with respect to the j^{th} criterion, m is the number of alternatives and n is the number of evaluation criteria. The steps of WASPAS method are as follows [Khodadadi et al., 2017]:

Step 1: Normalization of the initial decision matrix.

$$\bar{x}_{ij} = \frac{x_{ij}}{opt_i x_{ij}} \quad \text{where } i = \overline{1,m}\,; j = \overline{1,n} \quad (4)$$

If opt value is max.

$$\bar{x}_{ij} = \frac{opt_i x_{ij}}{x_{ij}} \quad \text{where } i = \overline{1,m}\,; j = \overline{1,n} \quad (5)$$

If opt value is min.

Step 2: Calculation of WASPAS weighted and normalized decision matrix based on weighted sum method.

$$\bar{\bar{x}}_{ij,sum} = \bar{x}_{ij} q_j \quad \text{where } i = \overline{1,m}\,; j = \overline{1,n} \quad (6)$$

Step 3: Calculation of WASPAS weighted and normalized decision matrix based on weighted product method.

$$\bar{\bar{x}}_{ij,mult} = \bar{x}_{ij}{}^{q_j} \quad \text{where } i = \overline{1,m}\,; j = \overline{1,n} \quad (7)$$

Step 4: Calculation of evaluation and priorization of alternatives.

$$WPS_i = 0.5 \sum_{i=1}^{n} \bar{\bar{x}}_{ij} + 0{,}5 \prod_{i=1}^{n} \bar{\bar{x}}_{ij}$$

$$\text{where } i = \overline{1,m}\,; j = \overline{1,n} \quad (8)$$

This method has been widely applied and also extended by integrating with other MCDM methods in decision making problems. Through a comprehensive literature search in the Web of Science, SWARA and WASPAS methods were used together in some studies. But in the view of sustainability this study will be one of the rare studies using SWARA - WASPAS to rank the suppliers.

ILLUSTRATIVE EXAMPLE

Top management of a company operating in the electronics sector that wants to assimilate and sustain sustainability in the face of environmental and social awareness, legal pressures and the sensitiveness of both employees and managers, has been planned sustainability process intrinsically and has begun to transform its activities into sustainability gradually. However, top management has also pressured the stakeholders of the company to work with the same vision of sustainability. The company wants to continue with those that are sustainable and to evaluate the existing and potential suppliers operating both within the country and internationally and to isolate their ways with those who do not want to adopt sustainability. Under these circumstances, company first focused to determine the criteria affecting sustainable supplier selection.

When dealing with the problem of sustainable supplier selection, firstly a team consisting of decision makers working in the purchasing department and also academicians was organized. The most important goal of the comprehensive literature review is to be able to show as a whole the criteria under the dimensions of sustainability and to prevent the decision makers to have dilemma (Table 1).

After a thorough literature review and the results of many interviews, criteria affecting the selection of sustainable suppliers were identified and accepted by the decision-making team taking into account the sector, the company and suppliers. The model of the study was established (Figure 1). Briefly, decision makers have been included in three important phases of this study. The first stage is the phase of the establishing the model and determining the criteria. In the second phase, the evaluation of the criteria by SWARA method was also carried out by including decision makers. The final phase is evaluation of the alternatives by WASPAS method.

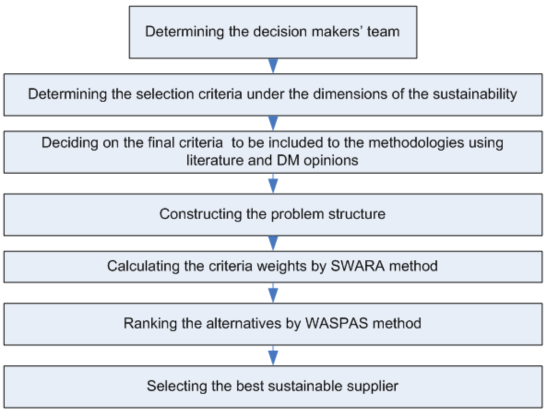

Fig. 1. Model of the study

Sustainable supplier selection can be defined as a supplier selection problem in which, among economic, environmental and social criteria are considered to evaluate a supplier's performance. One of the most important steps of a supplier selection problem is to specify the selection criteria and techniques. In the literature, many criteria are used in the selection of sustainable suppliers under the economic, environmental and social dimensions of sustainability. At this stage of the study, the criteria under these dimensions are summarized for evaluating sustainable suppliers.

The criteria used in this study are as follows:

Economic dimension: Traditionally in supplier selection, cost, price etc. are used under this dimension. In this paper criteria of cost (C_1), quality (C_2), inventory level reduction (C_3), on-time delivery (C_4) and productivity (C_5) criteria are preferred for economic dimension.

Environmental dimension: Companies which are aware of the environmental impact of production, pay special attention for evaluating the suppliers' environmental performance [Azadnia et al. 2015]. Criteria of green technology capabilities (C_6), reduction of the use of hazardous materials (C_7), eco-efficient transportation vehicles (C_8), green packaging and labeling (C_9), waste management and pollution prevention (C_{10}) and environment management system (C_{11}) are determined for environment dimension.

Social dimension: In last decades, companies realized the essentiality to add social responsibility issues to their supply chain activities because of increasing pressures. In this study, for social dimension, work safety and labor health (C_{12}), the right of stakeholders (C_{13}), local communities influence (C_{14}), community development (C_{15}) and rights of employee (C_{16}) are preferred.

Table 2. Criteria ranks and criteria weights

	DM_1	**DM_2**	**DM_3**	**DM_4**	**DM_5**	**q_j**
C_1	1	2	3	1	1	0,168
C_2	3	1	1	3	2	0,156
C_3	4	3	2	2	4	0,129
C_4	2	5	6	4	3	0,110
C_5	7	4	5	6	5	0,086
C_6	11	7	4	5	6	0,066
C_7	8	8	7	7	7	0,057
C_8	9	10	8	8	8	0,046
C_9	10	11	9	9	9	0,040
C_{10}	5	15	10	11	13	0,037
C_{11}	6	12	11	10	12	0,039
C_{12}	15	6	12	12	11	0,032
C_{13}	16	16	16	16	16	0,019
C_{14}	14	14	15	14	14	0,023
C_{15}	13	13	14	13	15	0,025
C_{16}	12	9	13	15	10	0,028

In order to determine the importance levels of all criteria, the decision makers ranked each criterion individually, from the most importantly to the least significant from 1 (the most important) to 16 (the least important). The ranking results are shown in Table 2.

The most striking feature in Table 2 is that economic criteria for all decision makers are overriding. Also weights of criteria (q_j) is illustrated in Table 2 using the Equations (1) - (3).

According to the results obtained by DMs, the criterion with the highest importance is the cost criterion under the economic dimension. The result is not surprising when we look at the first three criteria according to the order of importance. All of these criteria are under the economic dimension. As well as criteria under the environmental dimension appear to have medium importance, rights of employee under social dimension are the least important criterion. All criteria under social dimension are at the bottom of this sorting.

After the weights of the criteria were calculated by SWARA method, the alternatives were evaluated using the WASPAS method. Therefore, the decision-making group ranked the suppliers on the basis of the purchasing costs and amount of usage and they selected four alternatives, two of them are domestic, in the WASPAS method. DMs assessed these four alternatives using the criteria according to their know-how in relation to their suppliers, knowledge and experience. Thus, the decision matrix was obtained. The decision matrix has been normalized by taking into account the cost and benefit criteria (Table 3). In this study, C_1 and C_3 are cost criteria.

Table 3. Normalized Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0,67	0,71	0,80	1,00	0,83	1,00	0,67	0,60
A_2	0,80	0,57	0,80	1,00	0,83	0,86	1,00	1,00
A_3	0,80	0,43	1,00	0,67	0,67	0,86	1,00	1,00
A_4	1,00	1,00	1,00	0,83	1,00	0,57	0,33	0,80
Criteria weight	**0,1681**	**0,1564**	**0,1289**	**0,1102**	**0,0858**	**0,0663**	**0,0569**	**0,0458**
	C_9	**C_{10}**	**C_{11}**	**C_{12}**	**C_{13}**	**C_{14}**	**C_{15}**	**C_{16}**
A_1	0,86	0,60	0,83	1,00	0,57	0,83	0,60	0,86
A_2	1,00	1,00	0,83	0,83	0,86	0,67	1,00	1,00
A_3	0,71	1,00	0,67	0,83	0,57	0,83	1,00	0,71
A_4	0,57	0,80	1,00	0,50	1,00	1,00	0,80	0,57
Criteria weight	**0,0339**	**0,0393**	**0,0369**	**0,0323**	**0,0280**	**0,0251**	**0,0230**	**0,0188**

Table 4. Alternatives Evaluation with Different λ Values

	λ=0	λ=0,1	λ=0,2	λ=0,3	λ=0,4	λ=0,5	λ=0,6	λ=0,7	λ=0,8	λ=0,9	λ= 1
A_1	0,809	0,806	0,803	0,801	0,798	0,795	0,793	0,790	0,787	0,785	0,782
A_2	0,848	0,845	0,843	0,840	0,838	0,835	0,833	0,830	0,828	0,825	0,822
A_3	0,723	0,721	0,719	0,718	0,716	0,714	0,712	0,711	0,709	0,707	0,706
A_4	0,815	0,814	0,813	0,811	0,810	0,809	0,808	0,807	0,805	0,804	0,803

The total relative importance of the alternatives is calculated with both WSM and WPM methods using Equation (6) and (7). The criteria weights used at this stage of the study are the weights obtained from the SWARA method in the previous stage. The final relative importance for each alternative is calculated by Equation (8). Different λ values are used in evaluating alternatives (Table 4).

When Table 4 is analyzed, it is seen that the order of the alternatives does not depend on the λ value. In the order of sustainable suppliers, the first place has been the A_2 supplier, whose business is internationally engaged and whose sustainability awareness is high. The second place has been A_4 and the last has been A_3 alternative.

In the study, the supplier rank obtained depending on the criterion weights determined by the evaluations performed subjectively and therefore the decision-making consistency was examined by sensitivity analysis. Although the order of sustainable supplier alternatives may change depending on different decision makers, A_2 has been chosen as the best alternative.

CONCLUSIONS

Global warming, climate change, decreasing non-renewable energy sources and other issues about the environment have a serious impact on companies just like every individual has on. All these problems highlight the concept of sustainability. Nowadays companies feel compelled to consider and realize sustainability in terms of environmental, social and economic aspects. As a consequence, the importance of considering the sustainability in the supply chains has increased. Designing and implementing a sustainable supply chain which is an important parameter of sustainability, is an important issue for companies in competitive markets [Mavi et al. 2017].

Due to the increase in awareness on sustainability and the resulting regulations, the issue of sustainability in supply chains and sustainable supplier selection has become an important issue for companies. As it is known, supplier selection is one of the most important problems of supply chain management. The selection of traditional suppliers is based on criteria more like price, quality, service and so on. Nowadays, it has been seen that companies, stakeholders and governments have changed the way in which they view sustainability and adopted the vision of sustainability, not merely to use economic criteria and to evaluate the alternatives [Ghadimi and Heavey 2014]. This study proposes a sustainable and systematic approach to the sustainable supplier selection using the two-stage SWARA-WASPAS approach.

As the importance of sustainability in economic, environmental and social dimensions in the national and international markets becomes indispensable for competition, companies have to make all their business processes "sustainable" in order to adapt their own processes to this awareness, to meet the expectations of their customers and to fulfill legal obligations. Therefore, companies now have to act with the motto of sustainability throughout the entire value chain. Based on these facts, in this study, it is aimed to determine the indispensable criteria for a company in the electronics sector to provide "sustainable" conditions among the suppliers, to select the most suitable one among them based on these criteria and to rank the suppliers.

In this study, a set of appropriate sustainable criteria has been derived a rigorous literature search and in the light of expert opinions and a new model has been proposed for sustainable supplier selection for a company in the electronics sector. The main contribution of this paper is to select the most appropriate sustainable supplier among alternatives using both qualitative and quantitative criteria using SWARA and WASPAS methods under sustainability dimensions. Among the criteria under sustainability dimensions, cost criteria under economic dimension receives the top ranking. The result is not surprising as many companies consider economic factors even more important in terms of sustainability. When we list the criteria in order of importance, the criteria under the economic dimension in the first place and the social dimension in the last place can be evaluated as a result of not perceiving the importance of sustainability in the desired level and not paying attention. When the alternative ranking and the selection of the most appropriate calculated by WASPAS method is considered, it is determined that A_2 alternative is the supplier closest to the sustainability concept of the company. This alternative confirms the preferences of decision makers as it is a company that operates internationally and has a reputation and awareness in sustainability within its own country. As a result of the sustainable supplier evaluation with the WASPAS method, the ranking of four suppliers was obtained as $A_2 > A_4 > A_1 > A_3$. Sensitivity analysis was also performed.

As in all academic research, this research has also some limitations as well which create new study areas for further researches. 16 criteria have been determined for sustainable supplier selection, and when other criteria are added to the study or the selected ones are removed, the ranking may be changed. As is known, the results may vary according to the selected criteria. In this paper the most important criteria were selected based on the decision makers opinions, another study can be establishing a new model with other criteria and can evaluate alternatives disparately. The study findings are referred to a single company in a single sector so it isn't right to generalize the findings. Fuzziness was not considered in this study. In future studies, the method can be re-evaluated in a fuzzy environment. In addition, other MCDM methods can be applied in the study. Moreover, this model could be further investigated in other industries and researchers should pay more attention to supplier selection for different industries. In addition, increasing both the number of criteria and the number of decision makers will yield practical results. Also, order allocation of suppliers can be examined in future studies. It is thought that this study will contribute not only to the decision makers but also to the academicians who carry out sustainable supplier selection.

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REFERENCES

Abdel-Baset M., Chang V., Gamal A., Smarandache F., 2019. An integrated neutrosophic ANP and VIKOR method for achieving sustainable supplier selection: A case study in importing field. Computers in Industry, 106, 94-110. http://doi.org/10.1016/j.compind.2018.12.017

Ahmadi H.B., Petrudi S.H.H., Wang X, 2017, Integrating sustainability into supplier selection with analytical hierarchy process and improved grey relational analysis: A case of telecom industry. International Journal of Advanced Manufacturing Technology, 90, 2413-2427. http://doi.org/10.1007/s00170-016-9518-z

Alrasheedi M., Mardani A., Mishra A.R., Rani P., Loganathan N., 2021, An extended.

framework to evaluate sustainable suppliers in manufacturing companies using a new pythagorean fuzzy entropy-SWARA-WASPAS decision-making approach. Journal of Enterprise Information Management, http://doi.org/10.1108/JEIM-07-2020-0263

Amindoust A., Ahmed S., Saghafinia A., Bahreininejad A., 2012. Sustainable supplier selection: A ranking model based on fuzzy inference system. Applied Soft Computing, 12, 1668-1677. http://doi.org/10.1016/j.asoc.2012.01.023

Amindoust A., Saghafinia A., 2017. Textile supplier selection in sustainable supply chain using a modular fuzzy inference system model. TEXT Institute, 108, 1250-1258. http://doi.org/10.1080/00405000.2016.1238130

Awasthi A., Govindan K., Gold S., 2018. Multi-tier sustainable global supplier using a fuzzy AHP-VIKOR based approach. International Journal of Production Economics, 195, 106-117. http://doi.org/10.1016/j.ijpe.2017.10.013

Azadi M., Saen R.F., 2012. Developing a worst practice DEA model for selecting suppliers in the presence of imprecise data and dual-role factor. International Journal of Applied Decision Sciences, 5, 272-291. http://doi.org/10.1504/IJADS.2012.047671

Azadnia A.H., Saman M.Z.M., Wong K.Y., Ghadimi P., Zakuan N., 2012. Sustainable supplier selection based on self-organizing map neural network and multi criteria decision making approaches. Procedia - Social and Behavioral Sciences, 65, 879-884. http://doi.org/10.1016/j.sbspro.2012.11.214

Azadnia A.H., Saman M.Z.M., Wong K.Y., 2015, Sustainable supplier selection and order lot-sizing: an integrated multi-objective decision-making process. International Journal of Production Research, 53, 383-403.

http://doi.org/10.1080/00207543.2014.935827

Bai C., Kusi-Sarpong S., Ahmadi H.B., Sarkis J., 2019, Social sustainable supplier evaluation and selection: a group decision-support approach. International Journal of Production Research, 57, 7046-7067. http://doi.org/10.1080/00207543.2019.1574042

Büyüközkan G., Çifçi G., 2011, A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information. Computers in Industry, 62, 164-174. http://doi.org/10.1016/j.compind.2010.10.009

Carter C., Rogers D., 2008, A framework of sustainable supply chain management: moving toward new theory. International Journal of Physical Distribution & Logistics Management, 38, 360-387.

http://doi.org/10.1108/09600030810882816

Carter C.R., Easton P.L., 2011, Sustainable supply chain management: Evolution and future directions. International Journal of Physical Distribution & Logistics Management, 41, 46-62. http://doi.org/10.1108/09600031111101420

Cheraghalipour A., Farsad S., 2018. A bi-objective sustainable supplier selection and order allocation considering quantity discounts under disruption risks: A case study in plastic industry. Computers in Industry, 118, 237-250. http://doi.org/10.1016/j.cie.2018.02.041

Ghadimi P., Heavey C., 2014, Sustainable supplier selection in medical device industry: toward sustainable manufacturing. Procedia CIRP Conference on Life Cycle Engineering, 15, 165-170. http://doi.org/10.1016/j.procir.2014.06.096

Ghadimi P., Dargi A., Heavey C., 2017. Sustainable supplier performance scoring using audition check-list based fuzzy inference system: A case application in automotive spare part industry. Computers in Industry, 105, 12-27. http://doi.org/10.1016/j.cie.2017.01.002

Girubha J., Vinodh S., Kek V., 2016. Application of interpretative structural modelling integrated multi criteria decision making methods for sustainable supplier selection. Journal of Modelling in Management, 11, 358-388. http://doi.org/10.1108/JM2-02-2014-0012

Goren H.G., 2018, A decision framework for sustainable supplier selection and order allocation with lost sales. Journal of Cleaner Production, 183, 1156-1169. http://doi.org/10.1016/j.jclepro.2018.02.211

Govindan K., Khodaverdi R., Jafarian A., 2013. A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. Journal of Cleaner Production, 47, 345-354. http://doi.org/10.1016/j.jclepro.2012.04.014

Hashim M., Nazam M., Yao L., Baig S.A., Abrar M., Ziar-ur-Rehman M., 2017, Application of multi-objective optimization based on genetic algorithm for sustainable strategic supplier selection under fuzzy environment. Journal of Industrial Engineering and Management, 10, 188-212.

Hollos D., Blome C., Foerstl K., 2011. Does sustainable supplier co-operation affect performance? Examining implications for the triple bottom line. International Journal of Production Research, 50, 2968-2986. http://doi.org/10.1080/00207543.2011.582184

Jamali G., Farrokhnejad K.H., Mohammadi M., 2015. Decision making on analyzing advanced manufacturing systems dimensions: SWARA and COPRAS_G integration (case study: automotive industry). Buletin Teknologi Tanaman, 12, 266-274.

Kannan D., 2018. Role of multiple stakeholders and the critical success factor theory for the sustainable supplier selection process. International Journal of Production Economics, 195, 391-418. http://doi.org/10.1016/j.ijpe.2017.02.020

Kersuliene V., Zavadskas E.K., Turksis Z., 2010. Selection of rational dispute resolution method by applying new stepwise weight assessment ratio analysis (Swara). Journal of Business Economics and Management, 11, 243-258. http://doi.org/10.3846/jbem.2010.12

Liu A., Xiao Y., Lu H., Tsai S.B., Song W., 2019. A fuzzy three-stage multi-attribute decision-making approach based on custo-mer needs for sustainable supplier sele-ction. Journal of Cleaner Production, 239, 1-16. http://doi.org/10.1016/j.jclepro.2019.118043

Lu H., Jiang S., Song W., Ming X., 2018. A rough multi-criteria decision-making approach for sustainable supplier selection under vague environment. Sustainability, 10, 1-20.

Luthra S., Govindan K., Kannan D., Mangla S.K., Garg C.P., 2017. An integrated framework for sustainable supplier selection and evaluation in supply chains. Journal of Cleaner Production, 140, 1686-1698. http://doi.org/10.1016/j.jclepro.2016.09.078

Matici B., Jovanovic S., Das D.K., Zavadskas E.K., Stevic Z., Sremac S., Marinkovic M., 2019. A new hybrid MCDM model: sustainable supplier selection in a construction company. Symmetry, 11, 1-24.

Mavi R.K., Goh M., Zarbakhshnia N., 2017. Sustainable third-party reverse logistic provider selection with fuzzy SWARA and fuzzy MOORA in plastic industry. International Journal of Advanced Manufacturing Technology, 91, 2401-2418. http://doi.org/10.1007/s00170-016-9880-x

Mehregan M.R., Hashemi S.H., Karimi A., Merikhi B, 2014, Analysis of interactions among sustainability supplier selection criteria using ISM and fuzzy DEMATEL. International Journal of Applied Decision Sciences, 7, 270-294. http://doi.org/10.1504/IJADS.2014.063226

Memari A., Dargi A., Jokar M.R.A. Ahmad, R., Rahim A.R.A., 2019. Sustainable supplier selection: A multi-criteria intuitionistic fuzzy TOPSIS method, Journal of Manufacturing Systems, 50, 9-24. http://doi.org/10.1016/j.jmsy.2018.11.002

Mohammed A., Setchi R., Filip M., Harris I., Li X., 2018. An integrated methodology for a sustainable two-stage supplier selection and order allocation problem. Journal of Cleaner Production, 192, 99-114. http://doi.org/10.1016/j.jclepro.2018.04.131

Mohammed A., Harris I., Govindan K., 2019. A hybrid MCDM-FMOO approach for sustainable supplier selection and order allocation. International Journal of Production Economics, 217, 171-184. http://doi.org/10.1016/j.ijpe.2019.02.003

Phochanikorn P., Tan C., 2019. A new extension to a multi-criteria decision-making model for sustainable supplier selection under an intuitionistic fuzzy environment. Sustainability, 2019, 11, 1-24.

Pishchulov G., Trautrims A., Chesney T., Gold S., Schwab L., 2019. The voting analytic hierarchy process revisited: A revised method with application to sustainable supplier selection. International Journal of Production Economics, 211, 166-179. http://doi.org/10.1016/j.ijpe.2019.01.025

Rabieh M., Rafsanjani A.F., Babaei L., Esmaeili M., 2019. Sustainable supplier selection and order allocation: An integrated delphi method, fuzzy TOPSIS and multi-objective programming model. Scientia Iranica, 26, 2524-2540.

Segura M., Maroto C., Segura B., 2019. Quantifying the sustainability of products and suppliers in food distribution companies. Sustainability, 11, 1-18.

Stevic Z., Durmic E., Gajic M., Pamucar D., Puska A., 2019. A novel multi-criteria decision-making model: Interval rough SAW method for sustainable supplier selection. Information, 10, 1-21. http://doi.org/10.3390/info10100292

Stevic Z., Pamucar D., Puska A., Chatterjee P., 2020. Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to compromise solution (MARCOS). Computers in Industry, 140, 1-15. http://doi.org/10.1016/j.cie.2019.106231

Tavana M., Yazdani M., Di Caprio D., 2017. An application of an integrated ANP-QFD framework for sustainable supplier selection. International Journal of Logistics-

Research and Applications, 20, 254-275. http://doi.org/10.1080/13675567.2016.1219702

Tirkolaee E.B., Mardani A., Dashtian Z., Soltani M., Weber G.H., 2020. A novel hybrid method using fuzzy decision making and multi-objective programming for sustainable-reliable supplier selection in two-echolon supply chain design. Journal of Cleaner Production, 250, 1-20. http://doi.org/10.1016/j.jclepro.2019.119517

Zolfani S.H., Zavadskas E., Turksis Z., 2013. Design of products with both international and local perspectives based on yin-yang balance theory and SWARA method. Ekonomska Istrazivanja-Economic Research, 26, 153-166. http://doi.org/10.1080/1331677X.2013.11517613

Zolfani S.H., Pourhossein M., Yazdani M., Zavadskas E.K., 2018. Evaluating construction projects of hotels based on environmental sustainability with MCDM framework. Alexandria Engineering Journal, 57, 57-365. http://doi.org/10.1016/j.aej.2016.11.002

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ORIGINAL PAPER

COOPERATIVE INNOVATION STRATEGIES – REVIEW AND ANALYSIS

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ABSTRACT. **Background:** As the terms innovation, innovation strategy and especially cooperative innovation strategy are owned and discussed by many business disciplines, they can have various definitions. But a defined innovation strategy is the first step to enable a generation of innovation in a constant way. There are different approaches how a strategy can be defined. One common approach of an innovation strategy which includes the idea of an exploratory and cooperative strategy is the Open Innovation method. It describes three possible cooperation archetypes of an organization and its environment. Caused by the increased importance of startups and their innovation approaches a transfer of the common Open Innovation approach to a cooperation between established organization and startups is the aim of this article and results in the description of the startup orientated cooperative innovation (SOCI) strategy.

Methods: This article gives at first an introduction in the topic of innovation and innovation strategy and its different approaches. The Open Innovation approach is described and in a further step the transfer to the new framework of (SOCI) strategies is presented.

Result: As a result, the paper presents a new framework for three archetypes of SOCI-strategies. Three archetypes of SOCI-strategies were identified, by relating the three archetypes of Open Innovation to cooperations between established companies and startups. The three SOCI-strategies are: Buy/rent a startup, spin-off and startup in coupled process.

Conclusion: The SOCI framework can be seen as a helpful to categorized cooperations between established companies and startups in context of generation innovation and gives an overview which archetypes of startup cooperations are possible.

Key words: innovation, strategy, defining innovation, cooperative innovation, open innovation, startup.

INTRODUCTION

One possible strategy for the generation of innovation is the cooperative innovation strategy. Its general approach is to open the internal corporate structures, state of knowledge and ideas of an organization to its environment. Through this opening, exchange and the transport of internal and external knowledge, the overall innovation potential and the creation of innovative products, services and organizational structures can be generated more easily [Jia, 2019]. The cooperation of established organizations and younger and smaller companies, startups, is a common way in which the idea of a cooperative innovation strategy can be implemented successfully [He & Tian, 2018].

This paper utilizes a review of literature on innovation and innovation strategies, especially cooperative innovation strategies to achieve a clear definition for all three terms. Therefore, a number of academic journal articles and books, in total 54 sources have been analyzed and reviewed in the light of cooperative innovation strategy and Open Innovation from which 28 sources were selected by the authors of this article.

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In a second step the most common implementation of a cooperative innovation strategy, the Open Innovation approach of H. W. Chesbrough is described and displayed by presenting the framework of the three archetypes of Open Innovation as defined in the research of Enkel, Gassmann and Chesbrough (2004). In a final step three startup based innovation strategies were identified and brought into relation to the framework of the three archetypes of Open Innovation. The result is the presenting of a new framework of startup oriented cooperative innovation strategy, the SOCI-strategy.

The terms innovation, innovation strategy, cooperative innovation strategy and Open Innovation are now defined in the next sections.

DEFINITION: INNOVATION

The term innovation is of Latin origin and means renovation or change. In general innovation stands for the three-step process of an idea, invention and diffusion [Fadiah et.al., 2016]. Therefore, in a business context innovation can be conceptualized as an incidence (idea) for a product (invention) which has not been there before and which results in a high market acceptance (diffusion) [Dörr & Müller-Prothmann, 2014]. The meanings of the term innovation are of high complexity and therefore result in a large number of existing definitions. According to Haddad and Williams (2019) common and general characteristics of the term innovation exist and are defined as an implementation of change that introduces improvements [Haddad & Williams, 2019]. Gault (2018) specifies the word implementation stating that innovation is an implementation of a new or significantly improved product. A product can be a good or a service [Gault, 2018]. In summary the mentioned aspects and characteristics of the term innovation leads to the following definition applied in the context of this article: An innovation is an idea which is developed to an invention which creates change in the form of new products/services or product/service improvements, accompanied by high market diffusion.

DEFINITION: INNOVATION STRATEGY

According to Mintzberg (1987) a strategy is defined as a plan which has some sort of consciously intended course of action and can be regarded as a guideline to deal with a situation [Mintzberg, 1987]. If a company choses to generate innovation, strategically, it needs a plan according to the given corporate strategy [Ramus et. Al., 2018]. Innovation strategy is therefore defined as a set of actions fostering all procedures in an organization, including strategic goals and guidelines which have the goal to generate innovations [Goffin & Herstatt & Mitchell, 2012, Wolf et al., 2021]. According to Jia [2017] there are two main types of innovation strategies called exploratory and exploitative innovation strategy [Jia, 2017]. Both approaches are described in more detail as follows.

EXPLOITATIVE INNOVATION STARTEGY

The exploitative innovation strategy focuses on short-term successes by evolutionary or incremental improvements of existing technologies. Thus, the results are more proximate and predictable. Exploitative innovation activities are therefore making use of existing approaches, capabilities and available knowledge. In addition, exploitative innovations are more likely to look familiar to the stakeholders of an organization, lowering pushback and speeding up the adaption of the innovation thus lowering their cost of implementation [Jia, 2017]. Exploitative strategies therefore focus on incremental changes and short-term returns [Berraies, 2019].

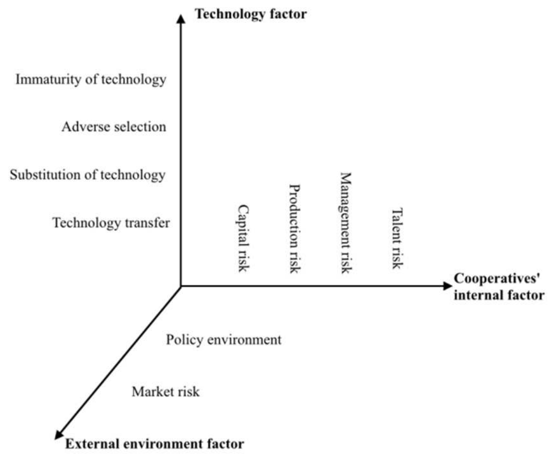
EXPLORATORY INNOVATION STRATEGY

On the contrary the exploratory innovation strategy focuses on long-term success, by revolutionary or disruptive innovations. Along with this strategy comes an opportunity for potentially higher returns and at the same time an increased risk of failure [Jia, 2017].

According to Charue-Duboc et. Al. [2010] exploratory innovation has the intention to discover something that was unknown before as well as to create something new [Charue-Duboc et. Al., 2010]. These so-called breakthrough innovations are usually generated through time-consuming research and development processes. Caused by the experimenting nature of exploratory innovation strategies, this strategy could impose higher risk of failure and potentially a knowledge and information gap between the organization and its stakeholders [Jia, 2017]. For the success of an organization both innovation strategies, exploitative and exploratory, are of high importance, but resource-constrained organizations may not be able to implement both strategies at the same time. Often an organization has to decide for a singular strategic approach. If a company decides to implement an exploratory innovation strategy this is often realized through cooperation with the external environment of an organization. This results in a utilization of the exploratory strategic approach through the use of a cooperative innovation strategy [Jia, 2019].

COOPERATIVE INNOVATION STARTEGY

The general approach of cooperative innovation strategy is to open the organization to its environment in order to include external ideas, inspiration and expertise for its own innovation process. One motivation of this strategy is to overcome limitations in resources and or a lack of know-how within the organizations [Sarpong & Teirlinck, 2017]. According to Li, Liao and Albitar [2020] there is a correlation between the application of a cooperative innovation strategy and the long-term success and value of an organization, resulting in a clear competitive advantage. Furthermore, this innovation strategy can pursuer technological innovation and profit [Zhoua, Yangb, Wangc, 2020]. The cooperative approach puts the organization in the position to discover market developments or customer needs early in the process and therefore develop more custom-fit products. As a result, an organization gains a competitive advantage in the market [Li, Liao, Albitar, 2020]. Beside the advantages of cooperative strategies there are some risks which a cooperative behavior also includes. Luo and Hu [2015] define three main risk paradigms: Cooperatives' internal factor, Technology factor and External environment factor. Each of the three risk paradigms have several underlying risks which are display in the following figure.



Source: Luo & Hu [2015]

Fig. 1. Main risk paradigms of cooperative innovation strategy

The first paradigm, Cooperatives' internal factor, describes the risk factor arising from innovation project's activities within the cooperatives. Cooperatives' internal factor of risk includes capital risk, production risk, management risk and talents risk. Furthermore, technology innovation is difficult and advanced with high technical barriers. Therefore, cooperatives will take more risks and uncertainty when participating in technology innovation. Technology factor of risk originates from the risk of technology immaturity, adverse selection, technology substitution and technology transform. In addition to this, External environment factors could have a negative influence on cooperative innovation caused by unpredictable changes in markets or political developments [Luo & Hu, 2015].

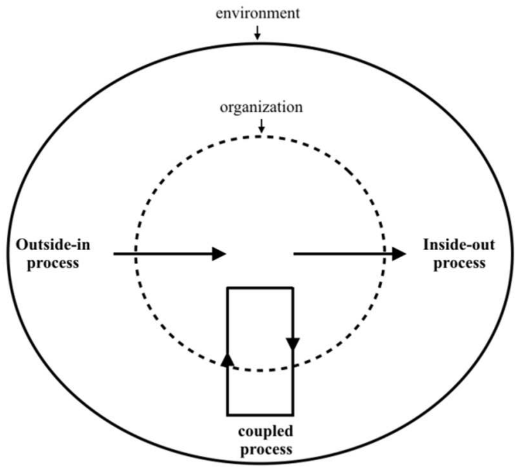
In spite of the potential risks of cooperative innovation strategy, He and Tian [2018] state that cooperative innovation becomes more important and has attracted great attention from academic researchers in recent years [He & Tian, 2018]. Cooperative innovation strategies are seen to be executed in many different types, for example research joint ventures, non-equity contractual collaborations, joint projects and formal or informal arrangements and cooperation with startups [Antonioli & Marzucchi & Savona, 2016]. One popular approach is the so-called Open Innovation approach described first by H. W. Chesbrough Enkel & Gassmann & Chesbrough [2009].

OPEN INNOVATION

The Open Innovation concept provides insights into how firms can harness inflows and outflows of knowledge to improve their innovation success [Enkel & Gassmann & Chesbrough, 2009]. On this basis, Gassmann and Enkel [2004] have defined three archetypes of Open Innovation. The three archetypes of Open Innovation differentiate in their process and the way of the information streams inside or outside the organization.

- The outside-in process describes that a company opens its innovation processes to external inputs and contributions [Bogers & Chesbrough & Moedas, 2018]. The organization gets its knowledge through the integration of customer, suppliers and its general external environment [Gassman, Enkel, 2004].
- The inside-out process requires organizations to allow unused and underutilized ideas to go outside the organization for others to use in their businesses and business models [Bogers & Chesbrough & Moedas, 2018].
- The coupled process combines the characteristics of outside-in and inside-out processes. This is aimed through cooperations with complementary partners and the general environment [Gassman, Enkel, 2004].

The three archetypes are illustrated in the following figure 2.



Source: Gassman, O., Enkel, E. [2004]

Fig. 2. Three archetypes of Open Innovation

THE THREE ARCHETYPES OF THE SOCI FRAMEWORK

There is no existing universal definition of the term startup. In general, it can nevertheless be stated, startups are young organizations which create new products or services under market conditions of high uncertainty and which try to find a repeatable and scalable business model [Bortolini, Cortimiglia & Danilevicz, 2018]. A cooperation between an organization and external startups is nothing unusual. 262 companies out of the 500 world's biggest public companies cooperate with startups. The way this coworking is happening is of high diversity [Bonzom & Netessine, 2017]. However, it has not been tried to thoroughly analyze and classify those cooperation types, yet. Through the relating of the three archetypes of Open Innovation to a cooperation between an organization and a startup as the external input, three possible way of cooperation are possible: Buy / rent a startup, spin-off, startup in a coupled process as a mixed method. How the mentioned possible cooperations can now be integrated in the three archetypes of Open Innovation is described in the next sections.

BUY/RENT A STARTUP AS AN OUTSIDE-IN PROCESS

Most organizations have realized that the innovation potential of startups per definition is much higher than the internal innovation potential. Thus, organizations are trying to boost their own innovation potential acquisition of a startup. For startups this is one of the so-called exit strategies where the owners of the small company sell their shares to an established organization (European Union/European Regional Development Fund, 2017). One emasculate way for this cooperation for established organization is not to buy but to rent a startup for a defined period of time. The worldwide increase of the acquisition of startups (1.217 [2011] to 4.217 [2017]) shows the relevance of the method of the outside-in process of an Open Innovation approach through a cooperation with a startup [Crunchbase, 2017; Wolf et al., 2020].].

SPIN-OFF AS AN INSIDE-OUT PROCESS

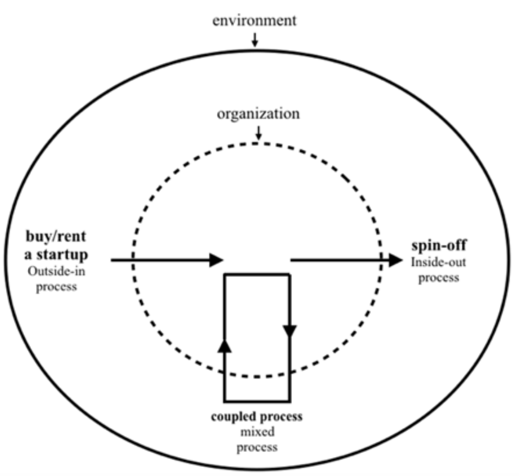
According to Davenport, Carr and Bibby [2002] a spin-off is when a company is formed through the transfer of technology from an R&D company (inside-out), which is independent of the parent company and involves the transfer of human and technological capital to a new formed market entity [Davenport, Carr & Bibby, 2002]. The innovation potential of for example the R&D unit of an established organization is used to found a new company which continues the innovation process as an quasi-autonomous entity. The smaller, more flexible and more agile structure of the new founded company aims to contribute to the innovation potential of the parent company. For example, the strategy of spin-off is often used, when an innovation has great future potential but doesn't fit in the general approach of the parent company [Wolf et al., 2020].

STARTUP IN A COUPLED PROCESS

A clearly definable type of a coupled process through a cooperation with a startup is not existing in the reviewed literature. There is no academically defined coupled process approach of a cooperation between a startup and an established company. Nevertheless, it is theoretically imaginable that such a startup-orientated cooperative innovation strategy approach, which includes the general characteristics of the third archetype of Open Innovation, can be consistently identified. Therefore, it remains as a hypothetical part of the framework [Wolf et al., 2020].

THE THREE ARCHETYPES OF THE SOCI FRAMEWORK

The mentioned three approaches of startup orientated cooperative innovation (SOCI) strategies can be related to the framework of the three archetypes of Open Innovation. Out of this a new framework, the SOCI-framework results in which all three possible cooperation approaches between an established organization and a startup are considered. The following figure now illustrates the three archetypes of SOCI-framework in analogy to the Open Innovation framework as the final result of this paper [Wolf et al., 2020].



Source: Wolf et al [2020]

Fig. 3. Startups based cooperative innovation strategy framework

Figure 3 demonstrates the integration of the three described approaches of cooperative innovation with startups in the three archetypes of Open Innovation: Buy/rent a startup as an outside-in process, spin-off as an inside-out process and startup in coupled process. The last process cannot be defined in one specific approach.

In general, a new framework results which intension it is to make clear which possible cooperations between organizations and startups are possible. In addition to this, the new framework helps to categorize the different cooperation approach with startup in the Open Innovation context. Caused by the orientation of the new framework on the popular Open Innovation approach, the characteristics of cooperations with startups can be understood more easily.

CONCLUSION AND DISCUSSION

This paper introduces the definitions for the key term innovation, innovation strategy, cooperative innovation strategy and Open Innovation through the means of a literature review. In a second step, the three archetypes outside-in, inside-out and a couple process of Open Innovation are described in more detail. In this step the article describes that the general approach of Open Innovation is that organizations cooperate and interact with their external environment. One possible way of interacting with the external environment is defined as the cooperation between established organization and startups.

In a third step, three possible approaches of startup based cooperative innovation strategy which include the characteristics of the three archetypes of Open Innovation are introduced and described: Buy/rent a startup, spin-off and startup in a coupled process (undefined). Through this description it is possible to identify a gap of knowledge for the third approach. Finally, the three approaches of startup based cooperative innovation strategy are integrated into the framework of the three archetypes of Open Innovation. Through this a new framework of startup orientated cooperative innovation strategies is achieved and presented as the final result, the SOCI-framework. Based on the identification of the knowledge gap it appears reasonable to recommend further and more specified research in the area of a coupled process between established companies and startups. It thus appears reasonable to recommend more empirical studies which describe and analyze cooperative innovation strategies in general.

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REFERENCES

Antonioli D., Marzucchi A., Savona M., 2016. Pain shared, pain halved? Cooperation as a coping strategy for innovation barriers. Springerlink 42, 841-864. http://doi.org/10.1007/s10961- 016-9545-9

Berraies S., 2019. The effect of enterprise social networks use on exploitative and exploratory innovations. Journal of Intellectual Capital, 20 (3). http://doi.org/10.1108/JIC-02-2019-0030

Bogers M, Chesbrough H., Moedas C., 2018. Open Innovation: Research, Practices, and Policies. California Management Review 60 (2), 5-16. http://doi.org/10.1177/0008125617745086

Bonzom A., Netessine S. ,2017, How do the World's Biggest Companies Deal with the Startup Revoluton. INSEAD.

Charue-Duboc F., Aggeri F., Chanal V., Garel G., 2010. Managing exploratory innovation. Sciences de l'Homme et de la Société.

Davenport S., Carr A., Bibby D., 2002. Leveraging talent: spin-off strategy at Industrial Research. R&D Management 32 (3). http://doi.org/10.1111/1467-9310.00257

Dörr N., Müller-Prothmann T, 2014. Innovationsmanagement: Strategien, Methoden und Werkzeuge für systematische Innovationsprozesse. (Innovation Management: Strategies, methods and tolls for systematical innovation processes), München: Hanser.

Enkel E., Gassmann O., Chesbrough H., 2009. Open R&D and open innovation: exploring the phenomenon. R&D Management 39 (4), 311-316. http://doi.org/10.1111/j.1467-9310.2009.00570.x

European Union/European Regional Development Fund, 2017. Startup Manual. Springboard.

Fadiah N. Wahab S.A., Al Mamun A., Yaacob A.S., Samy N.K., Fazal S. A., 2016. Defining the Concept of Innovation and Firm Innovativeness: A Critical Analysis from Resorce-Based View Perspective. International Journal of Business and Management 11 (6), 87-94. http://doi.org/10.5539/ijbm.v11n6p87.

Fazzi Bortolini, R., Nogueira Cortimiglia, M.,de Moura Ferreira Danilevicz, A., 2018. Lean Startup: a comprehensive historical review. Management Decision. http://doi.org/10.1108/MD-07-2017-0663

Gassmann O., Enkel E., 2004. Towards a Theory of Open Innovation: Three Core Process Archetypes, in: Proceedings of the R&D Management Conference (RADMA). Sesimbra, Portugal July 8-9, 2004.

Gault F., 2018. Defining and measuring innovation in all sectors of the economy. Research Policy 47(3), 617-622. http://doi.org/10.1016/j.respol.2018.01.007

Goffin K., Herstatt C., Mitchell R., 2012. Innovationsmanagement: Strategien und effektive Umsetzung von Innovationsprozessen mit dem Pentathlon-Prinzip (Innovation management: Strategies and efficient implementation of innovation processes through Pentathlon principle), München: Finanzbuchverlag.

He J., Tian X., 2018. Finance and Corporate Innovation: A Survey. Asia-Pacific Journal of Financial Studies 47 (2), 165–212. http://doi.org/10.1111/ajfs.12208

Jia N., 2017. Corporate Innovation Strategy, Analyst Forecasting Activities and the Economic Consequences. Journal of Business Finance & Accounting 44 (5-6). http://doi.org/10.1111/jbfa.12242

Jia N., 2019. The impact of accounting restatements on corporate innovation strategy. Journal of Accounting and Public Policy 38 (3), 219-237. http://doi.org/10.1016/j.jaccpubpol.2019.05.004

Li Z., Liao G., Albitar K., 2020. Does corporate environmental responsibility engagement affect firm value? The mediating role of corporate innovation. Business Strategy and the Environment 29 (3). http://doi.org/10.1002/bse.2416

Luo J., Hu Z., 2015. Risk paradigm and risk evaluation of farmers cooperatives' technology innovation. Economic Modelling 44, 80-85. http://doi.org/10.1016/j.econmod.2014.10.024

Mind the Bridge, Crunchbase, 2017. STARTUP M&As 2017 REPORT. Paper presented at the EIT Digital, Silicon Valley.

Mintzberg H., 1987. The Strategy Concept 1: 5 Ps for Strategy. California Management Review 30 (1), 11-24. http://doi.org/10.2307/41165263

Haddad M., Williams A., Dwyer R. J., 2019. Strategies for implementing innovation in small and medium-sized enterprises. World Journal of Entrepreneurship, Management and Sustainable Development 16(1), 12-29. http://doi.org/10.1108/WJEMSD-05-2019-0032

Sarpong O. Teirlinck P, 2017. The influence of functional and geographical diversity in collaboration on product innovation performance in SMEs. Springer Science+Business Media 43, 1667-1695. http://doi.org/10.1007/s10961-017-9582-z

Ramus T., La Cara B., Vaccaro A., Brusoni S., 2018. Social or Commercial? Innovation.

Strategies in Social Enterprises at Times of Turbulence. Business Ethics Quarterly 28 (4), 463-492. http://doi.org/10.1017/beq.2017.55

Wolf, V. Dobrucka R., Przekop R., Haubold S., 2020. The PANDA approach as a method for creating female STEMpreneurs. 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), Sakheer, Bahrain, 1-5. http://doi.org/10.1109/3ICT51146.2020.9312001

Wolf V., Dobrucka R., Przekop R., Haubold St., 2021. Innovation strategies in the context of the paradigm of the five dimensions of innovation strategy, LogForum, 2, 2021, http://doi.org/10.17270/J.LOG.2021.587

Zhoua X., Yangb S., Wangc G., 2020. Impacts of knowledge spillovers and cartelization on cooperative innovation decisions with uncertain technology efficiency. Computers & Industrial Engineering 143. http://doi.org/10.1016/j.cie.2020.106395

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ORIGINAL PAPER

THE POWER OF ADKAR CHANGE MODEL IN INNOVATIVE TECHNOLOGY ACCEPTANCE UNDER THE MODERATING EFFECT OF CULTURE AND OPEN INNOVATION

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ABSTRACT. **Background:** Continuous change is a vital factor for organization's sustainable growth and success. The implementation of modern information technology in business has become a core need of the hour. This study endeavours to answer how to cope with resistance to change when implementing new technology in the banking sector. A theoretical model has been developed with the blend of ADKAR change model, Technology Acceptance Model (TAM), and Hofstede dimensions of national culture to investigate the impact of the ADKAR change model on Technology Acceptance under the moderation of two national culture's dimensions.

Materials and Methods: In order to collect data, 500 self-administered questionnaires were dropped personally in five major banks of five cities of Pakistan using the convenience-based employee intercept sampling technique. The validated response rate was 68% by having 340 fit questionnaires for analysis using covariance-based structure equation modelling with the help of SmartPLS.

Results: The results uncover the significant existence of covariance between dimensions of the ADKAR change model and technology acceptance model. The findings are statistically significant, inferring the influential role of change management on technology adoption.

Conclusion: The study results provide promising implications based on these conclusions and findings for both theoretical aspects of these different models and practitioners.

Key words: ADKAR Change Model; Reinforcement, Uncertainty Avoidance; Perceived Ease of Use; Inbound and Outbound Open Innovation; Perceived Usefulness.

INTRODUCTION

Technology has become the primary element for organization's success. Innovative technology acceptance by end-user is designated as one of the best success factors in project excellent performance outcomes, in case of resistance in adopting technology leads to failure of project success [Pinto, Mantel, 1990]. KPMG asserted in a survey of European 134 companies that the IT project's cost of failures was from the range of $ 14 Million up to $240 Million. There had been faced an extreme level of unwillingness behavior of end-user with accepting Enterprise Resource Planning (ERP) software and many other software [Shehab, et al., 2004]. Similarly, Information Technology (IT) plays a tremendous role in resolving diversified business issues in every economic sector for the last two decades. The most crucial changes have occurred in the service sector due to the invention of information technology. With the inception of internet service, the financial services sector, especially the banking sector, brought a dramatic change in working; traditional banking was replaced with technological banking, including E-Banking, Automatic Teller Machine (ATM) and Phone

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Banking [Shima, Mohamadali, 2017]. Banking is only a sole sector that heavily takes information technology (IT) to obtain, process, and delivers it to its relevant technology user. Financial institutions have discovered that they must have to be innovative and updated their processes and system of working to save and retain their customers [Boonsiritomachai, Pitchayadejanant, 2017].

Online banking is now becoming an emerging concept promising vast benefits of online banking. Furthermore, the set-up cost of a new-fangled branch of any designated bank is roughly 3.7 up to 5 million in USA dollars, but on the other hand, online banking set up cost ranges from 1.8 $ up to 2.1 million USA dollar [Gkoutzinis, 2006]. Thus, online banking is considerably economical than any other traditional way of banking for bank's customers. Hence, the success point of online banking entirely depends on the adoption and usage behavior of end-users. Illinois National Bank (INB) of Springfield, USA, reported a 340% increase in staff productivity after implementing new technology. Only informational technology (IT) can be significant for a country, entity, and end-users if novel technology is accepted and used daily. In developed countries, innovative technology acceptance is considered an attractive area for research [Hu, 1999].

According to Fortune, 1,100 companies have exposed an elevated failure rate towards adopting and implementing new technology in business. The survey conducted by Fortune various executives represented that only major and core cause of IT failure is only resistance from the side of employees [Fomin, 2018]. Resistance to technology adoption is an emerging problem in every sector of the economy all over the world. The most significant issue is resistance to change from the side of employees when implementing the latest information technology in business. Organizational strategic goals remain unachieved without transitioning employees towards a new way of working from traditional working. National culture dimensions are also a big problem to mold employees' behavior.

In this regard, many models were proposed to envisage the use of a system, the Technology Acceptance/Adoption Model (TAM) is considered a helpful tool to put in plain words and see coming the reception of information technology by end-users [Chuttur, 2009]. Professor Fred Davis proposed the Technology Acceptance Model (TAM) renowned, high-ranking and thrifty model among many other models to measure the innovative technology acceptance level in users [Davis, 1989]. According to Davis, the use of a system is entirely predicted by user's motivation, which can be directly enhanced or influenced by an external stimulus. Historically, it was found that technology adoption is considered the hot research topic on the ground of information systems (IS) at the individual stage. Until now, TAM is over and over again installed in systems to gauge technology adoption level among individuals; it was inferred from over 100 studies on TAM from high-rank Information System (IS) journals from the past 20 years [Lee et al., 2003; Mugo, et al., 2017]. A case study on E-Banking concludes a highly positive influence of E-banking on satisfaction and loyalty of customers. The simplest use of technology will make service much more reliable, error and risk-free for both bank's employees as well as customers [Siyal, et al., 2019; Ferraris et al., 2019].

Open innovation is an essential component of business models [Bogers, et al., 2018]. Bogers et al. (2018) stated the first proposal, i.e., "Open Innovation" break the boundaries of the organization, have access to innovation processes; inside and outside enterprises that execute outside organization. Both businesses and organizations manage expertise and technological skills within the growth, and these innovations are more fundamental than incremental [Lauer, 2010]. Many processes are still under study regarding open innovation management.

There is a lack of room for insecurities, and there is the misuse of external resources for innovative ideas [Brettel, et al., 2015]. The outcomes of open inbound innovation to the organization for improvements and developments are the latest ideas and related employee expertise Chang, Gong, and Peng (2012). A firm's capacity to improve new technology and ideas in terms of using information techniques efficiently and leveraging those.

On the other hand, change management used as a vast field in organizations for the past five decades [Diefenbach, 2007]. There are many models, theories, and concepts used by managers to cope with resistance to change from the side of employees. Organizational change management means how things and behavior of people are changed from its status quo (current) into the expected situation by passing it out from the transformational phase [Diefenbach, 2007]. This kind of change management deals with the analysis, bring into the structure and plan in change phases proposed by the early findings of Kurt Lewin research in the ground of organizational changes [Burnes, 2004]. Primarily, there are two core reasons for resistance to change: lack of motivation and lack of ability. Many employees are not informed about change concerning its aims and benefits. This problem can also be solved through transparent and clear communication. Organizations do not change, but people change themselves. Employee resistance is a major hindrance in the organizational change process. ADKAR is an acronym of five letters building blocks (ADKAR) for successful change [Hiatt, 2006].

At present, more than 3500 organizations have adopted and using the ADKAR change model to manage the people side of change successfully. The previous studies reflect that a new user should choose the ADKAR model for managing change elements because each phase of the ADKAR change model is clearly explained. The first and foremost rule, one should never forget that no change will bring and success unless individuals are willing to adopt change; no concern whatever, change model is being used [Calder, 2013]. The success of a change project depends entirely on the desire of an individual to accept, support, and implement the desired change in the organization effectively [Ruele, 2015].

In past studies, the high degree of uncertainty avoidance (UA) and collectivistic culture are more probably may lessen and discourage technology adoption behaviors [Lai et al., 2016; Alhirz, Sajeev, 2015]. Whereas, power distance (PD) positively encourages and moderates the technology adoption behavior [Baptista, Oliveira, 2015]. The discussion concludes that there has been amplification in usage due to the inception of IT, but many challenges have to be faced across the cultures of different countries. In progress, the work intends to pack up space by investigating the effect of the ADKAR change model on technology adoption under the moderation effect of culture in the banking sector. Given that, this study has been designed to examine how change management helps reduce resistance levels in employees when implementing informational technology in the banking sector.

LITERATURE REVIEW

Technology Acceptance Model (TAM)

A number of theoretically based models have been developed and used to study the behavior of the user in the direction of acceptance and the practice behavior of up-and-coming information technologies, including Rogers' diffusion theory, the Theory of Reasoned Action (TRA), and the Theory of Planned Behaviour (TPB) [Ruele, 2015; Gu, et al., 2019; Rafiqu, et al., 2020]. From this research stream, the Technology Acceptance Model (TAM) has emerged as a powerful and parsimonious model representing the antecedents of technology usage through beliefs related to the Perceived usefulness and Perceived ease of use of technology [Al-Rahmi, et al., 2019]. Previous research has also shown that the TAM explains a higher level of variance in systems use than the TRA, TPB and the Decomposed TPB. Therefore, the TAM will be used in this study to understand employee adoption of the banking industry [Rahman, et al., 2017; Kashada, et al., 2020].

TAM has been gone under the process of testing, and various researchers have adopted it in IS as well as in IT. It was broadened to evaluate the "acceptance" and "voluntary use" of mobile phone camera technology in Kuwait.

In his study, Davis (1986) proposed that consumers' inspiration could be elaborated via three major factors: Perceived Ease of Use, Perceived Usefulness, and Attitude in the direction of using the system. He conjectured that the usage tendency is a crucial determining factor in whether the consumer will consume or refute the system [Rafique, et al., 2020]. ATU is affected by two main presuppositions: Perceived Usefulness and Perceived Ease of Use, with Perceived Ease of Use imposing direct impact on Perceived Usefulness. So, mutually the presuppositions were speculated to be affected straight by the system-designed features.

Table 1. Literature review Sum-up of TAM

Year	Author(s)	Technology Examined	Sample	Findings
2011	Abbasi et al	Internet usage	504 academics	Perceived usefulness was founded as the most important and significant assemble in Internet acceptance.
2010	Autry et al.	Supply Chain and Technology	195 End users	The current study concluded in technologically chaotic environments and interaction between the firms' supply chain, perceived usefulness and ease of use intentions towards technology usage in the supply chain are proved stronger.
2008	Venkatesh & Bala	Various office IT systems	150 Employees	Overall concluded results are supported in order to the extended model. TAM3
2007	Chen et al.	Electronic tolls and tax collection	255 individual motorists	Perceived usefulness by end-user was found to encompass inconsequential weight on the user intention electronic toll and tax collection acceptance
2006	Yi et al.	PDA	222 physicians	Perceived usefulness by end users was found to have the most noteworthy element of physician's willingness to admit a technology.
2005	Wixom & Todd	Warehouse predefined reporting and Software.	456 employees from	Consequences concluded the relevance of information and user satisfaction as exterior variables towards traditional TAM.
2004	Ong et al.	E-learning system	140 engineers working in 6 companies	Computer self-efficacy was proven to positively result in both constructs' perceived usefulness and perceived ease of use by end-users.
2004	Vijayasara-thy	Online shopping	281 residents USA	Security, usefulness compatibility and ease of use, have been proven significant effecting constructs on the attitude of users towards online shopping usage
2004a	Shih	E-shopping	212 employees of SMEs	The findings of the study confirmed the theoretical postulation of the TAM
2003	Gefen et al.	Online commerce	business students	Trust, perceived usefulness, and perceived ease of use were significant determinants of online shopping intention
2001	Moon & Kim	World Wide Web	152 graduate students	Perceived usefulness and perceived playfulness are considered significant effects on intention to use.
2000	Venkatesh	Online help system Multimedia system	70 employees 212 employee	Anchor elements were used to form perceived ease of use about a new system and with increased experience, adjustments play an important role in determining system-specific PEOU.
1999	Agrawal & Prasad	Software applications	230 Technology Educated Staff	Authentication of the relationship of individual dissimilarities and technology adoption intervened by the TAM and center beliefs.
1995	Igbaria et al.	Usage of Minicomputer	236 Masters Students	Deep-rooted the consequence of exterior variables on usage and verified previous associations among TAM beliefs and constructs.
1992	Adams et al.	Voice and email Software's applications	192 Staff member of different organization	Confirmed validity and reliability of two main beliefs of perceived usefulness and perceived ease of use measurement. It also found a major role of perceived usefulness on system usage.
1989	Davis	Email and file editor, Plus, graphic systems	114 employees, 40 Master students	Six item scales with lofty reliability for the two constructs perceived usefulness and perceived ease of use.
1989	Davis et al.	Word Processor	107 Master students	Behavioral intentions towards technology adoption of consumers were found the chief component of technology usage behavior. Feelings and attitudes have no intervening effect between perceived usefulness and perceived ease of use towards technology behavioral intention.
2011	Kuanchin Chen et al.	Self-Efficacy and usage of smartphone	Service Company with sample size 376 in Taiwan.	The findings of this study portray in Taiwan that there is a major role of self–efficacy and technology usage.
2012	Judith Schoonen boom	Technological Learning system	One hundred and eight instructors of university	First, affected by task significance, an option is prepared to either carry out a definite task or not. Second, after the verdict has been ready to carry out the task, and affected by the usefulness and ease

Year	Author(s)	Technology Examined	Sample	Findings
				of use of the learning management system in school, an option is made between amateur dramatics the task using the LMS and using substitute means.
2012	Sun Joo Yoo et al.	Motivation and e-learning	261 employees in foodservice company in South Korea	The findings revealed that intrinsic motivators (effort expectancy, attitudes, and anxiety) affected employees' intention to use e-learning in the workplace more strongly than extrinsic motivators (performance expectancy, social influence, and facilitating conditions).
2013	Dr. Ibrahim Issa Abu-Nahleh	Information Technology and Leadership	Case Study at Al-Hikma Company" Size: 50	Leadership is a crucial element in organizational success and failure. IT helps bring organizational change. Therefore, dynamic leadership is an important part of most organizations for organizational competitive advantage and continued existence.
2014	Hsien-Cheng Lin	Culture, information technology and Knowledge Management System	146 physicians from the United States and 460 from Taiwan	The findings provide that disparities in culture might influence the perceptions of a physician of the united states and Taiwan about the system of knowledge management in adoption in the healthcare institutions of twin countries.
2014	Escobar-Rodríguez a, Carvajal-Trujillo	UTAUT Model and Electronic ticking	One thousand ninety-six customers of LCC flights	The study results show that significant buying factors behavior is trust, customer's habit, cost-saving behaviour, technology ease of use, the performance of e-ticking, and pleasant motivation and societal factors.
2015	Maria Tsourela, Manos Roumeliot-is	Technology readiness index (TRI) and TAM	Three Hundred Banking Employees	There are three mediators found with the four beliefs and intention of an employee towards using technology in a real-time scenario for developers and managers of the bank.
2016	Mohamed Abou-Shouk et al.	E-commerce	A sample size of four hundred fifty one travel agents of renowned entities of Egypt.	The results of the study show the noteworthy influence of environmental pressures lead to perceived advantages and constraints in e-commerce acceptance. Whereas the strategies of small and medium enterprises travel, agents are moving their business towards e-commerce in order to capture the global travel market share.
2016	Indrajit Sinha, Sujit Mukherjee	E-banking after working hours	From 428 bank employees in India	The following factors were found significantly influential in electronic banking acceptance by the end-users, as mentioned below. User trust in technology and financial institution User perception of ease and usefulness about technology with less complexity.
2017	Huayi Chen, Tieju Ma	heterogeneous agents and Technology Acceptance	Two hundred and fifty Sale Officers of china	When there are similar features in attitudes and foresight of commercial agents, an extreme level of resistance is faced by the entity due to people's common belief. Whereas, When there is a different and heterogeneous nature of features in attitudes and foresight of commercial agents, there are high chances of technology acceptance by end-users/ commercial agents.
2017	Rui Li, Te-Lin Doreen Chung,	E-auctions in the economy China	210 were current e-auctions' users	The findings of the study portray significant technology ingredients acceptance, like, social influence, technological playfulness, also recommended as the component to create an e-auctions environment in China business economy.

ADKAR Change Model

Organizations do not change, but people always change themselves. Employees' resistance is a first and foremost obstacle in the organizational change process. ADKAR is an acronym of five letters building slabs for successful change [Hiatt, 2006].

- Awareness about the necessitate of new changing
- Desire to shore up the changes
- Knowledge about how to bring change
- Ability to apply requisite talents and behavior
- Reinforcement to preserve the brought changes

ADKAR was initially discovered by Hiat in 2003, but after in-depth research carried out by Prosci on more than 700 companies that were gone through by major change project and ADKAR became a practical instrument of managing the people side of change. Prosci is the world's largest and leading change management consultancy center founded by

Hiat in 1994. It exclusively pays attention to the managing people side of change.

Uncertainty Avoidance

Uncertainty avoidance reveals the level to which the individual of a civilization believes is endangered by indistinctness and is rule-oriented based. According to the literature, fragile uncertainty avoidance cultures have some extent, better enthusiasm to receive risks connected with new processes and measures. This culture, for instance, might be supplementary willing to strive for new-fangled technology before it that has been demonstrated in erstwhile organizations [Shore, Venkatachalam, 1996]. Shore & Venkatachalam (1996) also said that while cultures are classified by strong uncertainty avoidance, the introduction of new technology will surely elevate the nervousness level of its mass for implements, top managers/bosses and end-users. There is always a vast, exciting demand for static regulations, more in written or unwritten form. Workers in well-built uncertainty avoidance cultures tend to reside amid their organizations for a very long time. In difference, those from weak and softness uncertainty avoidance cultures show more transportable towards Organizational changes, whereas, in strong and robust uncertainty avoidance cultures, employees are probably to entertain physically powerful resistance, which creates difficulty relocating to change the administer [Vörös, Choudrie, 2011].

Knowledge Transfer

This is obvious to technology transmit totally depends on knowledge transfer to execute new technology successfully. For several novel technologies, supplementary information ought to be transmitted to make use of not presently technological knowledge. Besides, community knowledge concerning who gets know what it is to smooth the progress of superior technology makes use of after it execution process. The information that perceived cultural distance persuades professional executive decisions to come into specific overseas markets consisted of the national cultures and cultural distance influencing the knowledge transfer process. This is because cultural characteristics have hampered the transfer and transit of technology due to substantial and insubstantial knowledge because of communication hurdles [Fletcher-Brown, et al., 2020].

Research conducted by Bhagat et al. (2002), at what time it is to receive and transfer knowledge, then individualists always looking for information in its relative contextual form, along with they emphasize the importance of information in printed form that are more to be expected to believe such information [Bhagat, et al., 2002]. Whereas persons in collectivist-based cultures are less expected except individualists to emphasize the importance of information in black and white and are supplementary expected than individualists to close the eyes to the same information? Individualistic cultures are additionally expected than collectivistic cultures to operationalize the risk.

Uncertainty avoidance states that individuals in the culture have a preference planned over shapeless and formless situations. In simple words, do persons think and feel endangered by confusing events, and have they formed attitudes, beliefs, and organizations that seek to keep away from these? According to Pauleen's (2007) research findings, these feelings are uttered from side to side anxious stress, avoidance or yet penalty of risk-based, and the necessitate for safekeeping, preventability, and in addition to in black and white plus unrecorded rules. Uncertainties avoiding based cultures are likely to encompass an additional institutionalized set of laws to transfer knowledge compared to uncertainty acceptance cultures because clear regulations are formed to preserve refuge and obviousness.

Inbound and Outbound Open Innovation

Inbound open innovation and outbound open innovation play a vital role in acquiring new knowledge and developments, specifically developing SI. The current studies define that open innovation has to pay ever-increasing attention to the research of strategic innovation. Chesbrough, 2006, described open innovation as purposive inflows and outflows of knowledge to accelerate internal innovation and expand markets for external use of innovation. The managing board of open innovation (inbound or outbound) increasingly significantly incorporates strategies, and many scholars are able to find the OI that is the best crucial component to the achievements of organization's SI [West, Bogers, 2017].

On the other hand, we have faced a shortage of research in active explicit inquiry that is straightly capable of recognizing the paradigm of open innovation. Instead of consuming factual and concreting kind of open innovation (open inbound innovation) in past researches, th¬¬¬¬¬e scholars also focused patent analysis was emerging latest classification of our individual outcomes [Petruzzelli, et al., 2015]. Similarly, limited research was tried to choose realistic and rivals associates by open innovation, deprived of concern about diverse open innovation.

In recent times, the most significant way to emphasize open inbound innovation and the vigorous deviations by anticipating ways of cooperation and relationship [Yun, et al., 2016]. Therefore, this study intends to active functions and roles, classifying the open innovation system's vibrant revolution and imposing different technological techniques in open innovation. This research emphasizes vibrant "metaphor" in lieu of the open innovation types, inbound open innovation and outbound open innovation. These analysis metaphors of inbound open innovation and outbound open innovation performing quantitative and inevitable perceived (system power and relationship [Lee, et al., 2016].

Conceptual Framework

Based on a concentrated literature review, the following conceptual framework developed for research.

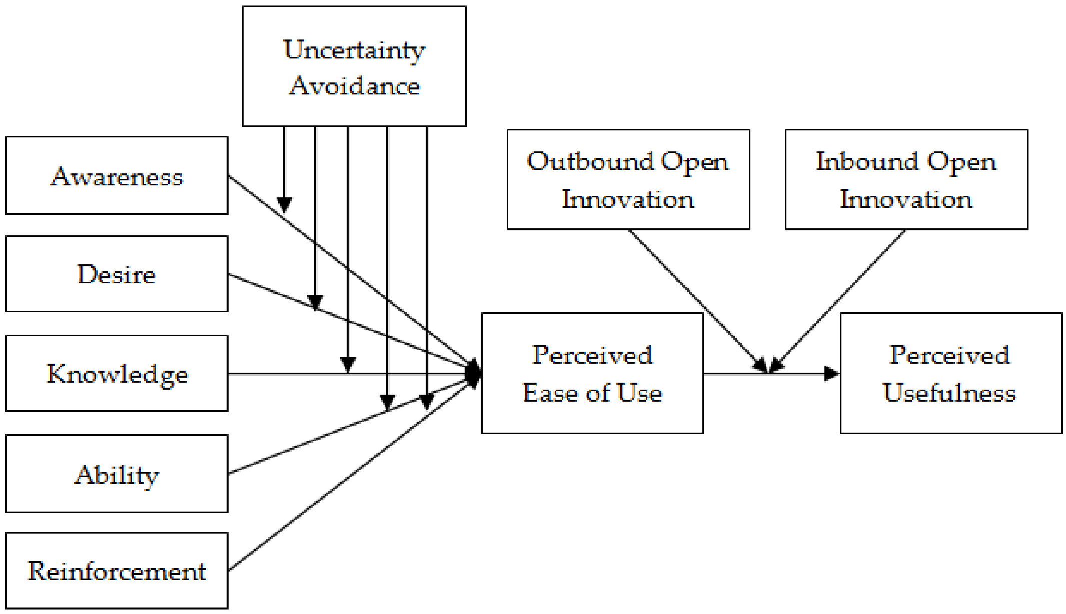

Fig. 1. Conceptual Framework

Research Hypothesis

H1: There is a significant relationship between Awareness and Perceived Ease of Use.

H2: There is a significant relationship between Desire and Perceived Ease of Use.

H3: There is a significant relationship between Knowledge and Perceived Ease of Use.

H4: There is a significant relationship between Ability and Perceived Ease of Use.

H5: There is a significant relationship between Reinforcement and Perceived Ease of Use.
H6: Perceived Ease of Use positively influence Perceived Usefulness.
H7: Perceived Ease of Use significantly mediates the relationship between Awareness and Perceived Usefulness.
H8: Perceived Ease of Use significantly mediates the relationship between Desire and Perceived Usefulness.
H9: Perceived Ease of Use significantly mediates the relationship between Knowledge and Perceived Usefulness.
H10: Perceived Ease of Use significantly mediates the relationship between Ability and Perceived Usefulness
H11: Perceived Ease of Use significantly mediates the relationship between Reinforcement and Perceived Usefulness.
H12: Uncertainty Avoidance significantly Moderates the relationship between Awareness and Perceived Ease of Use.
H13: Uncertainty Avoidance significantly Moderates the relationship between Desire and Perceived Ease of Use.
H14: Uncertainty Avoidance significantly Moderates the relationship between Knowledge and Perceived Ease of Use.
H15: Uncertainty Avoidance significantly Moderates the relationship between Ability and Perceived Ease of Use.
H16: Uncertainty Avoidance significantly Moderates the relationship between Reinforcement and Perceived Ease of Use.
H17: Outbound Open Innovation Moderates the relationship between Perceived Ease of Use and Perceived Usefulness.
H18: Inbound Open Innovation Moderates the relationship between Perceived Ease of Use and Perceived Usefulness.

RESEARCH METHODOLOGY

A research methodology and plan is known as a helpful pattern used by a researcher to define the research boundaries. According to Cooper and Schindler (2001), a research design is defined as an outline or plan to examine and answer the study questions, consisting of some critical elements: explaining study category, investigations of study, unit of analysis, and data collections techniques [Cooper, Schindler, 2001]. The present research is based on casual-oriented research that demonstrates the impact of the change management model, especially the ADKAR change model, on Technology Acceptance variables, whereas national culture dimensions are also considered in this respect. For this, the target population for the present quantitative cross-sectional research was employees of 05 chief market shareholding banks named ABL, HBL, MCB, NBP and UBL.

Talking about sampling, the convenience-based employee intercept sampling technique was used for data collection. A self-administered questionnaire using 5 points Liker scaling was used to collect data. In this study, the sample size (n) = 340 subjects comprised functional responses from everyone who participated in this study and representative of the population regarding generalizability. This sample size is used for statistical techniques in this type of research portrayed in a detailed topic underlying in the study. Five hundred self-administered questionnaires were dropped personally in 05 major banks of five cities of Punjab. The returned questionnaires were 400 out of which only 340 questionnaires at 68% response rate considered for final analysis using variance-based, on Structure Equation Modelling (SmartPLS-SEM) [Hult, et al., 2018].

STATISTICAL DATA ANALYSIS AND RESULTS

Descriptive Statistics

The very first part of the questionnaire and analysis is a descriptive segment. The entire 340 respondents who filled out the questionnaire were technology users in their banks' branches Table 2 provides the sum up a glimpse of descriptive statistics.

Table 2. Descriptive Statistic of Demographics Variable

Descriptive	Frequency	Valid Percentage	Descriptive	Frequency	Valid Percentage
Branch Visit			**Marital Status**		
ABL	12	21.80%	Single	215	63.20%
HBL	8	14.50%	Married	125	36.80%
MCB	13	23.60%	**Gender Category**		
NBP	7	12.70%	Masculine	197	57.80%
UBL	15	27.30%	Femininity	143	42.20%
Employees			**Highest Level of Education**		
ABL	73	21.50%	Bachelor	47	13.80%
HBL	55	16.20%	Master	270	79.40%
MCB	70	20.60%	M.Phil./Doctorate	23	6.80%
NBP	68	20.00%	**Managerial Experience**		
UBL	74	21.80%	Less than 2years	122	35.90%
Age			2-5 years	98	28.80%
Less than 30	152	44.70%	5-10 years	80	23.50%
30 to 50	145	42.60%	More than 10 years	40	11.80%
50 above	43	12.60%	**Total**	**340**	**100%**

A total of 340 respondents of banks' employees participate in completing this survey. While demographic variables like basic information about respondents were not added in the data analysis, their descriptive analysis is portrayed here. The results depict that 45 branches of five banks were considered for data collection from their employees. A majority of employees were in the range of fewer than 30 years (44.7%) regarding age factor, and male respondents were 196 (57.6%). Whereas according to education-wise, there were 270 (79.4%) master degree holders. Marital status-wise, a major portion of respondents was single 195 (57.4%). There was major participation towards questionnaire filling out of 122 (35.9%) respondents regarding managerial experience less than 2 years.

Instrument Content Validity

Content validity is also known as face validity that assesses the communication between the person items plus the concept in the course of ratings via specialist judges, along with pre-tests employing numerous sub-populations or any other means [Cooper, Schindler, 2001]. It was also used in this research. The present research has used both types of strategies to analyze content validity (face validity) by:

- To ask three specialists in information technology to offer their decisions at the questionnaire, particularly at the items in each set (idea), to determine whether individual items may make communication with the concept. A number of slight revisions were prepared to the questionnaire according to their recommendations.
- Further to this, the instrument has been twice pre-tested with a sub-population in addition to a cluster of PhD students plus with one pilot study was experienced and tested with a cluster of similar type subjects because of the population.

Reliability of Constructs

Reliability refers to the consistency of respondents' responses to all items of aquestionnaire [Thakkar, 2020; Larsson, 2015]. For evaluating the reliability of a variable or instrument, Cronbach alpha and composite reliability were considered to assess the internal consistency. The rule of thumb for reliability coefficient is suggested greater than 0.7 for both, which shows the goodness of a construct for testing the reliability and validity of the mentioned measures in the study. In other words, the term reliability of a measure/questionnaire points out the degree to which the measure taken is without bias and error-free. It helps review the goodness of measure and indicates accuracy in the measurement [Melchers, Beck, 2018].

Table 3. Reliability Results

Variables	Number of Items	Cronbach's Alpha	Composite Relaibility	Reliability Results
Awareness	4	0.770	0.854	Good
Desire	4	0.842	0.894	Good
Knowledge	4	0.840	0.892	Good
Ability	4	0.822	0.882	Good
Reinforcement	4	0.853	0.900	Good
Perceived Ease of Use	7	0.898	0.920	Good
Perceived Usefulness	6	0.749	0.833	Good
Uncertainty Avoidance	6	0.879	0.908	Acceptable
Outbound Open Innovation	4	0.872	0.940	Good
Inbound Open Innovation	5	0.886	0.915	Good

Table 3 presents the reliability coefficients for alpha and composite reliability values for the current study. According to Sekaran (2016), reliabilities < 0.6 are considered poor, acceptable in the 0.7 range, and those over 0.8 are good. The closer the reliability coefficient gets to 1.0, is regarded as the better. In others' point of view, the commonly decided upon lower edge for reliability is decided 0.70, however, this threshold value may decrease to 0.60 in exploratory nature research [Hult, et al., 2018]. The entire inner consistency reliabilities consist of reliability for the measurement items (for all interval scales) were > 0.70 and were ranked a good and acceptable threshold value. Approximately all types of reliability tests were fairly high (0.8 up), and it is indicated the items at each set (concept) were linked as positively correlated with one another. It is recommended that the questionnaire was considered a reliable measurement tool in the current study because the reliability of each construct (variables) is meet the threshold value and is regarded as a very good reliable instrument.

Factor Analysis

The factor analysis method is used to analyze the structure of the correlations within a great number. It considers multiple variables and summarizes (reduces) them by using a minor set of variables called components or factors [Melchers, Beck, 2018]. Consequently, at the initial stage, the researcher recognizes latent dimensions of the data arrangement and determines the level to which each factor elaborates understudy a test item (variable). The prime subsequently follows it uses factor analyses summarization and data reduction [Petruzzelli, et al., 2015].

Table 4. Factor Analysis Results

Variables	Items	Loading	AVE	Variables	Items	Loading	AVE	Variables	Items	Loading	AVE
Uncertainty Avoidance	UA1	0.801	0.623	Awareness	Aw1	0.659	0.597	Desire	De1	0.840	0.680
	UA2	0.821			Aw2	0.760			De2	0.850	
	UA3	0.850			Aw3	0.863			De3	0.846	
	UA4	0.783			Aw4	0.794			De4	0.759	
	UA5	0.750		Reinforcement	Re1	0.878	0.694	Perceived Usefulness	PU1	0.825	0.513
	UA6	0.723			Re2	0.789			PU2	0.803	
Perceived Ease of Use	PEu1	0.787	0.623		Re3	0.845			PU3	0.858	
	PEu2	0.621			Re4	0.817			PU4	0.608	
	PEu3	0.709		Inbound Open Innovation	IOI1	0.830	0.684		PU6	0.693	
	PEu4	0.847			IOI2	0.858		Ability	Ab1	0.743	0.653
	PEu5	0.831			IOI3	0.825			Ab2	0.778	
	PEu6	0.833			IOI4	0.776			Ab3	0.881	
	PEu7	0.869			IOI5	0.844			Ab4	0.823	
Outbound Open Innovation	OOI2	0.933	0.886					Knowledge	Kn1	0.819	0.675
	OOI3	0.950							Kn2	0.864	
									Kn3	0.821	
									Kn4	0.780	

Table 4 shows the value of each item with respect to its loading values and shows the average variance extracted for each variable. Item loading of each question supporting the factor analysis test meets the assumption of SEM in the prescribed acceptable range of normality and factor loading. Whereas AVE values are also higher than 0.5, showing support of convergent validity.

Discriminent Validity Fornell-Larcker Criteria

After discussing well reliability and convergent validity, next is to affirm discriminant validity, which is being tested through Fornell-Larcker correlational criteria, presented by Fornell and Larkcer in the 1970's. It basically discusses that each variable should have a maximum correlation value as compared to other variables.

Table 5. Fornell-Larcker Criteria

	Abl	Awr	Des	IOI	Kno	OOI	PEU	PUs	Ren	UAv
Abl	**0.808**									
Awr	0.690	**0.773**								
Des	0.578	0.653	**0.824**							
IOI	-0.182	-0.143	-0.165	**0.827**						
Kno	0.376	0.693	0.768	-0.200	**0.821**					
OOI	0.326	0.255	0.286	-0.480	0.364	**0.941**				
PEU	0.304	0.545	0.780	-0.195	0.385	0.364	**0.790**			
PUs	0.208	0.660	0.654	-0.207	0.668	0.343	0.416	**0.716**		
Ren	0.267	0.687	0.789	-0.176	0.279	0.321	0.435	0.602	**0.833**	
UAv	0.290	0.311	0.286	-0.143	0.248	0.219	0.315	0.307	0.269	**0.789**

Table 5 represents the Fornell-Larcker criteria results; as per recommendation, the upper diagonal values of the table show the value of each variable with its own, and below values show with other constructs. All the upper values are firstly having higher than 0.7. Secondly, it is also the maximum value with respect to other values in the table, which shows the significance of the discriminant validity of data.

Goodness-of-Fit Indices

Measurement of the goodness of fit typically summarizes the difference between observed values and the values expected underneath the model in the inquiry. Such type of measures can make use of it in statistical hypothesis testing. It involves CHI Square, GFI, NFI, CFI, and RMSEA tests for ensuring goodness [Sekaran, Bougie, 2016]. The chi-square test is widely used in the non-parametric statistical test that explains the size of discrepancy (divergence) between the observed as well as expected data that is to be obtained with a specific hypothesis.

Next, NFI is also known as the Bentler-Bonett normed fit index (NFI), the fit index varies from 0 to 1 range in which 1 is considered ideal. In simple words, an NFI with a value of 0.90 indicates the model of interest that improves the fit by 90% relative to the null (independence model). Next, the CFI compares the fitness of a target model with the fitness of an independent model. The value of CFI 0.95 or greater is considered a well-fitted model [Hadi, et al., 2016]. Lastly, the root means square errors of approximation (RMSEA) keep away from sample size issues by analyzing the difference between the hypothesized model and the population covariance matrix. It has a value ranging from 0 to 1, and the value of .06 or less indicates a good model fit.

Table 6. Goodness-of-Fit Indices of Measurement Model

Variables	CHI Square	GFI	NFI	CFI	RMSEA
Awareness	2.4	0.99	0.93	0.989	0.069
Desire	1.957	0.992	0.962	0.995	0.063
Ability	1.563	0.995	0.994	0.998	0.048
Knowledge	1.378	0.998	0.989	0.994	0.039
Reinforcement	2.3	.0.991	0.999	0.994	0.073
Perceived ease of use	0.195	0.901	0.998	0.999	0.024
Perceived usefulness	1.687	0.997	0.993	0.992	0.053
Uncertainty avoidance	1.67	0.92	0.912	0.95	0.057
Outbound Open Innovation	1.838	0.993	0.962	0.89	0.063
Inbound Open Innovation	1.78	0.909	0.972	0.9	0.043

According to the literature, four groups exist in the fitness of measure. The fit measures within each group give the same rank of ordering models [Hadi, et al., 2016]. The first group is RMSEA and TLI, the second group is CFI, the third group is CMIN and NFI, and the fourth group is GFI and AGFI. Among the many measures of fit, five popular measures are chi-square, normed chi-square (χ2 /df), the goodness of fit index (GFI), Tucker-Lewis Index (TLI), Root Mean-Square Error of Approximation (RMSEA). Table 5 shows the significant result of all the criteria's for the measurement model.

Measurement model and Correlation

Structural equation modeling (SEM) is a compilation of statistical models that finds details of relationships among multiple variables. It allows the researchers to inspect Interrelationships in many multiple dependent and independent variables at the same time. The reasons for choosing SEM for data analysis were that, initially, SEM could analyze underlying relationships between constructs with multiple measurement items [Mulaik, 1989]. Subsequently, it presents effective also precise statistical procedures to covenant with complex and composite models. The relationships amid many constructs as well as indicators (measurement items) are made validated through using confirmatory factor analysis (CFA), it is also recognized as the measurement model; furthermore, relationships that exist between constructs are tested by using the structural model [Marcoulides, Yuan, 2017]. The measurement models of all variables under study are obtained by the CFA procedure shown in figure 2.

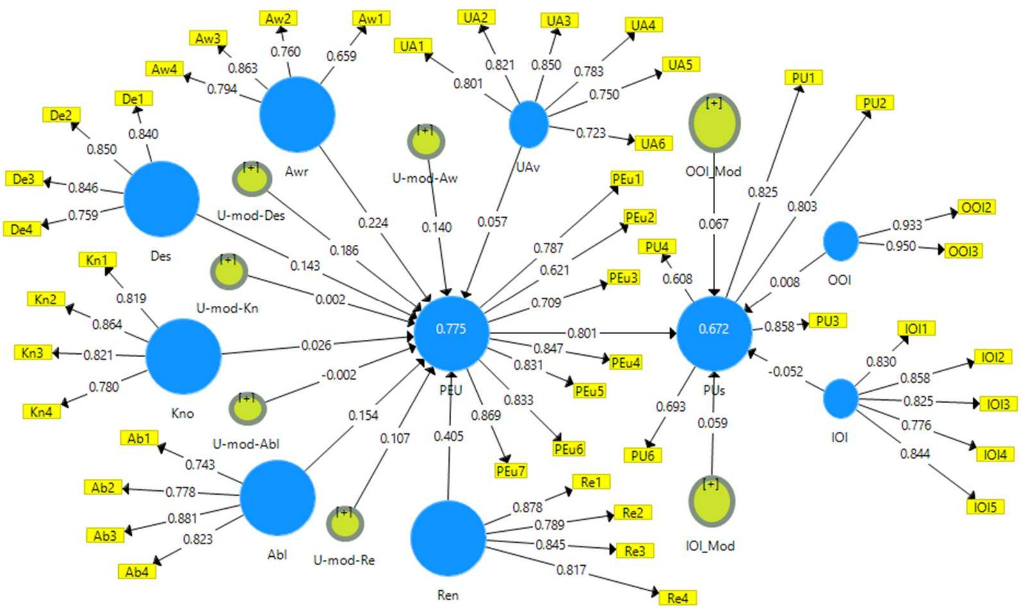

Fig. 2. Measurement model

In the structural equation model, the fit indices are established to analyze whether, on the whole, the proposed model is acceptable statistically or not. The proviso model has considered satisfactory. Then research scholars set up detailed paths for the model significant. Basically, it shows the two considerable models, i.e., inner model and outer model. The inner model shows the coefficient values for each relationship, whereas the outer model shows the significant factor loading values, which are higher than 0.6, recommended by Hair et al., 2015.

Direct and Mediation Hypotheses Testing

The first part of Table 7 portrays five direct hypotheses represented with causal paths that are used to make sure relationships amid latent constructs. Hence, showing results in the table for the shore up of all direct and mediation hypotheses, all hypotheses are shown in the feature mentioned in table 7 and Appendix A. The hidden constructs, which was used in the projected hypothetical model, were categorized into two major categories:

- Exogenous Constructs
- Endogenous Constructs

Exogenous constructs by name were Awareness (A), Desire (D), Knowledge (K), Ability (A) and Reinforcement (R), whereas endogenous constructs with the name were the Perceived Ease of Use (PEOU) in addition to Perceived Usefulness (PU). In this hypothetical link, the PEOU is playing the role of mediator between the ADKAR and PU. Lastly also moderation of (IOI) Inbound Open Innovation and (OOI) Outbound Open Innovation on the relationship of Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). Results show the significance and non-significance of each path as well.

Table 7. Hypotheses Testing

Hypotheses	Path	Effect	Result	
H$_1$	Aw > PEOU	0.224(**)	Accepted	**Direct Impact of ADKAR Model**
H$_2$	D > PEOU	0.143(**)	Accepted	
H$_3$	K > PEOU	0.026(N/S)	Rejected	
H$_4$	Ab > PEOU	0.154(**)	Accepted	
H$_5$	R > PEOU	0.405(***)	Accpeted	
H$_6$	PEOU > PU	0.801(**)	Accepted	
		Mediation		
Hypotheses	**Path**	**Effect**	**Result**	
H$_7$	Aw > PEOU > PU	0.179(**)	Accepted	**Mediation in ADKAR Model**
H$_8$	D > PEOU > PU	0.114(**)	Accepted	
H$_9$	K > PEOU > PU	0.021(N/S)	Rejected	
H$_{10}$	Ab > PEOU > PU	0.124(**)	Accepted	
H$_{11}$	R > PEOU > PU	0.324(**)	Accepted	
		Moderation		
Hypotheses	**Path**	**Effect**	**Result**	
H$_{12}$	UA Mod- Aw > PEOU	0.140(**)	Accepted	**Moderators**
H$_{13}$	UA Mod- D > PEOU	0.186(**)	Accepted	
H$_{14}$	UA Mod- K > PEOU	0.002(N/S)	Rejected	
H$_{15}$	UA Mod- Ab > PEOU	-0.002(N/S)	Rejected	
H$_{16}$	UA Mod- R > PEOU	0.107(**)	Accepted	
H$_{17}$	OOI Mod- PEOU > PU	0.067(**)	Accepted	
H$_{18}$	IOI Mod- PEOU > PU	0.059(**)	Accepted	

Source: own work

The next portion of Table 7 portrays five numbers of hypotheses represented with causal mediation paths (from H7 to H11) and also explained moderation paths (from H12 to H18). The results are based on the SEM technique, which tests significance through t-Statistics and P values; t value should be greater than 1.96, whereas P value should be less than 0.05. Acceptance of both of these values resulting in supporting the hypothesis. Like H1, the impact of awareness on PEOU shows a 22.4% significant impact on accepting the hypothesis. Next, in mediation, PEOU also mediates between Awareness and Perceived Usefulness by 17.9% under hypothesis H7, which is also significant. Lastly, moderation is explained as uncertainty avoidance moderates the relationship of Aw and PEOU by 14% significantly under hypothesis H12.

CONCLUSION AND DISCUSSION

Numerous other standardized technology adoption models (TAM2, TAM3, UTAUT, UTAUT2) can be linked with change management to gauge the behavior intention to use technology. Leadership and Human Resource Management Practices are also important for inspiring employees to opt and demonstrate a changed behavior. The results mentioned above for integrating the two different models, i.e., TAM and ADKAR model, provide empirical evidence. This hypothetical model was projected in this research and helped give details on the whole relationships amongst the predictor variables (ADKAR change model) plus the outcome variable (PEOU) and PU with the moderation of culture. ADKAR was bringing into being the most significant determinant in increasing PEOU and PU. PEOU mediates the PU partially, whereas Uncertainty Moderates the predictors and outcomes variables relationship negatively. Here, two other moderation of Inbound and Outbound open innovation are also found significant, showing that these innovations can enhance employee adaptability to technology.

Study results also provide promising implications based on these conclusions and findings for both theoretical aspects of these different models and practitioners. Firstly discussing the theoretical aspects, the study initially fulfills the literature gap because little researches had focused on two constructs that how these beliefs of usefulness and ease of use are produced, a current study examining the effects of external two variables on perceived usefulness (PU) and perceived ease of use (PEOU) in light of ADKAR model. Another aspect is that data of existing study based on empirical data was collected by using multi ways approach, for example via post/mail, or electronic mail, and face-to-face self-administered questionnaire method. In adding up, in this study, structural equation modeling (SEM) is run using the SmartPLS statistical package that was made in use to test the measurement and structural models, which provides empirical results regarding the integration of various theories.

Now talking about the implication for practitioners and diverse stakeholders, the unparalleled add to in the electronic-commerce in addition to paybacks. For example, communications-based firms, distribution, and online transactions are convincing various organizations and companies to build up systems that present users the right to use, anytime and anyplace, to carry out online transactions using internet-based technology. Understanding the underlying factors that influence the end users' acceptance of internet-based banking information systems helps the banks; consequently, they can prioritize their resources successfully. In addition, the ADKAR change model was found to put forth a considerable impact on the belief of technology that is perceived usefulness. This would assist in strengthening the users' trust in banks in addition to online banking channels. Additionally, banks could lend a hand to build users' faith by offering an undertaking to cover pecuniary losses faced by any illegal entrance. That could increase users' level of self-assurance on banks and online business conduits and boost the speed of acceptance of the online banking system.

Limitations for Future Researchers

The current study outcomes are precious because this research has concluded a wide variety of theoretical points of view and comprise a suitable large sample size that has covered banking staff within five major Banks located in five major cities of Pakistan. The research journey cannot be free from limitations; these always arise during the research procedure. Hence a good researcher should contribute something valuable addition to knowledge by keeping in mind research limitations. Non-probability-based sampling technique was also used, which was also a limitation because coverage of the suitability of data might reduce from this type of sampling technique. This study is only conducted in a specific area of baking, and due to time constrain, it only focuses on five banks, which is also a limitation of this study. The geographical area coverage is also a limitation due to which a large number of geographical areas could not cover. Some theoretical limitations also exist in the study; for example, the study just considered one moderation of uncertainty, while hurdles in technology adoption may also be included and some cultural and personality traits. So, authors should consider cultural and personality trait factors that might strengthen the relationship between ADKAR and TAM model for future research.

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REFERENCES

Alhirz H., Sajeev A.S.M., 2015. Do cultural dimensions differentiate ERP acceptance? A study in the context of Saudi Arabia. Information Technology & People, 28(1), 163-194. http://doi.org/10.1108/ITP-07-2013-0127

Al-Rahmi W.M., Yahaya N., Aldraiweesh A.A., Alamri M.M., Aljarboa N.A., Alturki U., Aljeraiwi A.A., 2019. Integrating technology acceptance model with innovation diffusion theory: An empirical investigation on students' intention to use E-learning systems. IEEE Access, 7, 26797-26809. http://doi.org/10.1109/ACCESS.2019.2899368

Baptista G., Oliveira T., 2015. Understanding mobile banking: The unified theory of acceptance and use of technology combined with cultural moderators. Computers in Human Behavior, 50, 418-430. http://doi.org/10.1016/j.chb.2015.04.024

Bhagat R.S., Kedia B.L., Harveston P.D., Triandis H.C., 2002. Cultural variations in the cross-border transfer of organizational knowledge: An integrative framework. Academy of management review, 27(2), 204-221. http://doi.org/10.5465/amr.2002.6588000

Bogers M., Chesbrough H., Moedas C., 2018. Open innovation: research, practices, and policies. California Management Review, 60(2), 5-16. http://doi.org/10.1177/0008125617745086

Boonsiritomachai W., Pitchayadejanant K., 2017. Determinants affecting mobile banking adoption by generation Y based on the Unified Theory of Acceptance and Use of Technology Model modified by the Technology Acceptance Model concept. Kasetsart Journal of Social Sciences. Reterived From: https://www.sciencedirect.com

Brettel M., Chomik C., Flatten T.C., 2015. How organizational culture influences innovativeness, proactiveness, and risk-taking: Fostering entrepreneurial orientation in SMEs. Journal of small business management, 53(4), 868-885. https://www.tandfonline.com/doi/pdf/10.1111/jsbm.12108?needAccess=true

Burnes B., 2004. Kurt Lewin and complexity theories: back to the future?. Journal of change management, 4(4), 309-325. http://doi.org/10.1080/1469701042000303811

Calder A.M., 2013. Organizational change: Models for successfully implementing change. Undergraduate Honors Theses. Paper 144.

Chuttur M.Y., 2009. Overview of the technology acceptance model: Origins, developments and future directions. Working Papers on Information Systems, 9(37), 9-37. http://adam.co/lab/pdf/test/pdfs/TAMReview.pdf

Cooper D.R., Schindler P.S., 2001. Business Research Methods Boston: McGraw-HiIIln\'in.

Davis F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, 319-340. http://doi.org/10.2307/249008

Diefenbach T., 2007. The managerialistic ideology of organizational change management. Journal of organizational change management, 20(1) 126-144. http://doi.org/10.1108/09534810710715324

Ferraris A., Erhardt N., Bresciani S., 2019. Ambidextrous work in smart city project alliances: unpacking the role of human resource management systems. The International Journal of Human Resource Management, 30(4), 680-701. http://doi.org/10.1080/09585192.2017.1291530

Fletcher-Brown J., Carter D., Pereira V., Chandwani R., 2020. Mobile technology to give a resource-based knowledge management advantage to community health nurses in an emerging economies context. Journal of Knowledge Management. http://doi.org/10.1108/JKM-01-2020-0018

Fomin V.V., Heldal I., Wijkmark C.H., 2018, September. Technology Adoption Failure Through the Prism of Organizational Regulation Model. In Norsk konferanse for organisasjoners bruk at IT, 26, 1. https://ojs.bibsys.no/index.php/Nokobit/article/view/534/454

Gkoutzinis A.A., 2006. Internet banking and the law in Europe: Regulation, financial integration and electronic commerce. Cambridge University Press. Reterived From: books.google.com

Gu D., Khan S., Khan I.U., Khan S.U., 2019. Understanding mobile tourism shopping in Pakistan: an integrating framework of innovation diffusion theory and technology acceptance model. Mobile Information Systems, 2019. http://doi.org/10.1155/2019/1490617

Hadi N.U., Abdullah N., Sentosa I., 2016. An easy approach to exploratory factor analysis: Marketing perspective. Journal of Educational and Social Research, 6(1), 215. http://doi.org/10.5901/jesr.2016.v6n1p215

Hiatt J., 2006. ADKAR: a model for change in business, government, and our community. Prosci. Reterived From: books.google.com

Hu P.J., Chau P.Y., Sheng O.R.L., Tam K.Y., 1999. Examining the technology acceptance model using physician acceptance of telemedicine technology. Journal of management information systems, 16(2), 91-112. http://doi.org/10.1080/07421222.1999.11518247

Hult G.T.M., Hair Jr. J.F., Proksch D., Sarstedt M., Pinkwart A., Ringle C.M., 2018. Addressing endogeneity in international marketing applications of partial least squares structural equation modeling. Journal of International Marketing, 26(3), 1-21. http://doi.org/10.1509/jim.17.0151

Kashada A., Ehtiwsh E., Nakkas H., 2020. The role of technology acceptance model (TAM) towards information systems implementation success: A Meta-Analysis. The International Journal of Engineering and Science (IJES), 9(01), 30-36.

Lai C., Wang Q., Li X., Hu X., 2016. The influence of individual espoused cultural values on self-directed use of technology for language learning beyond the classroom. Computers in Human Behavior, 62, 676-688. http://doi.org/10.1016/j.chb.2016.04.039

Larsson O.S.K.A.R., 2015. Reliability analysis. Lecture notes, Lund University.

Lauer T., 2010. Change management. Springer Berlin Heidelberg. https://link.springer.com/book/10.1007%2F978-3-662-62187-5

Lee S., Kim W., Lee H., Jeon J., 2016. Identifying the structure of knowledge networks in the US mobile ecosystems: patent citation analysis. Technology Analysis & Strategic Management, 28(4), 411-434. https://doi.org/10.1080/09537325.2015.1096336

Lee Y., Kozar K.A., Larsen K.R., 2003. The technology acceptance model: Past, present, and future. Communications of the Association for information systems, 12(1), 50. http://doi.org/10.17705/1CAIS.01250

Marcoulides K.M., Yuan K.H., 2017. New ways to evaluate goodness of fit: A note on using equivalence testing to assess structural equation models. Structural Equation Modeling: A Multidisciplinary Journal, 24(1), 148-153. http://doi.org/10.1080/10705511.2016.1225260

Melchers R.E., Beck A.T., 2018. Structural reliability analysis and prediction. John wiley & sons. Reterived From: books.google.com

Mugo D.G., Njagi K., Chemwei B., Motanya J.O., 2017. The technology acceptance model (TAM) and its application to the utilization of mobile learning technologies. Journal of Advances in Mathematics and Computer Science, 1-8. https://karuspace.karu.ac.ke/handle/20.500.12092/2444

Mulaik S.A., James L.R., Van Alstine J., Bennett N., Lind S., Stilwell C.D., 1989. Evaluation of goodness-of-fit indices for structural equation models. Psychological bulletin, 105(3), 430. http://doi.org/10.1037/0033-2909.105.3.430

Petruzzelli A.M., Rotolo D., Albino V., 2015. Determinants of patent citations in biotechnology: An analysis of patent influence across the industrial and organizational boundaries. Technological Forecasting and Social Change, 91, 208-221. http://doi.org/10.1016/j.techfore.2014.02.018

Pinto J.K., Mantel S.J., 1990. The causes of project failure. IEEE transactions on engineering management, 37(4), 269-276. http://doi.org/10.1109/17.62322

Rafique H., Almagrabi A.O., Shamim A., Anwar F., Bashir A.K., 2020. Investigating the acceptance of mobile library applications with an extended technology acceptance model (TAM). Computers & Education, 145, 103732. http://doi.org/10.1016/j.compedu.2019.103732

Rahman M.M., Lesch M.F., Horrey W.J., Strawderman L., 2017. Assessing the utility of TAM, TPB, and UTAUT for advanced driver assistance systems. Accident Analysis & Prevention, 108, 361-373. http://doi.org/10.1016/j.aap.2017.09.011

Ruele V.T., 2015. An investigation into the management of change in Design and Technology: a qualitative inquiry based on the implementation of a new curriculum for senior secondary schools in Botswana (Doctoral dissertation, Loughborough University). Reterived From: http://pstorage-loughborough-53465.s3.amazonaws.com/16969943/Thesis2015Ruele.pdf

Sekaran U., Bougie R., 2016. Research methods for business: A skill building approach. John Wiley & Sons.

Shehab E.M., Sharp M.W., Supramaniam L., Spedding, T.A., 2004. Enterprise resource planning. Business process management journal, 10(4), 359-386. http://doi.org/10.1108/14637150410548056

Shima N., Mohamadali A.K., 2017. Examining the factors affecting willingness to use electronic banking: the integration of TAM and TPB models with electronic service quality (case study: Eghtesad Novin Bank). Journal of Fundamental and Applied Sciences, 9(1S), 824-841. http://doi.org/10.4314/jfas.v9i1s.736

Shore B., Venkatachalam A.R., 1996. Role of national culture in the transfer of information technology. The Journal of Strategic Information Systems, 5(1), 19-35. http://doi.org/10.1016/S0963-8687(96)80021-7

Siyal A.W., Donghong D., Umrani W.A., Siyal S., Bhand S., 2019. Predicting mobile banking acceptance and loyalty in Chinese bank customers. SAGE Open, 9(2), 2158244019844084. http://doi.org/10.1177/2158244019844084

Thakkar J.J., 2020. Structural Equation Modelling: Application for Research and Practice (with AMOS and R) (Vol. 285). Springer Nature. Reterived From: books.google.com

Vörös T., Choudrie J., 2011. Uncertainty avoidance and technology acceptance in emerging economies: A comparative study. In Proceedings of the 4th Annual SIG GlobDev Workshop. http://archive.ceu.hu/sites/default/files/publications/31-revised-voros-uncertainty-avoidance-and-techacceptance.pdf

West J., Bogers M., 2017. Open inn ovation: current status and research opportunities. Innovation, 19(1), 43-50. http://doi.org/10.1080/14479338.2016.1258995

Yun J.J., Won D., Jeong E., Park K., Yang J., Park J., 2016. The relationship between technology, business model, and market in autonomous car and intelligent robot industries. Technological Forecasting and Social Change, 103, 142-155. http://doi.org/10.1016/j.techfore.2015.11.016

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ORIGINAL PAPER

EXPLORING GREEN PACKAGING ACCEPTANCE IN FAST MOVING CONSUMER GOODS IN EMERGING ECONOMY: THE CASE OF MALAYSIA

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ABSTRACT. **Background**: Green packaging plays an important role to reduce environmental wastes and protect the environments which aligned with the Sustainable Development Goals (SDG). However, the lack of environmental awareness, inconvenience of support, cost, and lack of government enforcement is the most frequently cited reasons for discouraging green packaging usage. This study aims to establish a model to understand the motivational drivers of green packaging acceptance from the lens of the Theory of Consumption Value.

Methods: Data from self-administered questionnaire were obtained for this qualitative study to address the affirmation hypotheses. A total of 426 questionnaires were distributed among the shopping centres consumer's in Klang Valley, Malaysia. Each individual was approached at the major shopping centers where the green packaging was in practice. The researchers employed a partial least squares-structural equation modeling (PLS-SEM) approach using the SmartPLS 3 package to analyze the data.

Results: Findings from this study indicated that three values have a significant impact on consumer's green packaging acceptance which is emotional, functional, and social value while conditional and epistemic have no statistical impact on consumer's green packaging acceptance.

Conclusion: These research findings contribute to the growing body of knowledge on the drivers that motivate consumers to shift from traditional packaging to green packaging and subsequently contributing to long-term urban sustainability and quality of life predominantly in the emerging economy. Future researcher should be taken forward by undertaking further studies which include longitudinal and comparative studies of consumer acceptance towards green packaging in both developed and developing countries..

Key words: green packaging, sustainability, acceptance, environmental, consumption value.

INTRODUCTION

Green packaging is recognized as a sustainable wrapper to package the goods which have a very low negative effect on both environment and energy consumption. Green packaging is not only eco-friendly in nature, nonetheless, it includes sustainable materials that are produced from the environmentally aware method by energy-efficient phases [Auliandri, et al., 2018]. Green packaging is made from materials that can be broken down into oxygen, hydrogen, and carbon [Dharmadhikari, 2012]. The products in the market are mostly come with packaging to ensure the product are in a safe condition as well as for marketing purpose. For instance, green packaging brings favourable feeling to green consumers which create loyalty and confidence for customers to consume the products [Rajendran et al., 2019]. Recently, there is strong awareness regarding sustainability packaging globally [Singh and

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Pandey, 2018]. This is because, non-environmentally friendly products had created serious issues of waste pollution worldwide bring negative impacts to humans and the environment [Kristensson et al., 2017; Siracusa & Rosa, 2018]. Thus, sustainable packaging is important for people's health, waste disposal, energy consumption, resources, environment [Wang & Zhou, 2015].

Thus, green packaging had successfully caught attention to be eco-friendlier and sustainable. The market of green packaging worldwide is expected to provide significant growth in the coming years through strong policies and regulatory enforcement by the government. A few initiatives have taken place which includes bio-plastics as a raw material to eliminate waste and pollution [Groh et al., 2019], no more petroleum and oil products require for future packaging which is completely biodegradable that able to reduce the environmental burden of carbon footprint [Guillard et al., 2018]. Green packaging is crucial in most industries including pharmaceutical, personal body care, and Fast-Moving Consuming Goods (FMCG) [Ma et al., 2020]. Several reasons to handpicked green packaging comprising carbon footprint reduction, easy disposal, biodegradable, flexible and versatile, secure and improve the image of the brand, save cost, ability to recycle, reuse and reduce, customer base expansion, cost reduction and eliminate plastic usage [Moustafa et al., 2019; Nguyen et al., 2020].

All countries are implementing the 2030 Agenda for Sustainable Development which was adopted in 2015 by United Nations Member States to provide harmony and peace. Green packaging associated with Goal 9: Industry, Innovation, and Infrastructure which much related to packaging innovations and improvements, Goal 12: Responsible Production and Consumption focusing on encouragement to the organization and individual to utilize sustainable packaging and Goal 14: Life Below Water concerned on waste management to reduce and prevent marine pollution [UNDP, 2015]. Asian countries including Malaysia, Singapore, Thailand, India, Korea, Japan, and China are practicing green concepts by launching their scheme of eco-labelling connected to the material of non-toxic plastic packaging, hazardous metal-free electrical, agricultural and degradable products [Wong & Yazdanifard, 2015]. According to Martinho et al. [2015], the majority of the respondents are willing to pay more than the usual price for sustainable fast food packaging.

Malaysia government also apply a holistic approach of AFFIRM comprising of Awareness, Faculty, Finance, Infrastructure, Research, and development as well as Marketing to acquire commitment from stakeholders (employees, customers, and government) to accomplish Malaysia's environment protection [Rajadurai et al., 2018; Osman et al., 2015]. Alike, Indonesia had emerged as one of the competitive markets in these areas by implementing campaigns such as practicing less usage of plastic packaging and focus more on green packages and green products [Auliandri, et al., 2018; Rajendran & Wahab, 2017]. It is proof that acceptance among Asian consumers towards sustainable packaging is high [Prakash & Pathak 2017]. Therefore, the objective of this study is to reaffirm factors that influence the acceptance of green packaging among Klang Valley's consumers in the emerging economy based on the theory of consumption values (TCV). In line with the commitment towards sustainable environment practices, factors that scrutinize green packaging acceptance could potentially benefit stakeholders within the Malaysian entrepreneurs and the retailing industry. Findings from this study would provide better thoughtful to practitioners on the factors affecting green packaging acceptance in general. It is an avenue for the practitioners to frame strategies to further advance these study findings towards better green packaging implementation within their organizations. As this research effort appears to be among a few to examine factors affecting green packaging from the lance of TCV in Klang Valley, Malaysia, it could enrich the green packaging literature and contributes to the overall body of knowledge.

Onwards, the next section starts with describing the underpinning research theory that grounds the green packaging acceptance. Then, the paper continues by reviewing previous literature that is associated with green packaging and subsequently proposes a conceptual model, followed by the methodology employed for this study. Further, data analysis and findings were discussed and finally, a concluding remark is drawn which covers several research implications and necessary for future research initiatives.

LITERATURE REVIEW

Theory of Consumption Values

The theory of consumption values consists of social, emotional, functional, conditional, and epistemic value to explain the purchase intention or consumer decision. The values are the basic aspects of human beings' daily lives. This theory is concentrating on consumption values in three aspects, namely, the choice to accept or not accept the usage of green packaging products, the choice of using green packaging products, and the choice of using a specific brand of green packaging [Sheth et al., 1991]. There are numerous areas, such as sociology, economics, and user acceptance have contributed this theory to the values. This study is associated with consumer behaviour towards green packaging, hence, this theory seen able to engage consumer consumption-related value [Gonçalves et al., 2016; Biswas & Roy, 2015a]. User's acceptance may be affected by any of the five consumption values. Thus, this theory serves as the foremost factor representing consumer acceptance of green packaging.

Hypotheses Development

Functional value in the context of this study relates to the disintegration, reusable or recyclability, size of the packaging, and packaging simplification that highly triggering customer's decision making. The right size of green packages that enable generating benefits such as space utilization, costs reduction, and able to improve the overall supply chain efficiency will eventually attract consumer's attention [Wilson, et al., 2017; Rundh, 2016]. Consumers are not favored to pay a higher price on green packaging since quality, durability, and reliability are the main focus in product decision and selection making [Barber et al., 2014; Lin & Huang, 2012]. The quality of green packaging must be good which includes non-radiation, ecologically friendly, and non-toxic material at a reasonable price [Huang, 2017]. Moreover, green packaging with an artistic design able to attract customer's interest [Biswas & Roy, 2015b; McCarthy & Liu, 2017]. Considering the preceding discussion, the below hypotheses is derived:

H1: Functional value has a positive influence on green packaging acceptance.

Social value is associated with the improvement of self-image which brings impacts on consumer behaviour on green packaging [Gonçalves et al., 2016]. Social value in green packaging refers to aspects that included personal convenience, moral norms, self-image, and social pressures [Sun et al., 2019; Gilli et al., 2018]. A sense of responsibility, social awareness, and motivation towards the green environment will trigger consumer's actions towards green packaging buying behaviour [Czajkowski et al., 2015; Paul et al., 2016]. Additionally, individual lifestyle or influences from family, friends, society, and the government will eventually influence the eco-friendly packaging decision towards sustainable environment practices [Mamun, et al., 2018; Hao et al., 2019]. Alike, according to Joshi & Rahman [2015], environmental awareness and green environment knowledge will highly influence the eco-friendly packaging products buying decision. Given the above thoughtful, the following hypotheses are postulated:

H2: Social value has a positive influence on green packaging acceptance.

Emotional value related to the consumer's feeling grounded on their self-experiences and emotion that leads to green purchasing intention [Kato & Tsuda, 2017]. Consumer's intention to purchase green packaging is precisely related to positive, negative, or mixed feelings. For instance, customers with positive emotions will trigger high acceptance of green packaging products due to their responsibility and trust to protect the environment [Xie et al., 2015; Asshidin et al., 2016]. Contrarily, negative emotion implies other-condemning emotions consists of inappropriate and immoral feeling such as guilt, disgust, anger, and contempt that affects purchasing decision [Liang et al., 2019]. Customers prefer products that composition, production, and packaging which bind to each other. Thus, some non-degradable products will trigger negative emotions to green consumer's which include higher prices [Mamun et al., 2018]. Researchers have noticed that attractive packaging, informative and user-friendly green packaging will influence consumer's green packaging acceptance [Sijtsema et al., 2016]. Subsequently, the underneath hypothesis is derived:

H3: Emotional value has a positive influence on green packaging acceptance.

The epistemic value was well-defined as the perceived value derived from services or products that enable to stimulate the interest, provide uniqueness, or fascinate a desire consumer knowledge [Gonçalves et al., 2016]. Knowledge is a vital element that enables the stimulus of consumer choice towards new products or services [Majid et al., 2018]. Consumers with high epistemic value tend to seek more innovative products which will make a significant impact on the purchase decision such as green packaging (Barnes, 2016). Alike, consumer's lifestyles are varied with different information, perception, and personal values perceived [Olaisen & Revang, 2017]. Biswas & Roy [2015a] affirm that consumers are more likely to purchase green packaging items with sufficient environmental information such as certifications, eco-labels, and extensive insight regarding its impacts. Knowledge and innovation work simultaneously to generate effective acceptance of green packaging. The higher the concern and information related to ecological packaging, the higher possibility for consumers to purchase green packaging items [Joshi & Rahman, 2015]. Hence, the following hypotheses are posited.

H4: Epistemic value has a positive influence on green packaging acceptance.

Conditional value is denoted as a situational and circumstances capability that enables to influence the acceptance of the decision-maker. [Lin & Huang, 2012]. A study by Gonçalves et al. [2016] confirms that there is a positive impact on green packaging product behaviour when there is a clear indication of the importance of the need to protect the environment through sustainable packaging [Ali, 2017]. Similarly, Biswas & Roy [2015b] in their study highlight the negative impact of not opt the green packaging. Consequently, to support green purchasing, the Indian government continuously encouraged green innovation and investment to mitigate the pressure on the environment [Van Leeuwen & Mohnen, 2017]. Likewise, the Malaysian government is actively encouraging consumers to support environmentally friendly packaging products through the execution of green subsidy and policy which includes the Green Government Procurement initiatives [Ahmad et al., 2016; Mohamed et al., 2015]. Conditional value is concerning with the awareness of utility that a service or product able to deliver to the decision-maker [Gadenne et al., 2011]. The different situations will influence the purchasing behaviour and decision of consumers differently. Lin & Huang [2012] mentioned in their study that conditional value will affect the behaviour of green customers. Considering these conditions, this study posited the following hypothesis:

H5: Conditional value has a positive influence on green packaging acceptance.

The proposed framework provides a more precise and transparent explanation of the earlier discussion as illustrated in Figure 1.

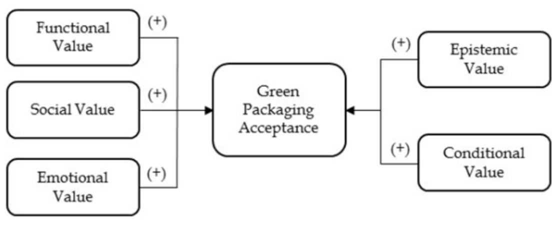

Fig. 1. Theoretical framework

METHODOLOGY

Respondents and Procedure

Data from the self-administered questionnaire were obtained for this qualitative study to address the affirmation hypotheses. A total of 426 questionnaires were distributed among the shopping centres consumer's in Klang Valley, Malaysia. Each individual was approached at the major shopping centers where the green packaging was in practice. Data were collected between May to August 2020. A total of 253 questionnaires were collected yielding a 59.39% valid response rate. According to Krejcie and Morgan [1970], 384 would be the minimum sample size required when the target population is more than 1 million. However, the minimum sample size of 92 is adequate based on the G*Power 3.1 statistical analysis [Faul et al., 2009]. Therefore, the 253 sample size is adequate as it in line with good practices.

Variable Measurement

The questionnaire consists of three mains sections. Section A inquired about the respondent's demographic information and some basic information about green packaging. Next, Section B covers the acceptance of green packaging with seven items adapted from Lin and Huang [2012]. Finally, Section C discovered the consumption values adopted from Suki (2016) comprised of functional value (7 items), social value (7 items), emotional value (6 items), conditional value (6 items), and epistemic value (4 items). All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to (5 strongly agree).

Statistical Techniques

The researchers employed a partial least squares-structural equation modeling (PLS-SEM) approach using the SmartPLS 3 package to analyze the data. This software is appropriate in analyzing the non-parametric data, consider a robust software in evaluating the structural models [Aramburu and Pescador, 2019], and able to accept small sample sizes [Hair et al., 2018]. Following Anderson and Gerbing [1988], data for this study were analyzed in two stages. First the assessment of the measurement model, and secondly the assessment of the structural model.

FINDINGS AND DISCUSSIONS

Demographics profile of respondents

As shown in Table 1, a total of 174 respondents were female, and 79 were male. The majority of respondents were aged 19 to 35 years old (62.1%) and 36 to 49 years old (27.7%). Respondents aged less than 18 years old and more than 50 years old formed minorities in this study. It is a slightly equal distribution in terms of the respondent's race. In the aspect of salary, the majority of the respondents (85%) earned a monthly salary below RM 4,000 (roughly USD 960) and the rest earned RM4,000 and above. They are mainly worked in the private sector (80.6%) while 19.4% worked in the public sector.

Table 1. Respondents profile information

Demographics	Descriptions	Frequency	Percentage
Gender	Male	79	31.2
	Female	174	68.8
Age	< 18 years old	25	9.9
	19-35 years old	157	62.1
	36-49 years old	70	27.7
	> 50 years old	1	0.4
Race	Malay	72	28.5
	Chinese	80	31.6
	Indian	98	38.7
	Others	3	1.2
Monthly Income	< RM 2500	11	4.3
	RM 2501 - RM 3000	98	38.7
	RM 3001 – RM 4000	106	41.9
	> RM 4001	38	15.0
Occupation	Government	49	19.4
	Private	204	80.6

Figure 2 demonstrated the green packaging decision making by the respondents. The majority of the respondent is in the position of the green packaging decision making (63.6%). Most of the respondents decided to use green packaging two to three times a week (46.6%) and less than one time a week. This might be due to work constraints. Others will decide to use green packaging more than four times a week.

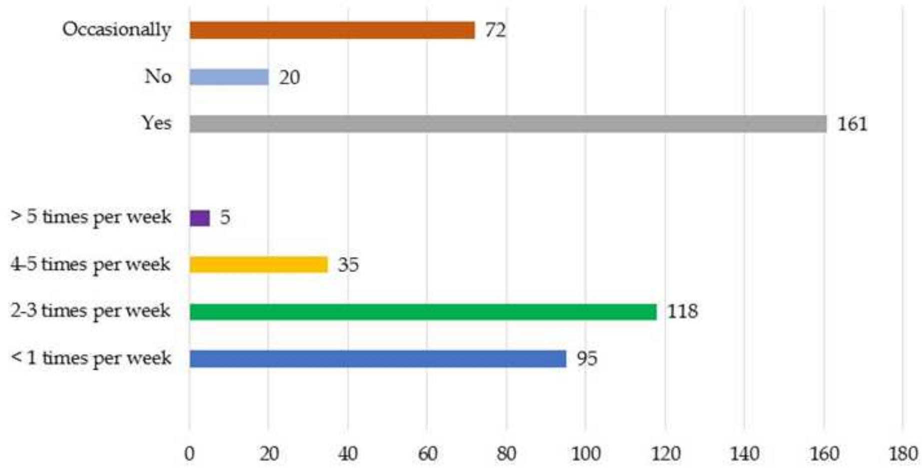

Fig. 2. Purchasing decision and green packaging usage (in numbers)

Measurement model test

Table 2 present the reliability and validity of all constructs. The result reveals that epistemic value presents the higher average variance extracted (AVE) value (0.780). The result indicates that the construct reliability and validity is achieved as recommended by Hair et al. [2017]. Similarly, all of the constructs have AVE and CR values of above 0.5 and 0.7 respectively. The higher composite reliability (CR) is achieved by social value (0.957) and the higher Cronbach's alpha value was also for social value (0.947). Hence, this indicates that the constructs are measuring what they are supposed to measure, and the set of items is consistent with what it intends to measure [Hair et al., 2017]. The factor loading value for all constructs was above 0.60 which indicated that the construct reliability of this study was attained (Figure 3).

Table 2. Construct reliability and validity

Constructs and Items	Code	Factor Loadings	AVE	CR
Functional Value (FunV)		0.933	0.712	0.945
The green packaging has…				
… reasonably priced.	FunV1	0.859		
… economically priced.	FunV2	0.852		
… acceptable standard of quality.	FunV3	0.825		
… good quality.	FunV4	0.845		
… consistency in quality.	FunV5	0.852		
… comfortability to practice.	FunV6	0.838		
… reliability to practice.	FunV7	0.836		
Social Value (SocV)		0.947	0.760	0.957
Using green packaging would help me to feel acceptable.	SocV1	0.821		
Using green packaging would give its owner social approval.	SocV2	0.874		
Using green packaging would make a good impression on me.	SocV3	0.873		
Advice from family and friends are crucial to use green packaging.	SocV4	0.892		
People's surroundings can motivate individuals to use green packaging.	SocV5	0.895		
Trustable news from social media will motivate me to use green packaging.	SocV6	0.870		
The current trend of society will influence me to use green packaging.	SocV7	0.875		

Constructs and Items	Code	Factor Loadings	AVE	CR
Emotional Value (EmoV)		0.923	0.722	0.940
Using green packaging instead of traditional packaging would…				
… feel like contributing to the environment.	EmoV1	0.858		
… feel like a better person.	EmoV3	0.879		
… feel like preserving the planet.	EmoV4	0.853		
… feel positive.	EmoV5	0.827		
… feel energetic.	EmoV6	0.833		
… change how people judge.	EmoV7	0.848		
Epistemic Value (EpiV)		0.906	0.780	0.934
I prefer using green packaging when there is…				
… new design attracts my attention.	EpiV3	0.871		
… new and creative innovation.	EpiV5	0.862		
… desire for knowledge.	EpiV6	0.898		
… new experience.	EpiV7	0.899		
Conditional Value (ConV)		0.915	0.703	0.934
I will use green packaging when there is…				
… subsidy by the government.	ConV1	0.726		
… availability in the market.	ConV2	0.876		
… reduction of environmental issues.	ConV3	0.869		
… high health precaution.	ConV5	0.879		
… good functionality.	ConV6	0.783		
… good characteristics.	ConV7	0.886		
Green Packaging Acceptance (GPA)		0.932	0.711	0.945
I am aware that environmentally friendly packaged products are available in the market.	GPA1	0.856		
I am more likely to buy green products that are packaged in an eco-friendly manner and made easy for recycling or composting.	GPA2	0.864		
I am willing to pay more to buy green packaged products to save the environment.	GPA3	0.854		
I always purchase a green product in my daily shopping.	GPA4	0.855		
I acknowledge different brands offering green products.	GPA5	0.787		
I will switch to a different product if it is eco-friendly.	GPA6	0.862		
I am aware of the benefit of green products on the environment and human health.	GPA7	0.823		

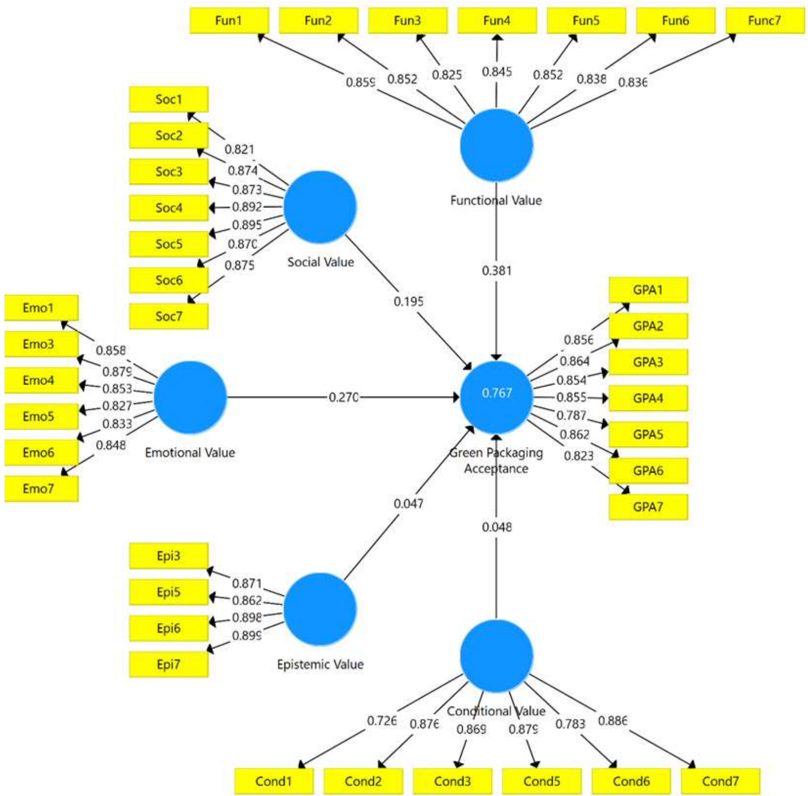

Fig. 3. Measurement model

Discriminant analysis

The discriminant validity of the measurement model was then assessed by using the Heterotrait-Monotrait Ratio (HTMT) technique. The maximum HTMT values are well below the threshold of 0.9 [Henseler et al., 2015]. Table 3 details all the values which fulfil the criterion of HTMT. HTMT values of <0.90 denote that the true correlation between two constructs should differ, and this indicates that the discriminant validity is observed within the measurement model, signifying an acceptable level of discriminant validity. The square root of AVE for each latent construct higher than the correlations of any other latent constructs. Given that the VIF values are consistently below the value of 5, this, is also not an issue for multicollinearity [Hair et al., 2017]. These results infer that discriminant validity has been ascertained. Besides, the result of HTMT inference also displays that the confidence interval does not portray a value of 1 on any of the constructs, which also confirms discriminant validity [Henseler et al. 2015].

Table 3. Discriminant validity

	GPA	ConV	EmoV	EpiV	FunV	SocV
GPA	*0.843*					
ConV	0.760	*0.839*				
EmoV	0.819	0.805	*0.850*			
EpiV	0.755	0.842	0.774	*0.883*		
FunV	0.838	0.793	0.829	0.800	*0.844*	
SocV	0.798	0.791	0.814	0.791	0.810	*0.872*

Diagonal entries are the square root of the average variance extracted (italicized). Off-diagonal elements are correlations among constructs

Structural model test

Five direct hypotheses are developed between the constructs (Table 4). Based on the assessment of the path coefficient as an exhibit in Table 4, three relationships are found to have a t-value ≥ 1.645, therefore, significant at 0.05 level of significance. Explicitly, the predictors of functional value (β = 0.376, p = 0.001), social value (β = 0.209, p = 0.015), and emotional value (β = 0.249, p = 0.037) are significantly influence consumers green packaging acceptance. Thus, H1, H2, and H3 are supported. However, epistemic value (β = 0.053, p = 0.255) and conditional value (β = 0.057, p = 0.293) have no statistical impact on consumer's green packaging acceptance. Hence, H4 and H5 are rejected. The R2 values of 0.767 are above the 0.75 value as suggested by Hair et al. [2017] which indicates a substantial model. Since the correlation figures are below 0.7, the constructs are discriminant from each other, and common method bias is not a severe concern in this study [Bagozzi et al., 1991]. Figure 4 shows the results of the empirical analysis of the research model.

Table 4. Discriminant validity

	Relationship	*β*	*SE*	*t-value*	*p-value*	*Decision*
H1	FunV → GPA	0.376	0.122	3.132	0.001	Supported
H2	SocV → GPA	0.209	0.090	2.173	0.015	Supported
H3	EmoV → GPA	0.249	0.151	1.784	0.037	Supported
H4	EpiV → GPA	0.053	0.071	0.659	0.255	Not supported
H5	ConV → GPA	0.057	0.087	0.546	0.293	Not supported

Note: *p < 0.05

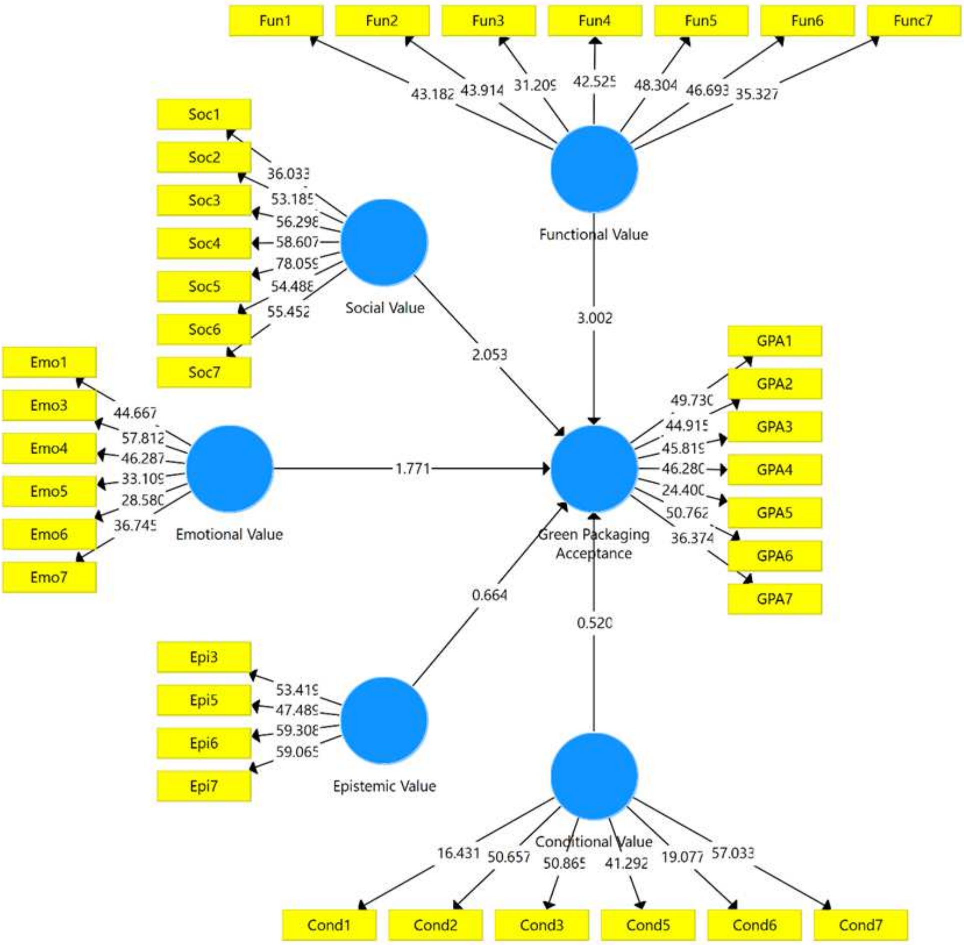

Fig. 4. Results of the structural equation model

DISCUSSION

This study determines the five values to be the predictors of green packaging acceptance through the lens of TCV. The PLS-SEM analysis revealed that, out of five values, three values are proven and accepted to have a direct effect on green packaging acceptance. The finding for the first hypotheses which is functional value is consistent with Wilson et al. [2017], Rundh (2016), and Lin and Huang [2012] and therefore, supported H1. These findings show that consumers valued the functionality of the green packaging particularly in terms of its disintegration, reusable or recyclability, size, and simplicity. Additionally, cost, quality, and design factors likewise capable to fascinate consumer's attention to opting for green packaging. This study result reprises the findings from Biswas and Roy [2015b], McCarthy and Liu [2017], and Huang [2017] that the functional value affects and influences consumer's green packaging acceptance.

Furthermore, the empirical results showed that the second hypothesis results of this study support the acceptance of H2, which means the acceptance of green packaging among Klang Valley's consumers in the emerging economy was stimulus by social value. The result asserted that the acceptance of green packaging depends on personal convenience or environmental responsibility and social awareness. Alike, individual lifestyle or encouragement from family, friends, society, and the government will motivate the acceptance of green packaging. This is also consistent with preceding studies, for instance, Gonçalves et al. [2016], Sun et al. [2019], and

Paul et al. [2016]. The influence from social media platforms which includes Facebook and Instagram are greatly influenced and prompts mindfulness and confidence among consumers to elect green packaging products in their daily life.

Additionally, the PLS-SEM analysis of the structural model concerning the influence of emotional value on green packaging acceptance was significant, hence supporting H3. It is also consistent with previous studies [Asshidin et al., 2016; Liang et al., 2019]. Consumers will be further enticed to embrace green packaging when user-friendly features are being embedded. Similarly, attractive and informative packaging will ultimately influence a consumer's decision choice. These results are concurred by the earlier studies which include Mamun et al. [2018] and Sijtsema et al. [2016]. Xie et al. [2015] acknowledged that deep feelings to protect the environment will raise the mindfulness and self-obligation among consumers to accept green packaging. The work from Kato and Tsuda [2017] enriched the importance to upraise consumer's self-experiences and emotions while opting for green packing towards a better green purchase experience. This will led to a rise in their trust and responsibility to protect the environment. These outcomes also coincided with those of previous literature, e.g., Asshidin et al. [2016], Sijtsema et al. [2016].

On the other hand, the result for epistemic value is contradictory with earlier studies, hereafter H4 was not supported. The insignificant outcomes inferred that the acceptance of green packaging required uniqueness and innovativeness to stimulate consumer's purchase decisions. This result contradicts with the earlier studies, e.g., Majid et al. [2018] and Barnes [2016]. Beforehand, scholars have witnessed that sufficient environmental information such as green certifications, eco-labels and extensive insight concerning green packaging has a significant impact on green packaging acceptance [Biswas & Roy, 2015a]. Hence, this study result enlightened that the lack of informative and less attractive packaging resulted in a weak connection between the epistemic values and green packaging acceptance. Although the green concept is considered new to the Klang Valleys consumers in the emerging economy, the awareness of the environmental issues enables to facilitate consumers to shift their purchase decision towards green packaging products. As highlighted by Joshi & Rahman [2015], the information about ecological packaging must be made accessible through a variety of platforms to allow consumers to be more conscious of the importance of green packaging towards the environment.

Concerning the influence of conditional value on green packaging acceptance, this relationship was insignificant, thus H5 was not supported. The insignificant results in line with Biswas and Roy [2015b] findings whereby they indicated that consumers required strong evidence on the importance and implication to protect the environment through green packaging. Although the government continuously encouraged consumers to upkeep environmentally friendly packaging products, consumers still not aware due to lack of awareness and unpleasant packaging. Similarly, Gadenne et al. [2011] acclaimed that awareness will strongly affect the behaviour of green customers. Findings from this study validated that attractive packaging conditions delineated by entrepreneurs, retailing industry and government including promotional discounts, subsidy and monetary benefits would contribute to consumer's green packaging acceptance [Lin & Huang, 2012]. Besides, conditional value characteristics (i.e., quality of package materials based on durability, colour and shape) are also vital in the effort to enhance the acceptance of green packaging among Klang Valley's consumers [Rajendran et al., 2019].

CONCLUSION AND DIRECTION FOR FUTURE RESEARCH

Findings from this study have vigorous implications for both scholars and practitioners as the association of TCV able to provides a unique influence on future decision-making among entrepreneurs and the retailing industry.

Theoretical implication

From the perspective of theoretical viewpoint, the application of TCV and the findings of this research contribute to the growing body of literature which associate with the five consumption values and acceptance of green packaging, a topic that has not received considerable empirical attention. It is subsequently donated to the theory advancement relevant to sustainable practices. The empirical result from this study discloses how the five consumption values tie with green packaging acceptance. The findings presented in this study may help to advance a better thought, particularly in the emerging economy context. Wilson et al. [2017], Sun et al. [2019], and Rajenderan et al. [2017] in their study, proven functional, social, and emotional values as the essential facet that enables them to inspire a positive attitude concerning green packaging acceptance. Surprisingly, the epistemic and conditional value appears as not having any significant impact on consumer's green packaging acceptance which is considered new to the existing literature. Thus, sufficient environmental information and awareness on the importance to protect the environment must be made available by the relevant stakeholders [Rajendran et al., 2019]. Alike, according to Biswas & Roy [2015a], Gadenne et al. [2011], and Rajenderan et al. [2017], packaging must be informative, attractive, and always of high quality thus, stimulus consumer's decision choice. This study enlightens factors affecting green packaging acceptance, consequently extends the TVC framework. It delivers adequate clarification of the green packaging acceptance among Klang Valley's consumers in the emerging economy. Remarkably, this study broadens the mounting literature associated with green packaging and sustainable practices. It is favorable that this research framework can be replicated, extended, and used as a supporting article and act as a foundation for any related study of green packaging in a Malaysian perspective or even broader scope in different fields of studies.

Practical implication

Meanwhile, from a practical standpoint, the findings proposed an active promotion of the need to opt for green packaging. The entrepreneurs and regulators need to promote the functional values of green packaging in their marketing activities towards encouraging consumers to keep aware of the importance of green packing particularly to protect the environment. With a basic model of five consumption values, it provides direction for managers to continue and start the execution of green packaging constructively. Functional aspects of cost, quality and practicality of the green packaging should be given a priority. Additionally, managers should be very sensitive to improve the epistemic and conditional values towards attracting more consumers to opt for green packaging to achieve long-term sustainable development and improve quality of life. Realizing the importance of green packaging to enhance sustainable development goals, practitioners may formulate strategies for improving the awareness of the importance of green packaging among consumers. It is hoped that this study able to offer insights for key players such as entrepreneurs, decision-makers, and regulators to understand the disposition of the current green practices within Klang Valley and re-think on leveraging their current marketing practices to boost sustainable practices and at the same time sustaining companies a competitive advantage.

Future research directions

This study could be valuable hence, a future researcher should be taken forward by undertaking further studies which include longitudinal and comparative studies of consumer acceptance towards green packaging in both developed and developing countries. It is also important to analyse greater samples to attain better generalisability of findings. Taking COVID-19 as a serious pandemic issue, future research should consider running two groups of respondents offline and online to see the difference in data generalization. Moreover, this study is only focusing on five values based on the TCV, nevertheless, few other factors might influence consumer's acceptance towards green packaging. Factors include convenience, reusability, and protective capability could be undertaken to assess the effect of moderating and mediating variables in the proposed research framework thus, increase the overall study explanatory power.

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REFERENCES

Ahmad N., Buniamin S., Rauf F., Johari N., Rashid A., 2016. Green Government Procurement Practices (GGP) in Malaysian Public Enterprises. Procedia Economics and Finance, 35, 27-34. http://doi.org/10.1016/S2212-5671(16)00006-X.

Ali J., 2017. Consumer Perception Towards Green Practice: An Empirical Study on Young Consumer from Bangladesh Perspective. Journal of Economics and Sustainable Development, 8(23), 10–18.

Anderson J.C., Gerbing D.W., 1988. Structural equation modelling in practice: A review and recommended two-step approach. Psychological Bulletin, 103(3), 411–423.

Asshidin N., Abidin N., Borhan H., 2016. Perceived Quality and Emotional Value that Influence Consumer's Purchase Intention towards American and Local Products. Procedia Economics and Finance, 35, 639-643. http://doi.org/10.1016/S2212-5671(16)00078-2.

Auliandri T.A., Thoyib A., Rohman F., Rofiq A., 2018. Does green packaging matter as a business strategy? Exploring young consumers' consumption in an emerging market. Problems and Perspectives in Management, 16(2), 376-384.

Bagozzi R.P., Yi Y., Phillips L.W., 1991. Assessing Construct Validity in Organizational Research. Administrative Science Quarterly, 36(3), 421-458.

Barber N., Bishop M., Gruen T., 2014. Who pays more (or less) for pro-environmental consumer goods? Using the auction method to assess actual willingness-to-pay. Journal of Environmental Psychology, 40, 218-227. http://doi.org/10.1016/j.jenvp.2014.06.010.

Barnes C., 2016. Omni-Channel Retail-Challenges and Opportunities for Packaging Innovation. Integrating the Packaging and Product Experience in Food and Beverages, 59-76. http://doi.org/10.1016/B978-0-08-100356-5.00004-8.

Biswas A., Roy M., 2015a. Green products: an exploratory study on the consumer behaviour in emerging economies of the East. Journal of Cleaner Production, 87, 463-468. http://doi.org/10.1016/j.jclepro.2014.09.075

Biswas A., Roy M., 2015b. Leveraging factors for sustained green consumption behavior based on consumption value perceptions: testing the structural model. Journal of Cleaner Production, 95, 332-340. http://doi.org/10.1016/j.jclepro.2015.02.042

Czajkowski M., Hanley N., Nyborg K., 2015. Social Norms, Morals and Self-interest as Determinants of Pro-environment Behaviours: The Case of Household Recycling. Environmental and Resource Economics, 66(4), 647-670.

Dharmadhikari S., 2012. Eco-friendly packaging in supply chain. IUP Journal of Supply Chain Management, 9(2), 7-18.

Faul F., Erdfelder E., Buchner A., Lang A.G., 2009. Statistical power analyses using G* power 3.1: tests for correlation and regression analyses. Behavior Research Methods, 41(4), 1149-1160.

Gadenne D., Sharma B., Kerr D., Smith T., 2011. The influence of consumers' environmental beliefs and attitudes on energy saving behaviours. Energy Policy, 39(12), 7684-7694.

Gilli M., Nicolli F., Farinelli P., 2018. Behavioural attitudes towards waste prevention and recycling. Ecological Economics, 154, 294-305. http://doi.org/10.1016/j.ecolecon.2018.08.009.

Gonçalves H., Lourenço T., Silva G., 2016. Green buying behavior and the theory of consumption values: A fuzzy-set approach. Journal of Business Research, 69(4), 1484-1491.

Groh K., Backhaus T., Carney-Almroth B., Geueke B., Inostroza P., Lennquist A., Leslie H., Maffini M., Slunge D., Trasande L., Warhurst A., Muncke J., 2019. Overview of known plastic packaging-associated chemicals and their hazards. Science of The Total Environment, 651(2), 3253-3268.

Guillard V., Gaucel S., Fornaciari C., Angellier-Coussy H., Buche P., Gontard N., 2018. The Next Generation of Sustainable Food Packaging to Preserve Our Environment in a Circular Economy Context. Frontiers in Nutrition. http://doi.org/10.3389/fnut.2018.00121

Hair J.F., Sarstedt M., Ringle C.M., Gudergan S.P., 2017. Advanced Issues in Partial Least Squares Structural Equation Modeling, Research Gate. Sage Publications, Thousand Oaks, CA.

Hao Y., Liu H., Chen H., Sha Y., Ji H., Fan J., 2019. What affect consumers' willingness to pay for green packaging? Evidence from China. Resources, Conservation and Recycling, 141, 21-29. http://doi.org/10.1016/j.resconrec.2018.10.001.

Hellström D., Olsson A., 2017. Managing Packaging Design for Sustainable Development: A Compass for Strategic Directions. John Willy & Son, Ltd.

Henseler J., Ringle C.M., Sarstedt M., 2015. A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science, 43(1), 115-135.

Huang J., 2017. Sustainable Development of Green Paper Packaging. Environment and Pollution, 6(2), 1-5.

Joshi Y., Rahman Z., 2015. Factors Affecting Green Purchase Behaviour and Future Research Directions. International Strategic Management Review, 3(1-2), 128-143.

Kato T., Tsuda K., 2017. Related Verification of Emotional Value and Company Brand Emitted from Pure Recall. Procedia Computer Science, 112, 1298-1307. http://doi.org/10.1016/j.procs.2017.08.093.

Khan S., Mohsin M., 2017. The power of emotional value: Exploring the effects of values on green product consumer choice behavior. Journal of Cleaner Production, 150, 65-74. http://doi.org/10.1016/j.jclepro.2017.02.187

Krejcie R.V., Morgan D.W., 1970. Determining sample size for research activities. Educational and psychological measurement, 30(3), 607-610.

Kristensson P., Wästlund E., Söderlund M., 2017. Influencing consumers to choose environment friendly offerings: Evidence from field experiments. Journal of Business Research, 76, 89-97. http://doi.org/10.1016/j.jbusres.2017.03.003

Liang D., Hou C., Jo M., Sarigöllü E., 2019. Pollution avoidance and green purchase: The role of moral emotions. Journal of Cleaner Production, 210, 1301-1310. http://doi.org/10.1016/j.jclepro.2018.11.103

Lin P., Huang Y., 2012. The influence factors on choice behavior regarding green products based on the theory of consumption values. Journal of Cleaner Production, 22(1), 11-18.

Ma X., Park C., Moultrie J., 2020. Factors for eliminating plastic in packaging: The European FMCG experts' view. Journal of Cleaner Production, 256, 120492. http://doi.org/10.1016/j.jclepro.2020.120492.

Majid I., Ahmad Nayik G., Mohammad Dar S., Nanda V., 2018. Novel food packaging technologies: Innovations and future prospective. Journal of the Saudi Society of Agricultural Sciences, 17(4), 454-462.

Mamun A.A., Mohamad M.R., Yaacob M.R., Mohiuddin M., 2018. Intention and behavior towards green consumption among low-income households. Journal of Environmental Management, 227, 73-86. http://doi.org/10.1016/j.jenvman.2018.08.061.

Martinho G., Pires A. Portela G., Fonseca M., 2015. Factors affecting consumers' choices concerning sustainable packaging during product purchase and recycling. Resources, Conservation and Recycling, 103, 58-68. http://doi.org/10.1016/j.resconrec.2015.07.012

McCarthy B., Liu H., 2017. Food waste and the 'green' consumer. Australasian Marketing Journal, 25(2), 126-132.

Mohamed Z., Hosseinpou M., Rezai G., Shamsudin M., AbdLatif I., 2015. How Go Green Campaign Effects on Malaysian Intention towards Green Behaviour. Journal of Applied Sciences, 15(6), 929-933.

Moustafa H., Youssef A.M., Darwish N.A., Abou-Kandil A.I., 2019. Eco-friendly polymer composites for green packaging: Future vision and challenges. Composites Part B: Engineering, 172, 16-25. http://doi.org/10.1016/j.compositesb.2019.05.048.

Nguyen A.T., Parker L., Brennan L., Lockrey S., 2020. A consumer definition of eco-friendly packaging. Journal of Cleaner Production, 252, 119792. http://doi.org/10.1016/j.jclepro.2019.119792.

Olaisen J., Revang O., 2017. Working smarter and greener: Collaborative knowledge sharing in virtual global project teams. International Journal of Information Management, 37(1), 1441-1448.

Osman A., Othman Y., Salahudin S., Abdullah M., 2016. The Awareness and Implementation of Green Concepts in Marketing Mix: A Case of Malaysia. Procedia Economics and Finance, 35, 428-433. http://doi.org/10.1016/S2212-5671(16)00053-8.

Paul J., Modi A., Patel J., 2016. Predicting green product consumption using theory of planned behavior and reasoned action. Journal of Retailing and Consumer Services, 29, 123-134. http://doi.org/10.1016/j.jretconser.2015.11.006.

Prakash G., Pathak P., 2017. Intention to buy eco-friendly packaged products among young consumers of India: A study on developing nation. Journal of Cleaner Production, 141, 385-393. http://doi.org/10.1016/j.jclepro.2016.09.116

Rajadurai J., Bathmanathan V., Azami N., 2018. Gen Y Green Purchasing Behavior in Relation YO Energy Conservation and Environmental Preservation Products in Malaysia. International Journal of Engineering & Technology, 7(4). http://doi.org/10.14419/ijet.v7i4.35.23113.

Rajendran S.D., Wahab S.N., 2017. Purchasing Intention towards Green Packaged Products: An Exploratory Study among Malaysian Consumers. 3rd International Conference on Advanced Research in Business and Social Sciences, 29-30 March, 347-355, Langkawi, Malaysia.

Rajendran S.D., Wahab S.N., Singh M.K.P., 2019. Malaysian Consumers Preference for Green Packaging. International Journal of Society Systems Science,11(4), 312-331.

Rundh B., 2016. The role of packaging within marketing and value creation. British Food Journal, 118(10), 2491-2511.

Sheth J., Newman B., Gross B., 1991. Why we buy what we buy: A theory of consumption values. Journal of Business Research, 22(2), 159-170.

Sijtsema S., Onwezen M., Reinders M., Dagevos H., Partanen A., Meeusen M., 2016. Consumer perception of bio-based products—An exploratory study in 5 European countries. NJAS - Wageningen Journal of Life Sciences, 77, 61-69. http://doi.org/10.1016/j.njas.2016.03.007.

Singh G., Pandey N., 2018. The determinants of green packaging that influence buyers' willingness to pay a price premium.

Australasian Marketing Journal, 26(3), 221-230.

Siracusa V., Rosa M., 2018. Sustainable Packaging. Sustainable Food Systems from Agriculture to Industry, 275-307. http://doi.org/10.1016/B978-0-12-811935-8.00008-1.

Suki M.N., 2016. Consumer environmental concern and green product purchase in Malaysia: structural effects of consumption values. Journal of Cleaner Production, 132, 204-214. http://doi.org/10.1016/j.jclepro.2015.09.087

Sun Y., Liu N., Zhao M., 2019. Factors and mechanisms affecting green consumption in China: A multilevel analysis. Journal of Cleaner Production, 209, 481-493. http://doi.org/10.1016/j.jclepro.2018.10.241

UNDP (United Nation Development Programme) (2015). Sustainable Development Goals. Retrieved July 10, 2018, from https://www.un.org/sustainabledevelopment/sustainable-development-goals/.

Van Leeuwen G., Mohnen P., 2016. Revisiting the Porter hypothesis: an empirical analysis of Green innovation for the Netherlands. Economics of Innovation and New Technology, 26(1-2), 63-77.

Wang Q., Zhou M., 2015. Research on the Food Green Packaging Under the Sustainable Development. Advance Journal of Food Science and Technology, 7(12), 910-913.

Wilson N., Rickard B., Saputo R., Ho S., 2017. Food waste: The role of date labels, package size, and product category. Food Quality and Preference, 55, 35-44. http://doi.org/10.1016/j.foodqual.2016.08.004.

Wong F., Yazdanifard R., 2015. Green Marketing: A Study of Consumers' Buying Behavior in Relation to Green Products. Global Journal of Management and Business Research, 15(5). 17-23.

Xie C., Bagozzi R., Grønhaug K., 2015. The role of moral emotions and individual differences in consumer responses to corporate green and non-green actions. Journal of the Academy of Marketing Science, 43(3), 333-356.

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ORIGINAL PAPER

POST-IMPLEMENTATION CHALLENGES OF ERP ADOPTION IN APPAREL INDUSTRY OF DEVELOPING COUNTRY

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ABSTRACT. **Background:** In the current tenure of fourth industrial revolution (Industry 4.0), time has come to revisit the issues of post-implementation challenges of Enterprise Resource Planning (ERP) systems in the apparel industry of developing countries around the globe. This bibliometric review aims to identify the post-implementation challenges of ERP in apparel industry of a developing country.

Methods and procedures: Total 4854 published papers during the period 2000-2021 from the databases of Scopus and ScienceDirect were scanned to identify the relevant 52 publications using PRISMA flow diagram. Full bibliometric information was synthesized to create term co-occurrence network map using VOSviewer1.6.16. Later, cross-mapping the bibliometric terms from the meta-analyses with the six in-depth qualitative interviews conducted in a developing country, authors established themes through three levels of association.

Results: Results of this study have portrayed three themes; technical, operational, and human. Apparel industry of developing country faces technical, operational, and human challenges at the post-implementation phase of ERP adoption.

Conclusions: Technical, operational, and human are the major categories of challenges that need to be addressed to sustain the ERP implementation for developing countries. So, practitioners at the industry level, consultants, policymakers in the apparel industry, IT experts along with other knowledge workers should pay attention to these issues to build ERP systems more stable. Finally, the qualitative paper ends with the direction for further research in this specific field of enterprise information systems.

Keywords: ERP, post-implementation, challenges; apparel, industry, bibliometric, qualitative.

INTRODUCTION

Enterprise Resource Planning (ERP) systems are designed to unite different functional areas of business. ERP solution integrates the segmented parts of data and information under a common database with the user interface. Thus, information becomes readily accessible on-demand to assist in the synchronization of business tasks as diverse as human resource management, accounting and finance, manufacturing and production, and supply chain management [Bjelland, Haddara, 2018]. ERP is the centralized and assimilated management of core business functionalities, habitually in real-time and eased by software and communication technology. ERP system can be defined as "an assimilated software suite that facilitates firms to attain a holistic sight of the business enterprise" [Ehie and Madsen, 2005]. ERP is a configurable information systems solution that incorporates data and information-based procedures within and across the functional extents of a firm [Parthasarathy, Sharma, 2017, Boza et al., 2015, Seethamraju, 2015]. With these features of ERP, it is clear that it has good potential to have been applied in the apparel industry. To enhance information sharing and other significant operations, many textile and apparel companies in developing countries employed centralized ERP systems as a solution for their

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day-to-day business operations [Ahmad et al., 2020, Nayak et al., 2019, Loon et al., 2016].

The prime objective of implementing the ERP solutions is to attain integration and coordination both within the firm and across the industry. This will in turn lead to cost reduction and profitability enhancement [Christopher, 2018, Lemonakis et al., 2018]. However, there is no certainty of success. Ruivo et al. [2020] argued that effective implementation of ERP systems is thoroughly related to a change in existing business processes. Specifically, firms that have implemented the ERP systems should have re-focused and relocated from a functional to a cross-functional and inter-organizational mode.

Rapid changes in the fashion and apparel industry compel firms in developing economies to adopt ERP though the total systems are costly, and once ERP systems are executed successfully, major benefits such as enhanced customer service, robust production arrangement, and condensed manufacturing costs can be attained [Syafira et al., 2020, Kamal, Mostafa, 2018 Majeed, Rupasinghe, 2017].

However, the success rate regarding the implementation is still squat and many firms that have obtained some advantages from ERP are yet to exploit the full potentials of ERP in their respective organizations. Gartner predicted that 90 percent of firms will face post-implementation problems regarding ERP [Sternad Zabukovšek et al., 2019]. Hence, for the developing countries, it has already been a big challenge.

Contemporary research suggests that the developing countries around the globe are emphasizing more on Information and Communication Technologies (ICTs), IT-enabled services (ITES), web, and mobile apps-based services, computer, and cloud-based information systems. To support this type of ICT based services, companies and SMEs have started adopting centralized information systems [Jayeola et al., 2020, Alsharari, Al-Shboul, Alteneiji, 2020, Razzaq, Mohammed, 2020, Moh'd Anwer, 2019, Kazmi, Mäntymäki, 2018, Rahman et al., 2017, Hoque et al., 2016, Venkatraman, Fahd, 2016]. Centralized information systems have also been implemented as ERP in the apparel manufacturing industry of a developing country, Bangladesh [Bashar, Hasin, Adnan, 2021; Chowdhury, Umme, Nuruzzaman, 2018, Bashar, Hasin, 2018, Asif, 2017].

Previous studies have been conducted basically on the adoption or pre-adoption stages of ERP in this specific field, especially in the context of developing countries. Studies have identified challenges regarding the pre-adoption of ERP in the apparel industry [Ahmad et al., 2020, Mahmud, Ramayah, Kurnia, 2017]. There is a dearth of enough literature on the post-implementation phase of ERP adoption in this field though challenges identification is very critical for any adopted information systems. Hence, identification of challenges at the post-implementation stage of information systems is required [Gcora, Chigona, 2019, Osnes et al., 2018]. In line with these studies, Lin et al. [2021], Domagała et al. [2021]; Hietala, Päivärinta [2021], Perera, Munasinghe [2020], Behera, Dhal [2020] have called for further research to explore and investigate the post-implementation challenges of ERP adoption. Thus this study underpins to investigate the following research question.

What are the post-implementation challenges of ERP adoption in the apparel industry of developing country?

To inspect and fulfill the research gap followed by the research question, the authors performed a bibliometric review of existing pieces of literature on the post-implementation challenges of ERP adoption in the apparel industry and compare it with in-depth qualitative interviews for further research augmentations.

METHODS AND PROCEDURES

We followed the basic four-step technique as suggested by Kovacs, Van Looy, Cassiman [2015]. The steps are literature search, selection process, data extraction, and outcome reporting. For yielding further robustness of this study, we compared the outcome with the feedback gathered from six employees working in the IT department of apparel manufacturing firms in Bangladesh. Using convenient sampling, those six employees were chosen and reached [Islam et al., 2021, Etikan, Musa, Alkassim, 2016]. Six qualitative interviews were deemed adequate [Creswell, Creswell, 2017, Sandelowski, 1995]. The qualitative data regarding the challenges of post-implementation of ERP systems in the apparel industry were transcribed and analyzed thematically [Saldana, 2011].

Literature search

A systematic search for scholarly peer-reviewed publications was carried out to explore the post-implementation challenges of ERP adoption in the context of the apparel industry. Two large full-text databases, Scopus and ScienceDirect have been chosen for this study. Scopus database has been chosen due to its wide range of dominant and advanced searching tools. Apart from this, it covers approximately 25 million abstracts from over 12,900 titles across 4,000 publishers. ScienceDirect has been chosen since it covers a wide variety of subject areas and disciplines, including information systems and technology.

Studies that were published during the period from 2000 to 2021 were included for both databases. Generic search strategies for systematic reviews have been followed [Koffel, 2015, Dieste, Padua, 2007].

Table 1. Searching parameters

Search keys	Data-base	Search field	Search parameters	Initial number of studies
ERP post-implementation challenges	Science Direct	All	ERP+post-implementation +challenges	4,071
ERP post-implementation challenges	Scopus	All	ALL (erp AND post-implementation AND challenges) AND PUBYEAR > 1999 AND PUBYEAR < 2022	783

Search keys, fields, parameters, and the initial number of studies (before filter) have been shown in Table 1. Initially, there were 4,071 and 783 studies were traced in ScienceDirect and Scopus respectively.

Selection process

For the selection process, authors followed the PRISMA flow diagram that is also known as "Preferred Reporting Items for Systematic Reviews and Meta-Analysis" [Stewart et al., 2015]. PRISMA flow diagram is widely used in identifying and analyzing quality publications in a specific domain of study [Panic et al., 2013].

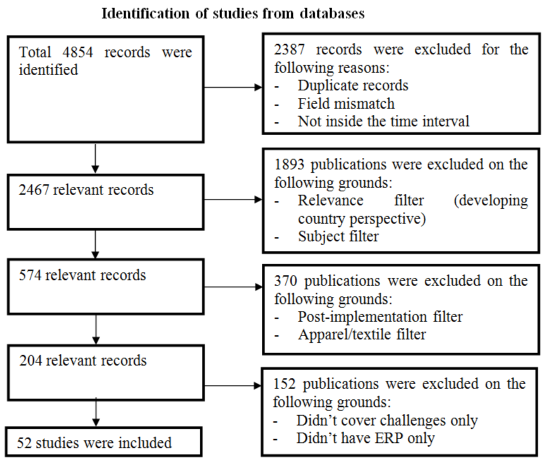

Fig. 1. Result of PRISMA flow diagram

Figure 1 depicts the step-by-step protocols followed to retrieve the final number of publications. An extensive filter-based search parameter has been used for the retrieval process. The exact search parameter is shown below.

ALL (erp AND post-implementation AND challenges AND apparel) AND PUBYEAR > 1999 AND PUBYEAR < 2022 AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ECON")) AND (EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "PSYC") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "MULT"))

52 publications have been retrieved finally through PRISMA flow diagram.

Data extraction

After the retrieval of those studies, the authors extracted the bibliometric information along with the text in the respective titles, abstracts, and keywords of the publications. Full bibliometric information is required to know the research trends [Safder, Hassan, 2019, Kalantari et al., 2017, Ellegaard, Wallin, 2015]. Hence, full bibliometric information has been exported in RIS form which is also known as the "Research Information Systems" format.

Outcome reporting

For reporting the outcome, at first, authors showed the trend of publications for the period 2000-2021 using pertinent graphs and charts. VOSviewer1.6.16 was used to create a map based on assembled bibliographic data. Co-occurrence as the type of analysis and keywords as the unit of analysis were set. Authors used full counting method. Later, term co-occurrence map was created based on extracted text data using VOSviewer1.6.16.

After the scientific reporting of the published papers, authors reported the result of the six in-depth qualitative interviews that were compared to the systematic reviews and added new insights to the body of knowledge in this specific field of research.

RESULTS

The trend of publications on ERP post-implementation challenges for the period 2000-2021 has been shown in Figure 2. The trend is upward rising as more and more publications came out after 2012. Because post-implementation challenges issue came to light after the initial adoption and implementation. Even when the authors extracted the publications from the database, it is seen that after 2012 the issue got the momentum, and still the challenges of post-implementation of ERP exist.

Figure 3 depicts the type of publications in the field of post-implementation challenges of ERP adoption. 61% of all publications recorded in the Scopus database during 2000-2021 were in the form of articles. 27.5% of publications were done in the form of conference papers since the issue is directly related to the industry.

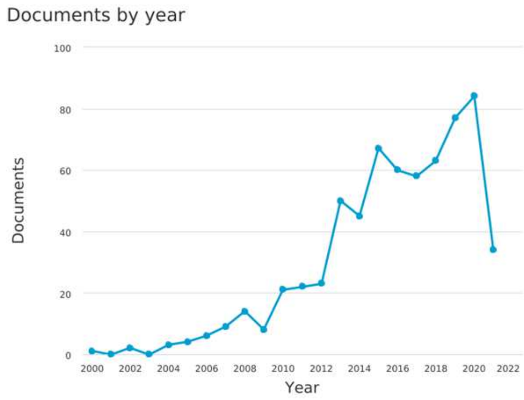

Fig. 2. Publications trend from 2000 to 2021

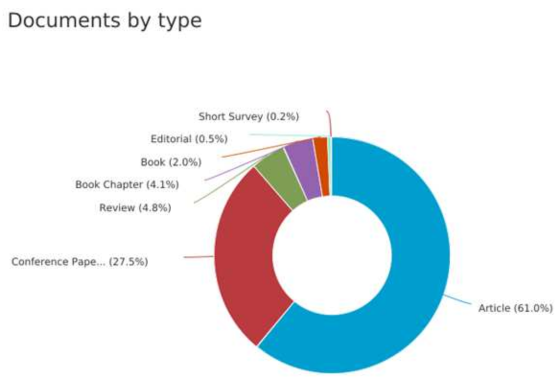

Fig. 3. Publications type from 2000 to 2021

Figure 4 exhibits a map based on bibliographic data. Co-occurrence as the type of analysis and keywords of the publications as the unit of analysis were set. Authors used full counting method to grip the whole picture. The map shows a network of identified terms like real usage of ERP, vendor support, cloud adoption, organizational performance, knowledge sharing and integration, training, customization. In the map, all of these terms are linked to the post-implementation of ERP.

Figure 5 is based on the title and abstract of the selected publications. The term co-occurrence map based on text data shows that risks, mechanism, organizational change, leadership style, intention, size of the firm, platform are the dominant terms that are connected to the post-adoption challenges in the network. External factors, key users, and cloud computing are not dominant in the network map though they are also connected.

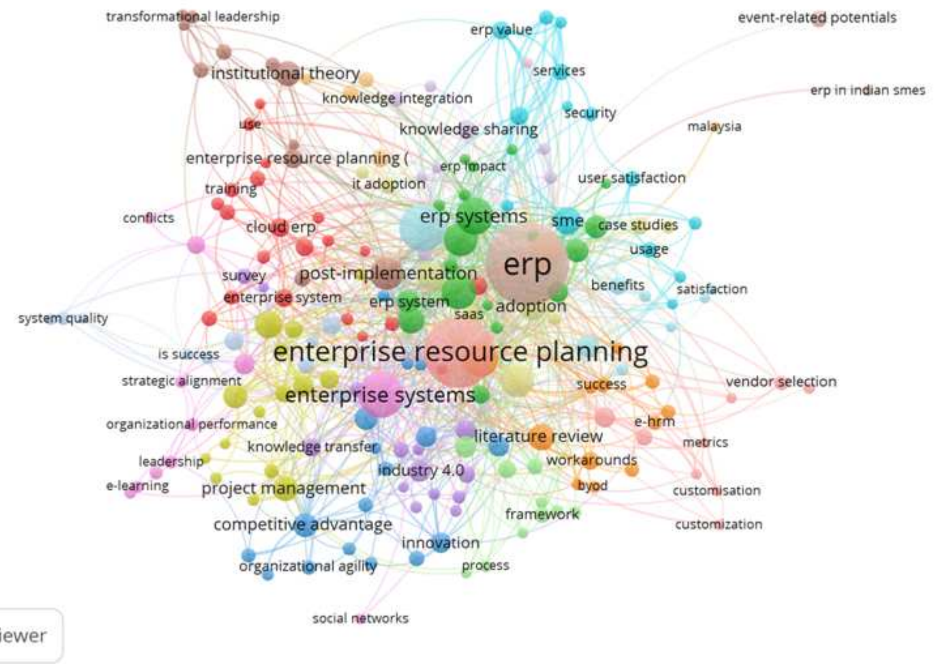

Fig. 4. Network mapping based on bibliographic data (full counting method)

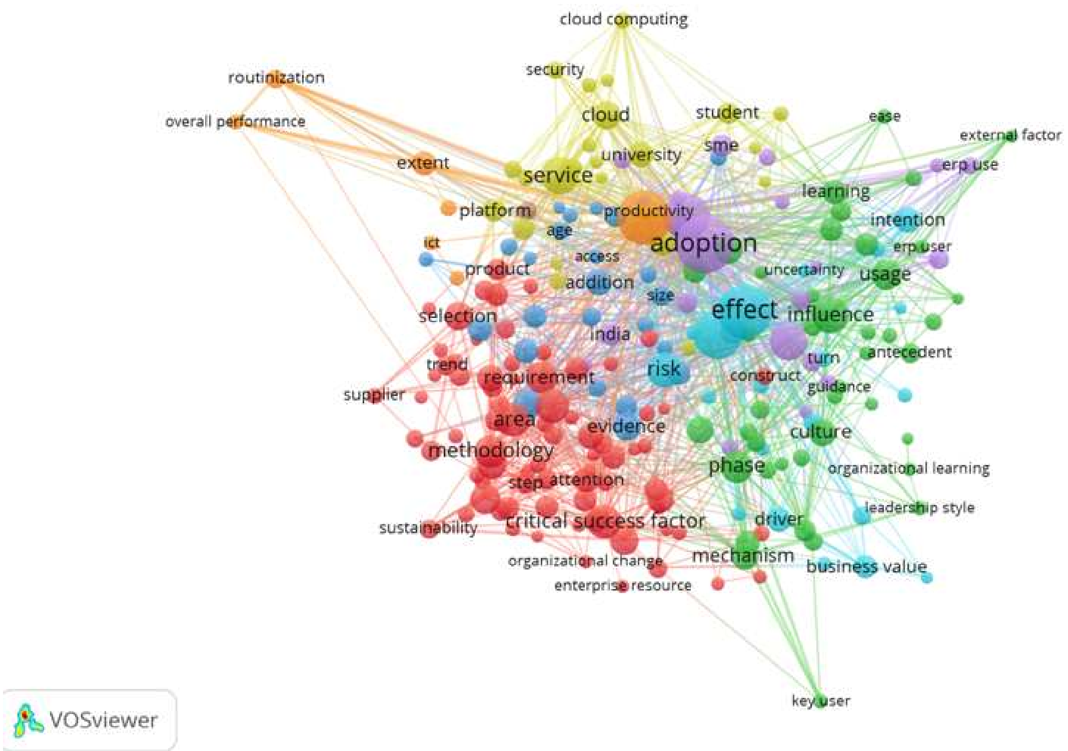

Fig. 5. Term co-occurrence mapping based on text data (full counting method)

INTERVIEW OUTCOMES

The interviews were taken from April, 2021 to May, 2021 via online platform due to COVID-19 issues. Before commencing each interview, interviewees were informed about the aims and objectives of the research. They were also informed that the interviews won't be revealed to any other party; so, they agreed to participate in the interview sessions. Each interview lasted for 15-20 minutes. The profiles of the interviewees are shown in Table 2.

Table 2. Interviewees' Profiles

Interviewees	Gender	Designation	Work experien-ce (years)
Interviewee 1	Male	Head of IT	16 years in apparel
Interviewee 2	Male	Systems Maintenance Engineer	5.5 years in apparel
Interviewee 3	Female	Systems Developer	3 years in ERP maintenance
Interviewee 4	Male	Head of MIS	14 years. But 6 years in the field of apparel.
Interviewee 5	Female	Database Analyst	4.5 years in apparel
Interviewee 6	Male	System Administrator	10 years in apparel

"I have been working as a database analyst for 4.5 years in this firm. We faced challenges like data loss, old and manually kept data export to the systems specifically. Personally, I worked on Oracle before, so I have found ERP easier to use. But after implementation, we need to have proper training since we worked on different software platforms before." [Interviewee 5]

Another interviewee opined that,

"*I have been working as a systems maintenance engineer. I am in this field for almost 5.5 years. We faced the first challenge last year while we wanted to upgrade the whole system. We had to rely heavily on our vendor company and it was costly. Now, we have decided to use open source ERP."* [Interviewee 2]

"I have been working specifically in the enterprise systems of apparel for six years. Well, as the head of this division, I try to lead the whole IT team. But you know, sometimes I see one or two of my team members feel stressed and they keen to change the department within our company. I have seen this type of challenge when the company introduced open source ERP." [Interviewee 4 added]

In this context interviewee 1 opined like that,

"*I am in this sector for almost 16 years and currently working as the head of IT at this firm. From my experience, some companies suffer at the post-implementation phase due to their financial constraints and lack of prior understanding. May be they haven't access the actual necessity before. We faced some problems related to the customization of our installed ERP. Actually, here in our company, we need production and manufacturing module blended with supply chain, accounting module, sales module, and HR module*." [Interviewee 1]

"I am currently working as the system administrator. We faced security risks while we opened our systems to our partners and resellers. Even this year when we started to launch our smartphone app, we faced problems because the app worked well on android devices only. Training and development is needed for our IT team especially in smartphone apps development which is very essential these days" [Interviewee 6]

"I am working as a systems developer for 3 years in the IT division of apparel. I often face security threats because of erroneous configuration. I need to fix frequent problems like inaccuracy in inventory, incorrect invoices, mismatch in shipment, and unaligned production volume. These things happen due to human error and thus cause the systems to be halt." [Interviewee 3 added].

CROSS-MAPPING AND THEMES DEVELOPMENT

At this stage, authors developed themes using cross-mapping the bibliometric terms from the meta-analyses with the interviews. Table 3 has been constructed to develop themes.

Table 3. Cross-mapping and themes development

Terms extracted from meta-analyses	Terms extracted from qualitative interviews	1st level association	2nd level association	3rd level association	Themes
Vendor support, cloud adoption, organizational performance, knowledge sharing and integration, training, customization, risks, mechanism, organizational change, leadership style, intention, size of the firm, platform, knowledge transfer, security, access, uncertainty, guidance, requirement, workarounds	Data loss, manually kept data, training, vendor, costly, open source ERP, stressed, financial constraints, customization, security, risks, production and manufacturing module, supply chain, accounting module, sales module, HR module, smartphone app, training and development, security threats, erroneous configurations, inaccurate inventory, incorrect invoices, shipment mismatch, unaligned production volume	Vendor access, data management, cloud support, security, open-source facility, smartphone apps facility, configurations problem, training and development	System vendor support, system configuration, IS routine training, platform, IS security	Systems and technological challenge	Technical
				Functional and organizational challenges	Operational
			Modules, scalability, organizational, functional	Human behavioral challenges	Human
		organizational performance, knowledge sharing and integration, knowledge transfer, ERP modules, production, inventory, shipment, organizational size	Individual, behavioral, human		
		Intention, leadership style, stress, human errors and erroneous activities			

DISCUSSION AND CONCLUSION

Post-implementation challenges of ERP adoption in apparel industry thematically fall into the categories of technical, operational, and human. The study measured and identified these themes from the perspective of developing country. Existing literatures were cross-mapped with the practical insights from a developing country to intend the themes. It is obvious that challenges at the post-implementation phase of ERP adoption stem from the technical perspective followed by operational and human perspectives. Human consequences have been prioritized for the post-implementation of the ERP system since new challenges may arise caused by intentional or unintentional errors and stress. Operational challenges stem from the inability to maintain organizational performance, lack of knowledge sharing and integration, inappropriateness of ERP modules, wrong estimations in production and inventory volume. This study has shown that these three are the major categories of challenges that need to be addressed to sustain the ERP implementation for the developing countries. Hence, practitioners at the industry level, consultants, policymakers in the apparel industry, IT experts along with other knowledge workers should pay attention and focus on these issues to build ERP systems more stable and advantageous.

Further empirical studies may be conducted taking into consideration these three themes; technical, operational, and human as the challenges of post-implementation of ERP adoption in apparel industry for the developing economies.

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REFERENCES

Ahmad S., Miskon S., Alabdan R., Tlili I., 2020. Exploration of influential determinants for the adoption of business intelligence system in the textile and apparel industry. Sustainability, 12(18), 7674. http://doi.org/10.3390/su12187674

Ahmad S., Miskon S., Alabdan R., Tlil, I., 2020. Towards sustainable textile and apparel industry: Exploring the role of business intelligence systems in the era of industry 4.0. Sustainability, 12(7), 2632. http://doi.org/10.3390/su12072632

Alsharari N.M., Al-Shboul M., Alteneiji S., 2020. Implementation of cloud ERP in the SME: evidence from UAE. Journal of Small Business and Enterprise Development. http://doi.org/10.1108/JSBED-01-2019-0007

Asif A.A.H., 2017. An overview of sustainability on apparel manufacturing industry in Bangladesh. Science Journal of Energy Engineering, 5(1), 1. http://doi.org/10.11648/j.sjee.20170501.11

Bashar A., Hasin M.A.A., 2018. Lean manufacturing awareness and its implementation status in the apparel industry in Bangladesh. International Journal of Lean Enterprise Research, 2(3), 202-217. http://doi.org/10.1504/IJLER.2018.093607

Bashar A., Hasin A.A., Adnan Z.H., 2021. Impact of lean manufacturing: evidence from apparel industry in Bangladesh. International Journal of Lean Six Sigma. http://doi.org/10.1108/IJLSS-01-2020-0005

Behera R.K., Dhal S.K., 2020. A Meta-Analysis of Impact of ERP Implementation. In Advances in Data Science and Management, 123-135. Springer, Singapore. http://doi.org/10.1007/978-981-15-0978-0_12

Bjelland E,. Haddara M., 2018. Evolution of ERP systems in the cloud: A study on system updates. Systems, 6(2), 22. http://doi.org/10.3390/systems6020022

Boza A., Cuenca L., Poler R., Michaelides Z., 2015. The interoperability force in the ERP field. Enterprise Information Systems, 9(3), pp.257-278. http://doi.org/10.1080/17517575.2013.866697

Chowdhury M.M.H., Umme N.J., Nuruzzaman M., 2018. Strategies for mitigating supply-side barriers in the apparel supply chain: A study on the apparel industry of Bangladesh. Global Journal of Flexible Systems Management, 19(1), 41-52. http://doi.org/10.1007/s40171-017-0180-6

Christopher M., 2018. New directions in logistics. In Global logistics and distribution planning, 27-38. Routledge. http://doi.org/10.1201/9780203753149-4

Creswell J.W., Creswell J.D., 2017. Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Dieste O., Padua A.G., 2007. September. Developing search strategies for detecting relevant experiments for systematic reviews. In First International Symposium on Empirical Software Engineering and Measurement, ESEM 2007, 215-224. IEEE. http://doi.org/10.1109/ESEM.2007.19

Domagała A., Grobler-Dębska K., Wąs, J., Kucharska E., 2021. Post-Implementation ERP Software Development: Upgrade or Reimplementation. Applied Sciences, 11(11), 4937. http://doi.org/10.3390/app11114937

Ehie I.C., Madsen M., 2005. Identifying critical issues in enterprise resource planning (ERP) implementation. Computers in industry, 56(6), 545-557. http://doi.org/10.1016/j.compind.2005.02.006

Ellegaard O., Wallin J.A., 2015. The bibliometric analysis of scholarly production: How great is the impact?. Scientometrics, 105(3), 1809-1831. http://doi.org/10.1007/s11192-015-1645-z

Etikan I., Musa S.A., Alkassim, R.S., 2016. Comparison of convenience sampling and purposive sampling. American journal of theoretical and applied statistics, 5(1), 1-4. http://doi.org/10.11648/j.ajtas.20160501.11

Gcora N., Chigona W., 2019. Post-implementation evaluation and challenges of Integrated Financial Management Information Systems for municipalities in South Africa. South African Journal of Information Management, 21(1), 1-12. http://doi.org/10.4102/sajim.v21i1.1066

Hietala H., Päivärinta T., 2021. Benefits Realisation in Post-Implementation Development of ERP Systems: A Case Study. Procedia Computer Science, 181, 419-426. http://doi.org/10.1016/j.procs.2021.01.186

Hoque M.R., Saif A.N.M., AlBar A.M., Bao Y., 2016. Adoption of information and communication technology for development: A case study of small and medium enterprises in Bangladesh. Information Development, 32(4), 986-1000. http://doi.org/10.1177/0266666915578202

Islam M.A., Igwe P.A., Rahman M., Saif A.N.M., 2020. Remote working challenges and solutions: Insights from SMEs in Bangladesh during the COVID-19 pandemic. International Journal of Quality and Innovation. http://doi.org/10.1504/IJQI.2021.10035030

Jayeola O., Sidek S., Rahman A.A., Bali Mahomed A.S., Jimin H., 2020. Contextual factors and strategic consequences of cloud enterprise resource planning (ERP) adoption in Malaysian manufacturing SMEs: a conceptual framework. https://www.um.edu.mt/library/oar/handle/123456789/63114

Kalantari A., Kamsin A., Kamaruddin H.S., Ebrahim N.A., Gani A., Ebrahimi A., Shamshirband S., 2017. A bibliometric approach to tracking big data research trends. Journal of Big Data, 4(1), 1-18. http://doi.org/10.1186/s40537-017-0088-1

Kamal M., Mostafa N., 2018. The Influence of Enterprise Resource Planning (ERP) systems on Apparel Factories. Architecture, Arts and Humanistic Science Magazine, 29(5913), 1-26. http://doi.org/10.12816/0045767

Kazmi S., Mäntymäki M., 2018. Benefits and challenges of enterprise resource planning for Pakistani SMEs (Master's thesis, University of Turku, Finland).

Koffel J.B., 2015. Use of recommended search strategies in systematic reviews and the impact of librarian involvement: a cross-sectional survey of recent authors. PloS one, 10(5), e0125931. http://doi.org/10.1371/journal.pone.0125931

Kovacs A., Van Looy B., Cassiman B., 2015. Exploring the scope of open innovation: a bibliometric review of a decade of research. Scientometrics, 104(3), 951-983. http://doi.org/10.1007/s11192-015-1628-0

Lemonakis C., Sariannidis N., Garefalakis A., Adamou A., 2020. Visualizing operational effects of ERP systems through graphical representations: current trends and perspectives. Annals of Operations Research, 294(1), 401-418. http://doi.org/10.1007/s10479-018-2851-x

Lin Y.Y., Nagai Y., Chiang T.H., Chiang H.K., 2021. SuccERP: The design science based integration of ECS and ERP in post-implementation stage. International Journal of Engineering Business Management, 13, p.18479790211008812. http://doi.org/10.1177/18479790211008812

Loon L.K., Hassan M.G., Udin Z.M., 2016. The effect of supply chain technology adoption: An empirical study of textile and apparel industry in Malaysia. Journal of Engineering and Applied Sciences, 100(8), 1727-1734.

Mahmud I., Ramayah T., Kurnia S., 2017. To use or not to use: Modelling end user grumbling as user resistance in pre-implementation stage of enterprise resource planning system. Information Systems, 69, 164-179. http://doi.org/10.1016/j.is.2017.05.005

Majeed A.A., Rupasinghe T.D., 2017. Internet of things (IoT) embedded future supply chains for industry 4.0: An assessment from an ERP-based fashion apparel and footwear industry. International Journal of Supply Chain Management, 6(1), 25-40.

Moh'd Anwer A.S., 2019. Towards better understanding of determinants logistical factors in SMEs for cloud ERP adoption in developing economies. Business Process Management Journal. http://doi.org/10.1108/BPMJ-01-2018-0004

Nayak R., Akbari M., Far S.M., 2019. Recent sustainable trends in Vietnam's fashion supply chain. Journal of Cleaner Production, 225, 291-303. http://doi.org/10.1016/j.jclepro.2019.03.239

Osnes K.B., Olsen J.R., Vassilakopoulou P., Hustad E., 2018. ERP systems in multinational enterprises: a literature review of post-implementation challenges. Procedia computer science, 138, 541-548. http://doi.org/10.1016/j.procs.2018.10.074

Panic N., Leoncini E., De Belvis G., Ricciardi W., Boccia S., 2013. Evaluation of the endorsement of the preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement on the quality of published systematic review and meta-analyses. PloS one, 8(12), e83138. http://doi.org/10.1371/journal.pone.0083138

Parthasarathy S., Sharma S., 2017. Impact of customization over software quality in ERP projects: an empirical study. Software Quality Journal, 25(2), 581. http://doi.org/10.1007/s11219-016-9314-x

Perera B.H.D., Munasinghe S.L.A., 2020. Factors Effect to the Post ERP Implementation in Sri Lankan Apparel Industry. http://ir.kdu.ac.lk/handle/345/2850

Rahman M.A., Qi X., Saif A.N.M., Ibrahim I.B., Sultana R., 2017. Assessing service quality of online bill payment system using extended SERVQUAL model (SERVQUAL-Butterfly model): A case study of Dhaka electric supply company limited (DESCO), Bangladesh. Cogent Business & Management, 4(1), 1301195. http://doi.org/10.1080/23311975.2017.1301195

Razzaq A., Mohammed A.A., 2020. Cloud ERP in Malaysia: Benefits, challenges, and opportunities. International Journal, 9(5). http://doi.org/10.30534/ijatcse/2020/85952020

Ruivo P., Johansson B., Sarker S., Oliveira T., 2020. The relationship between ERP capabilities, use, and value. Computers in Industry, 117, 103209. http://doi.org/10.1016/j.compind.2020.103209

Safder I., Hassan S.U., 2019. Bibliometric-enhanced information retrieval: a novel deep feature engineering approach for algorithm searching from full-text publications. Scientometrics, 119(1), 257-277. http://doi.org/10.1007/s11192-019-03025-y

Saldana J., 2011. Fundamentals of qualitative research. OUP USA.

Sandelowski M., 1995. Sample size in qualitative research. Research in nursing & health, 18(2), 179-183. http://doi.org/10.1002/nur.4770180211

Seethamraju R., 2015. Adoption of software as a service (SaaS) enterprise resource planning (ERP) systems in small and medium sized enterprises (SMEs). Information systems frontiers, 17(3), 475-492. http://doi.org/10.1007/s10796-014-9506-5

Sternad Zabukovšek S., Picek R., Bobek S., Šišovska Klančnik I., Tominc P., 2019. Technology acceptance model based study of students' attitudes toward use of enterprise resource planning solutions. Journal of Information and Organizational Sciences, 43(1), 49-71. http://doi.org/10.31341/jios.43.1.4

Stewart L.A., Clarke M., Rovers M., Riley R.D., Simmonds M., Stewart G., Tierney J.F., 2015. Preferred reporting items for a systematic review and meta-analysis of individual participant data: the PRISMA-IPD statement. Jama, 313(16), 1657-1665. http://doi.org/10.1001/jama.2015.3656

Syafira A., Puspitasari W., Witjaksono W., 2020. Analysis and Evaluation of User Acceptance on the Use of Enterprise Resource Planning (ERP) Systems at PT Trisco Tailored Apparel Manufacturing. IJAIT (International Journal of Applied Information Technology), 4(01), 17-26. http://doi.org/10.25124/ijait.v4i01.2852

Venkatraman S., Fahd, K., 2016. Challenges and success factors of ERP systems in Australian SMEs. Systems, 4(2), 20. http://doi.org/10.3390/systems4020020

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ORIGINAL PAPER

ORGANIZATIONAL AMBIDEXTERITY WITHIN SUPPLY CHAIN MANAGEMENT: A SCOPING REVIEW

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ABSTRACT. Background: Organizational ambidexterity is an emerging concept and it permeates too many functional domains in the discussion of organizational performance. The importance of understanding this concept motivates researchers to explore organizational ambidexterity as internal and external capabilities in the context of supply chain. Despite its importance in building oriented capabilities to organizations, little information is known about organizational ambidexterity in supply chain context. The objective of this review is to produce a comprehensive mapping of themes related to organizational ambidexterity studies in supply chain research, particularly in improving firm performance.

Method: A scoping review of the literature was conducted using Web of Science (WoS), Scopus and EconBiz databases to identify what is the nature of published scientific literature on this topic and what are the emerging themes of organizational ambidexterity in relation to supply chain studies.

Result: This study found three main themes and eleven sub-themes in relation to inter-organization ambidexterity in the supply chain context. The main themes include learning process, outcome and leadership. The review indicates that most of the studies are conducted in understanding learning process.

Conclusion: The management of supply chain has a positive association with organizational ambidexterity. Supply chain operations involve selection, development, and implementation of new process(es) or technology (exploitation) - the outcome of a prior search procedure (exploration), which has been described as a sequential approach to exploration and exploitation and both processes are important especially in a dynamic environment. The findings from this scoping review indicate the importance of developing and managing a supply chain that supports exploration and exploitation practices. Therefore, managers should understand that maximizing a firm's current skills is critical to profitability and market share. While continuous refinement of existing knowledge is important, it is the generation and application of new knowledge that leads to increased value (profitability) and competitive advantage. Organizational ambidexterity within supply chain management provides significant benefits to big firms in improving their long-term efficiency. This offers avenue for future research to compare the effect of organizational ambidexterity in small firm.

Keywords: scoping review, organizational ambidexterity, supply chain management, supply network.

INTRODUCTION

Recent development in the environment has compelled business organisations to revisit their strategies in building resilient network to survive in the volatile environment. Organizational ambidexterity has been introduced as the ability to pursue incremental and discontinuous innovation simultaneously and this is achieved by hosting multiple contradictory structures, processes, and cultures within the same firm [O'Reilly III, Tushman, 2013]. Many studies have ventured into this topic, and recently more researchers are interested to study organizational ambidexterity beyond the scope of a single organization [Aoki, Wilhelm, 2017; Kristal, Huang, Roth, 2010]. The main idea within this literature focuses on the pursuit of finding the balance between exploration and exploitation through inter-organizational relationships and

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alliances [Partanen et al., 2020]. As organizational ambidexterity has been extensively discussed from the lens of a single firm, researches related to achieving ambidextrous capabilities through inter-organizational collaboration such as supply chain is still at infancy and requires more deliberation.

According to Birkinshaw and Gibson [2004], organizational ambidexterity is the ability of an organization's to carry out exploration and exploitation activities in order to generate values needed for the organization's long-term success. In particular, exploration competence focuses on the ability of a firm to learn new knowledge, to find new capabilities and to explore new opportunities to expand business activities, while exploitation competence refers to the ability of a firm to use existing internal knowledge, to implement existing capabilities and to make sound decisions to maximize profits from firm activities [Benner, Tushman, 2003, O'Reilly III, Tushman, 2007]. However, balancing exploration and exploitation in the context of innovation for long-term success and sustainability is not easy, and in fact is a very challenging task [March, 1991, McGrath, 2001, McNamara, Baden-Fuller, 1999]. Some researchers i.e. Gupta, Smith and Shalley [2006] and; Simsek et al. [2009] suggested that the balance can only be achieved through structural or temporal separation. This notion is in line with earlier discussion on ambidexterity that suggests firms should develop different business units to simultaneously benefit from alignment and adaptation [i.e. Puranam, Singh, Zollo, 2006, Tushman, O'Reilly III, 1996]. As a result of this, organizational ambidexterity becomes a valid concept in large firms as structural or temporal separations are more evident in this type of firms.

Generally, the importance of ambidexterity can also be manifested through the collaborative initiatives in the supply chain environment [Aslam et al., 2020]. From the perspective of inter-organizational environment, ambidexterity capabilities would allow firm to mobilize the network to explore and exploit in order to make sound decisions for long-term profits [Cenamor, Parida & Wincent, 2019]. According to research, ambidexterity in the workplace leads to better levels of dynamism [Ricciardi, Zardini & Rossignoli, 2016], organization performance [Boumgarden, Nickerson & Zenger, 2012; Junni et al., 2013; Ramachandran, Lengnick-Hall & Badrinarayanan, 2019] and competitive advantage [O'Reilly III & Tushman, 2011]. While substantial study is under way into organizational ambidexterity, there is very little research from the supply chain perspective [see for some notable exceptions: Kristal, Huang & Roth, 2010; Ojha, Acharya & Cooper, 2018; Partanen et al., 2020; Rojo-Gallego-Burin, Llorens-Montes & Perez-Arostegui, 2016]. Clearly, organizational ambidexterity and supply chain management are rarely considered in the same context.

Thus, the aim of this paper is to produce a comprehensive mapping of the extant of research that has been done on organizational ambidexterity in the context of supply chain. To accomplish this, a scoping review was conducted in order to combine them and also to demonstrate research gaps and directions through several theoretical lenses. Scope review is an adequate approach for strengthening the suggested research problem, summarising and disseminating research findings and thus justifying the contribution of research via gaps in identification [Arksey & O'Malley, 2005; Peterson et al., 2016]. In other words, this scoping review would allow researchers to understand the importance of the concept from a different perspective that opens the door for more deliberation of the concept. Through contextual mapping of researches in this context would also inform us the plausibility of extending the concept beyond supply chain environment. In addition to this introductory section, this paper is structured as follows: Section 2 describes the proposed scoping review method, while Section 3 details the results. Finally, Section 4 brings the discussion, recommendation and conclusion in the subject.

Ambidexterity and supply chain

Ambidexterity in the context of supply chain can be discussed from several perspectives. Firstly, ambidexterity can be discussed as capabilities that can bring benefits by enabling the efficient use of existing supply chains while capitalizing on unexplored supply chain opportunities, particularly in a dynamic environment [Partanen et al., 2020]. As suggested by Abd Aziz, Hanafiah and Abd Latif [2020], a more systematic supply chain management will ensure continuity of firm's success. After all, innovations and new ideas frequently arise in networks [Baum, Calabrese, Silverman, 2000, Powell, Koput, Smith-Doerr, 1993], and suppliers in particular are instrumental in promoting innovation [Song, Di Benedetto, 2008]. Therefore, firms especially in the manufacturing sector are able to take advantage by exploiting existing capabilities and simultaneously building new competitive advantage for the future [Kristal, Huang, Roth, 2010].

Secondly, supply chain ambidexterity can be discussed from the perspective of process, looking at the combination of two separate activities, namely exploration and exploitation. According to Levinthal and March [1993], supply chain exploitation focuses on clearly specified short-term, measurable objectives, reliability, risk mitigation and overall supply chain performance which can be regarded as a conventional strategy for management of the supply chain. On the other hand, supply chain exploration refers to long-term success, uncertain outcomes, high autonomy and innovation in the supply chain [Adler, Goldoftas, Levine, 1999, Levinthal, March, 1993, Ojha et al., 2018]. Therefore, the combination of exploration and exploitation in the context of supply chain involves the process of refining and expanding the existing resources in the network, whilst developing skills for future advantages in the supply chain environment [Ojha et al., 2018, Partanen et al., 2020].

Emerging discussions in the supply chain environment indicate the importance to leverage the supply chain network through developing organizational level ambidexterity skills in exploiting existing supply chain related activities and exploring new capabilities. Past studies have shown empirical evidences about organizational ambidexterity and its impact on the supply chain. For example, Rojo-Gallego-Burin, Llorens-Montes and Perez-Arostegui [2016] found that supply chain ambidexterity helps manufacturing firms to achieve supply chain flexibility, which, in turn, builds supply chain skills and improves firm performance. A study by Im and Rai [2008] suggested positive effect on the performance when long-term relations between supply chain vendors stimulate explorative and exploitative knowledge sharing. Interestingly, Kristal, Huang and Roth [2010] found that the ambidextrous supply chain strategies are pursued to be abreast with combined competitive abilities of manufacturers (i.e. their capacity to simultaneously excel in quality, delivery speed, versatility in processes and low cost) that lead to firm efficiency. Drawing from these studies, a reciprocal and reinforcing effect is likely to exist between exploration and exploitation of organizational ambidexterity in the supply chain [He, Wong, 2004]. This indicates that in the context of supply chain, exploration practices enables the creation of new information and ideas, however, they can only generate value if they are exploited, selected and implemented [Ojha, Acharya, Cooper, 2018].

Nevertheless, review from previous literature shows that knowledge about organizational ambidexterity within supply chain is still at infancy and need more clarification. To the best of our knowledge, review on research works within this topic has not been specifically performed, yet issue of managing collaborative network is becoming the focal of discussion in dynamic business environment. Although systematic review has been done on organizational ambidexterity, it is focused on firm [Pertusa-Ortega et al., 2020], but not dedicated to explicate its importance in the supply chain context. Similarly, other narrative explorations only focus on persistent tensions arising from the exploration – exploitation continum [Andriopoulos, Lewis, 2009]. Looking at the importance of organizational ambidexterity in the context of supply chain, this scoping review is imperative to map previous works in this topic in order to set the importance of organizational ambidexterity within the supply chain. Using this approach, the conclusion will highlight the advantages that can be derived from leveraging the supply chain network using supply chain ambidexterity. The scoping review approach will establish the condition of evidence of an issue that offers ample opportunity to clarify before rigorous empirical studies are carried out [Levac, Colquhoun, O'Brien, 2010].

MATERIAL AND METHODS

The framework for this scoping review is based on the study of Arksey and O'Malley [2005], along with recommendations by Levac, Colquhoun and O'Brien [2010]. This method is applied to identify all materials related to this topic with the objective to provide comprehensive overview of the breadth of the concept, excluding the depth of the evidence [Davis, Drey, Gould, 2009]. In other words, scoping review does not comply with quality assessment [Levac, Colquhoun, O'Brien, 2010] and this issue posed a limitation to this exercise [Pham et al., 2014]. Based on this premise, five methodological stages in the scoping review process will be applied as explained below.

Stage 1 relates to the identification of research questions. For this scoping review, two research questions have been developed: Firstly, what is the nature of published scientific literature on organizational ambidexterity within supply chain literature? Secondly, what are the emerging themes in relation to ambidexterity within the context of supply chain?

Stage 2 relates to the identification of the relevant studies. Academic journals were retrieved from three main databases: Web of Science (WoS), Scopus and EconBiz. Web of Science (WoS) is a database by Thomson Reuters. The collection covers more than 12,000 live journals, 23 million patents, 148,000 congress proceedings, with more than 40 million and 760 million references comprising of various disciplines of knowledge such as environmental studies, sciences, social sciences, and technology since 1945. Scopus database was introduced by Elsevier in 2004, with citation analysis since 1996 that covers bibliographic database of scientific, multidisciplinary and international literature [Sánchez, Del Río, García, 2016]. Finally is EconBiz, a business and economic studies portal developed by the German National Library of Economics that includes over 10 million publications from various databases - journal articles, books, and working papers, online and print, open access and licenced material [Clermont, Dyckhoff, 2012]. The search strategy included a comprehensive search string of keywords related to organizational ambidexterity i.e. ambidexterity, organisational ambidexterity, ambidextrous, supply chain management, supply chain, supply network combined with Boolean operators OR and AND (Table 1).

Stage 3 relates to the screening to remove redundant articles. To perform this, the first criterion of selection is the type of literature in which this research is focused. For this exercise, only research articles and conference proceedings are included. Both sources of documents serve as the primary source of analytical evidences. In addition, the study exclude publications in the form of systematic review articles, review articles, meta-analysis articles, meta-synthesis articles, book series, book chapters and newspaper articles. All publications that are selected are published in English. Importantly, only articles published within the last six years (2016-2021) were included and articles from other fields of sciences such as agricultural science and biology are not selected in order to avoid irrelevant article or proceeding paper (Table 2).

Stage 4 involves the charting of the data. Specifically, the data obtained will be tabulated (Table 3) using Microsoft Excel to assist thematic and comparative analysis. Information on authorship, year, research design, variables or construct, key findings and theme were recorded in this form.

Stage 5 involves processes to collate, summarize, and report the results. Common themes and findings from the articles are compiled to understand the importance of organizational ambidexterity within suppply chain context and the extent of emerging themes researched under this topic. Other important information that is recorded is location of study, year of publication and other relevant information to the objectives of the study.

Table 1. The search string

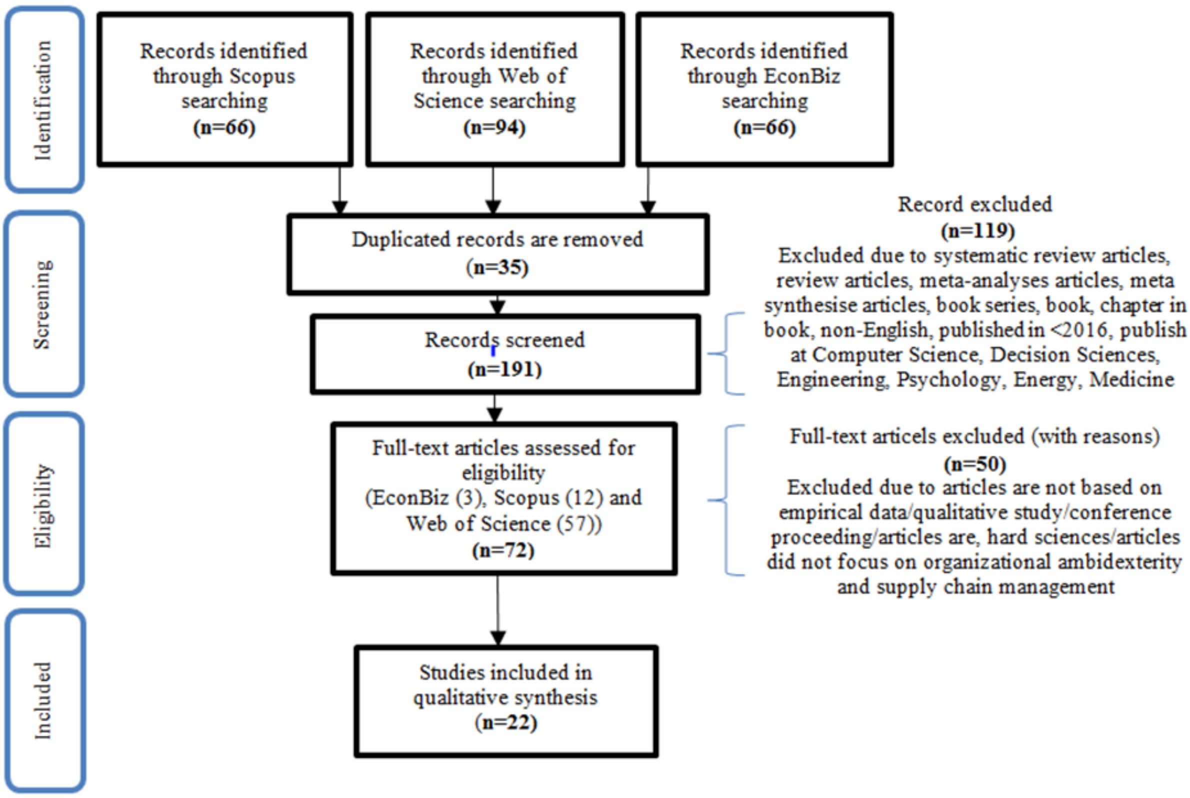
Database search string	
WoS	TS=(("Organizational ambidexterity" OR "ambidexterity" OR "organisational ambidexterity" OR "ambidextrous") AND ("Supply chain management " OR "supply chain" OR "supply network"))
Scopus	TITLE-ABS-KEY (("Organizational ambidexterity" OR "ambidexterity" OR "organisational ambidexterity" OR "ambidextrous") AND ("Supply chain management " OR "supply chain" OR "supply network"))
EconBiz	("Organizational ambidexterity" OR "ambidexterity" OR "organisational ambidexterity" OR "ambidextrous") AND ("Supply chain management " OR "supply chain" OR "supply network"))

Table 2. The inclusion and exclusion criteria

Criterion	Eligibility	Exclusion
Literature type	Journal (research articles), conference proceeding	Journals (review), book series, book, chapter in book,
Language	English	Non-English
Time line	Between 2016 and 2021	<2016
Subject area	Business, Management and Accounting, Social Sciences, Economics, Econometrics and Finance	Computer Science, Decision Sciences, Engineering, Psychology, Energy, Medicine

RESULTS

Following the search strategies explained above, 226 articles were identified from the database search. Out of this number, 35 articles were excluded from the initial hit due to duplication. Based on the title and abstract, 119 articles were then excluded due to types of review (systematic, meta-analysis etc.), language, and subject. From the remaining 72 articles, 50 articles were further excluded after full reading of the articles due to apparent irrelevancy to the objective of the scoping review. After going a rigor process of selection, only 22 articles were found to be relevant and fulfill the objective of this study based on preferred reporting items for systemic review (PRISMA, [Moher et al., 2015] (Fig. 1)).



Source: adapted from Moher et al., 2015

Fig. 1. Flow diagram of the study selection process using the Preferred Reporting Items for Systematic Reviews (PRISMA)

The selection of articles was only focused on quantitative empirical studies from journal articles within a period of 6 years based on several factors. Firstly, conference proceedings were not included because there was a lack of systematization and transparency due to traditional reviews which likely influenced by the author's subjectivity [Hodgkinson, Ford, 2014]. Secondly, the concept of supply chain ambidexterity only emerged after 2015 [Ojha et al., 2018, Partanen et al., 2020]. Thirdly, the research on particular topic which has been carried out for a period of at least 6 years indicates the maturity of the subject [Kraus, Breier, Dasí-Rodríguez, 2020]. Therefore, it is appropriate for this study to make a selection of quality articles at least within 6 years to conduct a scoping review.

Main findings

Based on the criteria above, Table 3 shows 22 articles of current research that were included for the scoping review [Ardito et al., 2018, Aslam et al., 2018, Aslam et al., 2020, Bravo, Ruiz-Moreno, Montes, 2018, Cheng, Lu, 2017, Gu, Yang, Huo, 2020, Gualandris, Legenvre, Kalchschmidt, 2018, Huang, Lu, 2020, Im, Rai, Lambert, 2019, Jermsittiparsert, Pithuk, 2019, Luu, 2017, Mehdi, Ahmed, 2019, Ojha, Acharya, Cooper, 2018, Partanen et al., 2020, Pu, Wang, Chan, 2018, Rojo-Gallego-Burin et al., 2020, Rojo-Gallego-Burin, Llorens-Montes, Perez-Arostegui, 2016, Rojo-Gallego-Burin, Perez-Arostegui, Llorens-Montes, 2020, Shukor et al., 2020, Tuan, 2016, Wamba et al., 2020, Wei et al., 2019].

The scoping exercise has identified 11 subthemes under three major headings. The major headings are process, outcome and enabler. First, the theme process emerged based on the developing capabilities to realize exploration and exploitation and the learning processes involved in knowledge acquisition and knowledge sharing. Two major capabilities that often become the subject of scrutiny under supply chain ambidexterity are network capability and information technology (IT) capability. Second, of the sub themes falls under outcome are agility, flexibility, resilience, and adaptability. Third, the sub theme for enabler that has been explored for organizational ambidexterity is leadership, whereby support from different types of leadership (i.e. transformational, ambidextrous) yields better supply chain ambidexterity.

The analysis also found that majority of the articles focus more on learning and agility which indicate the importance of supply chain ambidexterity assimilating new learning (exploration) and applying what is learned (exploitation) to improve profitability. Therefore, there is need to understand how supply chain ambidexterity could affect how businesses operate in the dynamic environment.

Table 3. Charting form

Publication	Variables/Construct	Key findings	Theme
Wamba et al. [2020] *United States*	Independent: big data analytics. Mediating: supply chain ambidexterity Moderating: environmental dynamism. Dependent: organizational performance	Big data analytics can help enhance supply chain ambixterity and organizational performance, but these effects are contingent upon the level of environmental dynamism	Learning, IT
Partanen et al. [2020] *Sweden*	Independent: supply chain ambidexterity. Moderating: network capability and strategic information flow Dependent: SMEs' financial performance	Supply chain ambidexterity is negatively associated with performance, network capabilities and strategic information flow may be necessary to lower the negative effects	Network capability
Shukor et al. [2020] *Malaysia*	Independent: uncertainties, organizational ambidexterity, supply chain integration. Dependent: supply chain agility, organizational flexibility	Organizational ambidexterity has a significant relationship with supply chain integration, and supply chain integrations were shown to have a positive impact on the firm's supply chain agility and organizational flexibility	Agility, flexibility
Rojo-Gallego-Burin et al. [2020] *Iberian*	Independent: ambidextrous supply chain strategy, ISO 9001 standard facilitates, ISO 9001 standard. Dependent: supply chain flexibility, sourcing flexibility, operating system flexibility, distribution flexibility, information system flexibility	Ambidextrous supply chain strategy is shown to have a positive effect on information system flexibility irrespective of the presence of ISO 9001 certification whereas for the other three dimensions of supply chain flexibility, the effect of ambidextrous supply chain strategyis dependent on ISO 9001 implementation	Flexibility, IT

Publication	Variables/Construct	Key findings	Theme
Aslam et al. [2020] *Pakistan*	Independent: supply chain ambidexterity. Mediating: supply chain agility. Moderating: uncertainty. Dependent: supply chain resilience	Supply chain ambidexterity on supply chain resilience a positive effect, supply chain agility positively mediates the relationship between supply chain ambidexterity and supply chain resilience, but this relationship does not vary at different levels of environmental uncertainty	Agility, resilience
Rojo-Gallego-Burin, Perez-Arostegui and Llorens-Montes [2020] *Spanish*	Independent: supply chain ambidexterity. Moderating: IT competence. Dependent: supply chain flexibility	Supply chain ambidexterity significant to supply chain flexibility, and a high IT competence facilitates can moderates the relationship between supply chain ambidexterity and supply chain flexibility	Flexibility, IT
Gu, Yang and Huo [2020] *China*	Independent: supplier IT use for exploitation, customer IT use for exploitation, ambidextrous supplier IT use, ambidextrous customer IT use, supplier IT use for exploration, customer IT use for exploration. Dependent: supplier resilience, customer resilience, supply chain performance	Supplier IT and customer IT resilience could improve supply chain performance. To achieve the two aspects of supply chain resilience, only explorative use of IT with suppliers and customers have significant effects, and the ambidextrous use of IT on the customer side takes effect. The exploitative and explorative use of IT complement each other to improve customer resilience	Resilience, IT
Huang and Lu [2020] *Taiwan*	Independent: configuration flexibility, rather than manufacturing flexibility, manufacturing flexibility, rather than configuration flexibility, degree of ambidexterity in its supply network flexibility. Dependent: exploratory partnerships, exploitative partnerships, both exploration and exploitation partnership	Configuration flexibility has a greater influence on exploratory partnerships, while manufacturing flexibility has a greater impact on exploitative partnerships. Ambidextrous (i.e. have both types of flexibility), they are able to simultaneously obtain both exploratory and exploitative partnerships.Balancing network flexibility is critical when firms execute ambidextrous alliance strategies	Flexibility
Jermsittiparsert and Pithuk [2019] *Indonesia*	Independent: supply chain ambidexterity. Mediating: supply chain agility. Dependent: supply chain adaptability, market sensing	Supply chain ambidexterity significant to supply chain adaptability and market sensing, and supply chain agility can mediates the relationship between supply chain ambidexterity and supply chain adaptability	Agility, adaptability
Mehdi and Ahmed [2019] *India*	Independent: knowledge practices, innovative practices, exploratory learning. Dependent: ambidextrous supply chain	Exploration factors (knowledge practices, innovative practices, exploratory learning) affecting an ambidextrous supply chain	Learning
Wei et al. [2019] *China*	Independent: information sharing, collaborative planning. Moderating: explorative IT capability, exploitative IT capability, explorative and exploitative IT capabilities. Dependent: firm performance	Information sharing and collaborative planning significant effect to firm performance. Explorative and exploitative IT capabilities are complementory in moderating the link between collaborative planning and firm performance but substitutive in moderating the relationship between information sharing and firm performance	Knowledge-sharing, learning, IT
Im, Rai and Lambert [2019] *United States*	Independent: goal ambidexterity, incentive ambidexterity. Mediating: knowledge-sharing ambidexterity. Dependent: relationship benefits	Goal ambidexterity an incentive ambidexterity significant effect to knowledge-sharing ambidexterity. Knowledge-sharing ambidexterity can mediate the relationship between goal ambidexterity, incentive ambidexterity and relationship benefits from supply chain relationships	Knowledge-sharing
Ojha, Acharya and Cooper [2018] *United States*	Independent: tranformational leadership. Mediating: supply chain organizational learning. Dependent: supply chain ambidexterity	Supply chain organizational learning is a mechanism through which leadership support influences supply chain ambidexterity	Learning, leadership
Ardito et al. [2018] *Italy*	Independent: sourcing knowledge from suppliers, sourcing knowledge from customers, sourcing knowledge from competitors. Dependent: innovation ambidexterity	Sourcing knowledge from suppliers, sourcing knowledge from customers, sourcing knowledge from competitors significant and positively affects innovation ambidexterity	Knowledge acquisition
Pu, Wang and Chan [2018] *China*	Independent: open e-logistic standards, supply chain process ambidexterity. Moderating: number of suppliers, relation-ship duration. Dependent: operational performance, financial performance	Open e-logistic standards, through balancing the contradictory requirements of integration and flexibility, can lead to ambidexterity in the supply chain	Knowledge, network capability
Bravo, Ruiz-Moreno and Montes [2018] *Iberian*	Independent: desorptive capacity. Moderating: balanced ambidexterity, combined ambidexterity. Dependent: supply chain competence	The positive and significant relationship between the buying organization's desorptive capacity and supply chain competence; and, second, the key moderating role of organizational ambidexterity, especially in its combined dimension, in this relationship	Learning

Publication	Variables/Construct	Key findings	Theme
Gualandris, Legenvre and Kalchschmidt [2018] *European*	Independent: balance dimension of purchasing ambidexterity, combined dimension of purchasing ambidexterity. Mediating: supplier product innovation, supplier efficiency. Dependent: buyer financial performance	Purchasing function's ability to advance the combined magnitude of exploratory and exploitative activities represents an essential determinant of supplier efficiency, supplier product innovation, and buyer financial performance; and also discovers that balancing the magnitudes of exploratory and exploitative activities on a relative basis produces negative effects on the innovativeness of the supply network	Ability, network capability
Aslam et al. [2018] *Pakistan*	Independent: market sensing, supply chain adaptability. Mediating: supply chain agility. Dependent: supply chain ambidexterity	Market-sensing capability is an antecedent of supply chain agility and supply chain adaptability; supply chain agility, directly, and supply chain adaptability, indirectly, affect supply chain ambidexterity; therefore, supply chain agility can mediates the relationship between supply chain adaptability and supply chain ambidexterity	Agility, adaptability
Cheng and Lu [2017] *Taiwan*	Independent: operating frontier, trajectory, absorptive capacity. Dependent supply chain resilience	Operating frontier, trajectory and absorptive capacity activities to improve proactive and reactive dimension of supply chain resilience	Learning
Luu [2017] *Vietnam*	Independent: ambidextrous leadership. Mediating: entrepreneurial orientation. Moderating: external supply chain integration. Dependent: market responsiveness	Ambidextrous leadership positive effect on entrepreneurial orientation, which in turn contributes to market responsiveness. The moderation role that external supply chain integration plays on the entrepreneurial orientation –market responsiveness linkage was also grounded on the data set	Leadership
Tuan [2016] *Vietnam*	Independent: organisational ambidexterity, external knowledge sharing. Moderating: competitive intelligence. Dependent: supply chain agility	Organizational ambidexterity has a positive effect on supply chain agility with competitive intelligence as a moderator for this effects	Knowledge-sharing, agility
Rojo-Gallego-Burin, Llorens-Montes, Perez-Arostegui [2016] *Spain*	Independent: supply chain ambidexterity, supply chain flexibility fit, supply chain competence. Dependent: supply chain flexibility fit, supply chain competence, firm performance	Supply chain ambidexterity helps to achieve the optimal level of supply chain fit and that supply chain management is important to firm performance	Flexibility

Background of the studies included in the review

Based on Figure 2, location for the study of organizational ambidexterity within supply chain management is detailed out to indicate the context of the studies. The analysis shows that 12 countries and one continent have been used as the location for this study. Specifically, three previous studies have focused on supply chain management in United States [Im, Rai, Lambert, 2019, Ojha, Acharya, Cooper, 2018, Wamba et al., 2020], three studies in China [Gu, Yang, Huo, 2020, Pu, Wang, Chan, 2018, Wei et al., 2019] and two studies in the Iberian [Bravo, Ruiz-Moreno, Montes, 2018, Rojo-Gallego-Burin et al., 2020], two studies in Pakistan [Aslam et al., 2018, Aslam et al., 2020], two studies in Spain [Rojo-Gallego-Burin, Llorens-Montes, Perez-Arostegui, 2016, Rojo-Gallego-Burin, Perez-Arostegui, Llorens-Montes, 2020], two studies in Taiwan [Cheng, Lu, 2017, Huang, Lu, 2020] and two studies in Vietnam [Luu, 2017, Tuan, 2016]. In addition, only one study has been conducted on supply chain management in Sweden [Partanen et al., 2020], Malaysia [Shukor et al., 2020], Indonesia [Jermsittiparsert, Pithuk, 2019], and India [Mehdi, Ahmed, 2019], Italy [Ardito et al., 2018]. There is one study which has been conducted in among European countries [Gualandris, Legenvre, Kalchschmidt, 2018].

These findings suggest that ambidexterity in supply chain management has been explored in both developed and developing countries and this allow us to understand supply chain ambidexterity in competitive market. In terms of concept, developed and developing countries are increasingly relying on functionally differentiated ambidexterity organizations (i.e., alliances based on their value chain functions such as exploratory R&D alliances or exploitative commercialization alliances) to achieve good long-term success, especially in the functional domain of supply chain management. Thus, innovative products will be the focus of manufacturing outcome to be competitive and sustain in the dynamic environment. Since environment dictates how firms strategize for long-term profits, incorporating organizational ambidexterity within supply chain management is one of the solutions to achieve differentiation and cost related advantages.

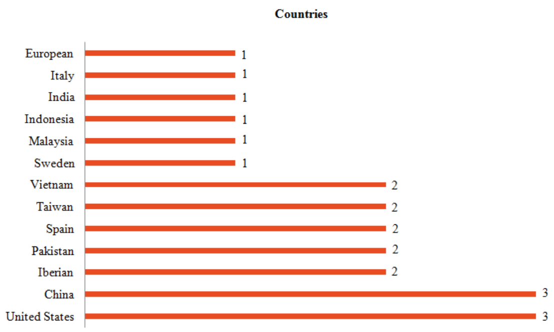


Fig. 2. Number of study based on countries

In terms of years of publication, Fig.3 shows the number of articles published in Web of Science (WoS), Scopus and EconBiz from 2016 to 2020. A total of two articles were published in 2016 [Rojo-Gallego-Burin, Llorens-Montes, Perez-Arostegui, 2016, Tuan, 2016] and 2017 [Cheng, Lu, 2017, Luu, 2017]. Next, six articles were published in 2018 [Ardito et al., 2018, Aslam et al., 2018, Bravo, Ruiz-Moreno, Montes, 2018, Gualandris, Legenvre, Kalchschmidt, 2018, Ojha, Acharya, Cooper, 2018, Pu, Wang, Chan, 2018], followed by four articles published in 2019 [Im, Rai, Lambert, 2019, Jermsittiparsert, Pithuk, 2019, Mehdi, Ahmed, 2019, Wei et al., 2019]. Recently, eight articles were published in 2020 [Aslam et al., 2020, Gu, Yang, Huo, 2020; Huang, Lu, 2020; Partanen et al., 2020; Rojo-Gallego-Burin et al., 2020, Rojo-Gallego-Burin, Perez-Arostegui, Llorens-Montes, 2020, Shukor et al., 2020, Wamba et al., 2020]. In addition, the articles were in the fields of business, management and accounting, social sciences, economics, econometrics and finance.

In summary, the number of articles published on this topic is increasing from year to year. However, the number is still small as compared to publication in the topic of ambidexterity in general. This shows that the concern about supply chain ambidexterity is still at infancy and more exploration about this topic is required. In 2020, the publication reached its peak of 8 articles and this shows that organizational ambidexterity has good potential to be a focus in future studies. This is not limited to supply chain context, since inter-organizational collaboration is evident especially in the context of operational expansion such as in project-based initiatives, consortium, and technology based alliances. This is in line with recommendations in existing publications on the potential of this topic to be deliberated in future studies [Zakrzewska-Bielawska, 2021]. More importantly, the issue of dynamic environment compelled organizations to identify best practices and factors that could enhance performance amidst the challenge of uncertainties. Thus, future researchers can continue this effort to help firms achieve maximum levels of innovation performance to thrive in the increasingly challenging business environment.

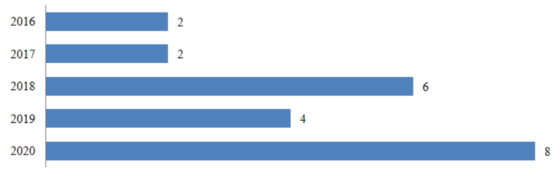


Fig. 3. Year of publication in Web of Science (WoS) Scopus and EconBiz database

DISCUSSION AND RECOMMENDATION

This scoping review provides an overview on organizational ambidexterity within supply chain. Generally, it was suggested from the findings of this review that supply chain ambidexterity will help improve business performance among large firms, especially in the manufacturing sector [Kristal, Huang, Roth, 2010]. On the other hand, small firms which are often challenged from the issue of resource shortages and lacking of capability to achieve fit between exploration and exploitation [Arend, Wisner, 2005], can leveraged network capabilities to mitigate the negative link between supply chain ambidexterity and performance [Partanen et al., 2020]. Therefore, it can be concluded that for small firms to get the advantage from supply chain ambidexterity, they need to have strong alliance management capability to generate interorganizational exploitation instead of exploration. Hence, they need to develop supply chain ambidexterity by building capabilities such as network and IT capabilities to support simultaneous process of exploration and exploitation. Using this framework, small firms can create advantages from the inter-organizational collaboration within the supply chain network.

Moreover, it can be concluded that majority of these studies concurred that supply chain ambidexterity could lead to outcomes such as agility, flexibility and adaptability that are incumbent in dynamic environment. Obviously, having these abilities will ensure firms to thrive and sustain in hostile competitive environment. The construct of supply chain ambidexterity is mainly positioned as independent variable to influence the organizational performance. In addition, only two studies that have been conducted in regards to the enabler. The studies indicate that leadership is an important factor that can influence supply chain ambidexterity particularly in big firms. On the other hand, supply chain ambidexterity also can moderate the relationship between leadership and market responsiveness. The mapping of previous studies based on the positioning of ambidexterity construct and major themes is illustrated in Table 4.

In another perspective, supply chain management that is involved in either R&D alliances (explorative) or commercialization alliances (exploitative) can be characterized as a sequential approach to achieve organizational ambidexterity [O'Reilly III, Tushman, 2013, Simsek et al., 2009]. The review of the articles in this study confirms that exploration activities will eventually be followed by exploitation in sequential manner [i.e. Huang, Lu, 2020, Wei et al., 2019] particularly in big firms. However, the analysis found that, the result is different in other functional activities such as marketing or finance that may experience non-sequential process in the application of this framework. This can lead to the conclusion that in the context of supply chain management, a sequential process of exploration and exploitation work best in big firms. This creates and avenue for future research to look into this effect on small firms.

The review of the quantitative studies also reveal that the outcome of supply chain ambidexterity can be explored from two different perspectives namely financial or non-financial performance. This offers inclusive perspective of how supply chain ambidexterity works in the context of dynamic environment. Hence, more appropriate and valuable implications can be offered in developing theory, evaluating programs, and developing interventions [Baxter, Jack, 2008].

Although this study focused only limited publications in the Web of Science (WoS), Scopus databases and EconBiz, the trend shows that the possibilities of increase in the number of publications in future is expected. This is due to the issue of organizational ambidexterity is drawing much attention and concerns among researchers recently. Existing studies that covers different geographic regions shows that the issue is imminent, and more need to be gauged to help firms discovers the potential of supply chain management in different economies. In line with this, exploring database sources such as Science Direct, Taylor Francis, Springer and Sage allows for more comprehensive data and future researchers can conduct systematic literature reviews. According to Petrosino et al. [2001], a systematic review can be characterized as identifying, integrating and analyzing all data available in quantitative and qualitative ways to provide an observationally determined answer to a committed research query. Therefore, future research studies may obtain more database resources to make an in-depth study about organizational ambidexterity within supply chain management.

Table 4. Positioning of organizational ambidexterity as a construct in supply chain research

	Independent	Mediating/Moderating	Dependent
Process	Partanen et al. [2020] Rojo-Gallego-Burin et al. [2020] Rojo-Gallego-Burin, Perez-Arostegui and Llorens-Montes [2020] Gu, Yang and Huo [2020] Im, Rai and Lambert [2019] Pu, Wang and Chan [2018]	Wamba et al. [2020] Wei et al. [2019] Im, Rai and Lambert [2019]	Huang and Lu [2020] Mehdi and Ahmed [2019] Ardito et al. [2018]
Outcome	Shukor et al. [2020] Rojo-Gallego-Burin et al. [2020] Aslam et al. [2020] Rojo-Gallego-Burin, Perez-Arostegui and Llorens-Montes [2020] Jermsittiparsert and Pithuk [2019] Gualandris, Legenvre and Kalchschmidt [2018] Cheng and Lu [2017] Tuan [2016] Rojo-Gallego-Burin, Llorens-Montes and Perez-Arostegui [2016]	Bravo, Ruiz-Moreno and Montes [2018]	
Enabler	Luu [2017]	Ojha, Acharya and Cooper [2018]	

CONCLUSION

The discussion about organizational ambidexterity within supply chain management has enriched the literature and strengthened the conceptualization of organizational ambidexterity. First, by developing specific supply chain ambidexterity to enhance exploration or exploitation capabilities, a firm can cultivate valuable, intangible, and differentiating capabilities that may lead to competitive advantage. Second, supply chain related activities may be involved in the selection, development and implementation of a new process or technology (exploitation) - the result of previous search initiatives (exploration). Furthermore, our paper informs management about the significance of developing and managing a supply chain that supports exploration and exploitation practices. While continuous refinement of existing knowledge is important, it is the production and application of new knowledge that results in the realisation of increasing value (profits). This is critical in providing significant advantages, particularly to major corporations in increasing their long-term efficiency. The findings of this study highlight three main themes with eleven sub-themes that are prevalent in the discussion on organizational ambidexterity within supply chain management context. This study suggests that future research could conduct in depth studies of organizational ambidexterity in the context of small firms to establish the sequential process of exploration and exploitation of organizational ambidexterity beyond the scope of size and types of collaboration. A systematic literature review could also offers a more comprehensive view in understanding supply chain ambidexterity concept.

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REFERENCES

Abd Aziz N.A., Hanafiah M.H., Abd Latif M.N. 2020. Supply chain management in franchising literature review: synthesis of conclusion. LogForum, 16(4), 521-534. http://doi.org/10.17270/J.LOG.2020.513

Adler P.S., Goldoftas B., Levine D.I., 1999. Flexibility versus efficiency? A case study of model changeovers in the Toyota production system. Organization Science, 10(1), 43-68. http://doi.org/10.1287/orsc.10.1.43

Andriopoulos C., Lewis M.W., 2009. Exploitation-exploration tensions and organizational ambidexterity: Managing paradoxes of innovation. Organization Science, 20(4), 696-717. http://doi.org/10.1287/orsc.1080.0406

Aoki K., Wilhelm M., 2017. The role of ambidexterity in managing buyer–supplier relationships: The Toyota case. Organization Science, 28(6), 1080-1097. http://doi.org/10.1287/orsc.2017.1156

Ardito L., Petruzzelli A.M., Dezi L., Castellano S. 2018. The influence of inbound open innovation on ambidexterity performance: does it pay to source knowledge from supply chain stakeholders? Journal of Business Research, 119(2018), 321-329. http://doi.org/10.1016/j.jbusres.2018.12.043

Arend R.J., Wisner J.D., 2005. Small business and supply chain management: is there a fit? Journal of Business Venturing, 20(3), 403-436. http://doi.org/10.1016/j.jbusvent.2003.11.003

Arksey H., O'Malley L., 2005. Scoping studies: towards a methodological framework. International Journal of Social Research Methodology, 8(1), 19-32. http://doi.org/10.1080/1364557032000119616

Aslam H., Blome C., Roscoe S., Azhar T.M., 2018. Dynamic supply chain capabilities: How market sensing, supply chain agility and adaptability affect supply chain ambidexterity. International Journal of Operations & Production Management, 38(12), 2266-2285. http://doi.org/10.1108/IJOPM-09-2017-0555

Aslam H., Khan A.Q., Rashid K., Rehman S.-u. 2020. Achieving supply chain resilience: the role of supply chain ambidexterity and supply chain agility. Journal of Manufacturing Technology Management, 31(6), 1185-1204. http://doi.org/10.1108/JMTM-07-2019-0263

Baum J.A., Calabrese T., Silverman B.S., 2000. Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology. Strategic Management Journal, 21(3), 267-294. http://doi.org/10.1002/(SICI)1097-0266(200003)21:3<267::AID-SMJ89>3.0.CO;2-8

Baxter P., Jack S., 2008. Qualitative case study methodology: Study design and implementation for novice researchers. The Qualitative Report, 13(4), 544-559. http://doi.org/10.46743/2160-3715/2008.1573

Benner M.J., Tushman M.L., 2003. Exploitation, exploration, and process management: The productivity dilemma revisited. Academy of Management Review, 28(2), 238-256. http://doi.org/10.5465/amr.2003.9416096

Birkinshaw J., Gibson C.B., 2004. Building an ambidextrous organisation. MIT Sloan Management Review, 45(4), 47-55. http://doi.org/10.2139/ssrn.1306922

Bravo M.I.R., Ruiz-Moreno A., Montes F.J.L., 2018. Examining desorptive capacity in supply chains: the role of organizational ambidexterity. International Journal of Operations & Production Management, 38(2), 534-553. http://doi.org/10.1108/IJOPM-12-2016-0751

Cheng J.-H., Lu K.-L., 2017. Enhancing effects of supply chain resilience: insights from trajectory and resource-based perspectives. Supply Chain Management: An International Journal, 22(4), 329-340. http://doi.org/10.1108/SCM-06-2016-0190

Clermont M., Dyckhoff H., 2012. Coverage of business administration literature in Google Scholar: Analysis and comparison with Econbiz, Scopus and Web of Science. Bibliometrie-Praxis und Forschung, 1(1), 1-54. http://doi.org/10.2139/ssrn.2016850

Davis K., Drey N., Gould D., 2009. What are scoping studies? A review of the nursing literature. International Journal of Nursing Studies, 46(10), 1386-1400. http://doi.org/10.1016/j.ijnurstu.2009.02.010

Gu M., Yang L., Huo B. 2020. The impact of information technology usage on supply chain resilience and performance: An ambidexterous view. International Journal of Production Economics, 232(2020), 1-24. http://doi.org/10.1016/j.ijpe.2020.107956

Gualandris J., Legenvre H., Kalchschmidt M., 2018. Exploration and exploitation within supply networks. International Journal of Operations & Production Management, 38(3), 667-689. http://doi.org/10.1108/IJOPM-03-2017-0162

Gupta A.K., Smith K.G., Shalley C.E., 2006. The interplay between exploration and exploitation. Academy of Management Journal, 49(4), 693-706. http://doi.org/10.5465/amj.2006.22083026

He Z.-L., Wong P.-K. 2004. Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis. Organization Science, 15(4), 481-494. http://doi.org/10.1287/orsc.1040.0078

Hodgkinson G.P., Ford J.K., 2014. Narrative, meta-analytic, and systematic reviews: What are the differences and why do they matter? Journal of Organizational Behavior, 35(S1), S1-S5. http://doi.org/10.1002/job.1918

Huang Y.-F., Lu L.-H. 2020. The differentiated and ambidextrous influence of network flexibility on exploratory and exploitative partnership formations. International Journal of Physical Distribution & Logistics Management, 50(6), 577-599. http://doi.org/10.1108/IJPDLM-02-2019-0057

Im G., Rai A., 2008. Knowledge sharing ambidexterity in long-term interorganizational relationships. Management Science, 54(7), 1281-1296. http://doi.org/10.1287/mnsc.1080.0902

Im G., Rai A., Lambert L.S., 2019. Governance and resource-sharing ambidexterity for generating relationship benefits in supply chain collaborations. Decision Sciences, 50(4), 656-693. http://doi.org/10.1111/deci.12353

Jermsittiparsert K., Pithuk L. 2019. Exploring the nexus between supply chain ambidexterity, supply chain agility, supply chain adaptability and the marketing sensing of manufacturing firms in Indonesia. Humanities & Social Sciences Reviews, 7(2), 555-562. http://doi.org/10.18510/hssr.2019.7266

Kraus S., Breier M., Dasí-Rodríguez S., 2020. The art of crafting a systematic literature review in entrepreneurship research. International Entrepreneurship and Management Journal, 16(3), 1023-1042. http://doi.org/10.1007/s11365-020-00635-4

Kristal M.M., Huang X., Roth A.V., 2010. The effect of an ambidextrous supply chain strategy on combinative competitive capabilities and business performance. Journal of Operations Management, 28(5), 415-429. http://doi.org/10.1016/j.jom.2009.12.002

Levac D., Colquhoun H., O'Brien K.K., 2010. Scoping studies: advancing the methodology. Implementation Science, 5(1), 1-9. http://doi.org/10.1186/1748-5908-5-69

Levinthal D.A., March J.G., 1993. The myopia of learning. Strategic management journal, 14(S2), 95-112. http://doi.org/10.1002/smj.4250141009

Luu T., 2017. Market responsiveness: antecedents and the moderating role of external supply chain integration. Journal of Business & Industrial Marketing, 32(1), 30-45. http://doi.org/10.1108/JBIM-07-2015-013

March J.G., 1991. Exploration and exploitation in organizational learning. Organization Science, 2(1), 71-87. http://doi.org/10.1287/orsc.2.1.71

McGrath R.G., 2001. Exploratory learning, innovative capacity, and managerial oversight. Academy of Management Journal, 44(1), 118-131. http://doi.org/10.5465/3069340

McNamara P., Baden-Fuller C., 1999. Lessons from the Celltech case: Balancing knowledge exploration and exploitation in organizational renewal. British Journal of Management, 10(4), 291-307. http://doi.org/10.1111/1467-8551.00140

Mehdi M., Ahmed S., 2019. Exploration factors affecting an ambidextrous supply chain. International Journal of Logistics Systems and Management, 32(2), 195-219. http://doi.org/10.1504/IJLSM.2019.09758

Moher D., Shamseer L., Clarke M., Ghersi D., Liberati A., Petticrew M., Shekelle P., Stewart L., A. 2015. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews, 4(1), 1-9. http://doi.org/10.1186/2046-4053-4-1

O'Reilly III C.A., Tushman M.L., 2007. Ambidexterity as a dynamic capability: Resolving the innovator's dilemma. Research in Organizational Behavior, 28(2007), 185-206. http://doi.org/10.1016/j.riob.2008.06.002

O'Reilly III C.A., Tushman M.L., 2013. Organizational ambidexterity: Past, present, and future. Academy of Management Perspectives, 27(4), 324-338. http://doi.org/10.5465/amp.2013.0025

Ojha D., Acharya C., Cooper D., 2018. Transformational leadership and supply chain ambidexterity: Mediating role of supply chain organizational learning and moderating role of uncertainty. International Journal of Production Economics, 197(2018), 215-231. http://doi.org/10.1016/j.ijpe.2018.01.001

Ojha D., Struckell E., Acharya C., Patel P.C., 2018. Supply chain organizational learning, exploration, exploitation, and firm performance: A creation-dispersion perspective. International Journal of Production Economics, 204(2018), 70-82. http://doi.org/10.1016/j.ijpe.2018.07.025

Partanen J., Kohtamäki M., Patel P.C., Parida V., 2020. Supply chain ambidexterity and manufacturing SME performance: The moderating roles of network capability and strategic information flow. International Journal of Production Economics, 221(2020), 1-12. http://doi.org/10.1016/j.ijpe.2019.08.005

Pertusa-Ortega E.M., Molina-Azorín J.F., Tarí J.J., Pereira-Moliner J., López-Gamero M.D., 2020. The microfoundations of organizational ambidexterity: A systematic review of individual ambidexterity through a multilevel framework. BRQ Business Research Quarterly, 23(2020), 1–17. http://doi.org/10.1177/2340944420929711

Petrosino A., Boruch R.F., Soydan H., Duggan L., Sanchez-Meca J., 2001. Meeting the challenges of evidence-based policy: The Campbell Collaboration. The ANNALS of the American Academy of Political and Social Science, 578(1), 14-34. http://doi.org/10.1177/000271620157800102

Pham M.T., Rajić A., Greig J.D., Sargeant J.M., Papadopoulos A., McEwen S.A., 2014. A scoping review of scoping reviews: advancing the approach and enhancing the consistency. Research Synthesis Methods, 5(4), 371-385. http://doi.org/10.1002/jrsm.1123

Powell W.W., Koput K.W., Smith-Doerr L., 1993. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. Administrative Science Quarterly, 41(1), 116-145. http://doi.org/10.2307/2393988

Pu X., Wang Z., Chan F.T.S., 2018. Leveraging open E-logistic standards to achieve ambidexterity in supply chain. Journal of Computer Information Systems, 60(4), 347-358. http://doi.org/10.1080/08874417.2018.1488543

Puranam P., Singh H., Zollo M., 2006. Organizing for innovation: Managing the coordination-autonomy dilemma in technology acquisitions. Academy of Management Journal, 49(2), 263-280. http://doi.org/10.5465/amj.2006.20786062

Rojo-Gallego-Burin A., Llorens-Montes F.J., Perez-Arostegui M.N., Stevenson M., 2020. Ambidextrous supply chain strategy and supply chain flexibility: the contingent effect of ISO 9001. Industrial Management & Data Systems, 120(9), 1691-1714. http://doi.org/10.1108/IMDS-01-2020-0038

Rojo-Gallego-Burin A., Llorens-Montes J., Perez-Arostegui M.N., 2016. The impact of ambidexterity on supply chain flexibility fit. Supply Chain Management: An International Journal, 21(4), 433-452. http://doi.org/10.1108/SCM-08-2015-0328

Rojo-Gallego-Burin A., Perez-Arostegui M.N., Llorens-Montes J., 2020. Ambidexterity and IT competence can improve supply chain flexibility? A resource orchestration approach. Journal of Purchasing and Supply Management, 26(2), 1-15. http://doi.org/10.1016/j.pursup.2020.100610

Sánchez A.D., Del Río M.d.l.C., García J.Á., 2016. Bibliometric analysis of publications on wine tourism in the databases Scopus and WoS. European Research on Management and Business Economics, 23(1), 8-15. http://doi.org/10.1016/j.iedeen.2016.02.001

Shukor A.A.A., Newaz M.S., Rahman M.K., Taha A.Z., 2020. Supply chain integration and its impact on supply chain agility and organizational flexibility in manufacturing firms. International Journal of Emerging Markets, ahead-of-print(2020), 1-24. http://doi.org/10.1108/IJOEM-04-2020-0418

Simsek Z., Heavey C., Veiga J.F., Souder D., 2009. A typology for aligning organizational ambidexterity's conceptualizations, antecedents, and outcomes. Journal of Management Studies, 46(5), 864-894. http://doi.org/10.1111/j.1467-6486.2009.00841.x

Song M., Di Benedetto C.A., 2008. Supplier's involvement and success of radical new product development in new ventures. Journal of Operations Management, 26(1), 1-22. http://doi.org/10.1016/j.jom.2007.06.001

Tuan L.T., 2016. Organisational ambidexterity and supply chain agility: The mediating role of external knowledge sharing and moderating role of competitive intelligence. International Journal of Logistics Research and Applications, 19(6), 583-603. http://doi.org/10.1080/13675567.2015.1137278

Tushman M.L., O'Reilly III C.A., 1996. Ambidextrous organizations: Managing evolutionary and revolutionary change. California Management Review, 38(4), 8-30. http://doi.org/10.2307/41165852

Wamba S.F., Dubey R., Gunasekaran A., Akter S., 2020. The performance effects of big data analytics and supply chain ambidexterity: The moderating effect of environmental dynamism. International Journal of Production Economics, 222(2020), 1-14. http://doi.org/10.1016/j.ijpe.2019.09.019

Wei S., Ke W., Liu H., Wei K.K., 2019. Supply chain information integration and firm performance: Are explorative and exploitative IT capabilities complementary or substitutive? Decision Sciences, 51(3), 464-499. http://doi.org/10.1111/deci.12364

Zakrzewska-Bielawska A., 2021. Ambidextrous Strategy: Antecedents, Strategic Choices, and Performance (1st Edition ed.). New York: Routledge. http://doi.org/10.4324/9781003127772

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ORIGINAL PAPER

INCLUSIVE WORKPLACE, SOCIAL MOBILITY AND LOGISTICS

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ABSTRACT. **Background:** This study practices the priorities of the World Economic Forum, Global Social Mobility Pillars 10th for the inclusive institutions. Global logistics discussed with accessibility needs in theoretical frameworks of Global Social Mobility Index (rankings for 2020 Turkey 64th, and Poland 30th). It is stated with sociological, technological, and economical improvements in line with on the global agenda.

Methods: This article provides a data research, which considers the economic effects of Covid-19 for adults (≥18 years of age and employed with high digital literacy) during lockdown. Theory of main synthesis is targeting UN Development Goals and WEF's Social Mobility Index. It is developed based on international literature and it is defined with total 100 Turkish people opinions and connected individual's budget with the logistics services.

Results: Digital technologies as an enabler of inclusive work are delivering the digital flow with Industry 4.0 by changing the way of logistic services function into another virtual transportation platform. In this paper, with the aim of identifying future directions, more than 100 surveys reviewed focusing on inclusive workplace options.

Conclusion: Economies with greater social mobility provide more opportunities with the content of the accessible procedures which useful instrument for each procurement mode; operational, tactical, and strategic. It confirms the efficiency, effectiveness, and experiences of people with the digitalization technologies (SIoV, IoT, Blockchain, RPA, AI, Data Analytics, etc.) It is recommended that the levels explained in this study contribute to future studies by accessible supply chain with inclusive work procedures.

Keywords: regional economics, social mobility, logistics, post autistic economics, business informatics.

INTRODUCTION

Today, the numbers of workers with disabilities who adopt the common values and multiculturalism of the global world and want to socialize in their life are increasing day by day. They are changing the way of carrying out a comfortable and low-cost lifestyle with professional distance working methods. With its new development form, it deals with technology, computing, and reasonable changes from the managements. This type of work started upscaling with COVID-19 and is rapidly becoming widespread in different professions and groups including logistics. For example, 3D online platforms empower consumers to design and print objects at home [Halassi et al. 2019]. This brings sociological, technological, and economical improvements in line with accessibility needs on the global agenda.

Economical access needs are diverse but new business models defining them by "actively pursuing diversity and inclusion enjoy significantly higher revenues" [Cassidy, 2021]. Logistics services provide international sectoral connections within the individual's budget. It also connects the domestic economy to the international economy. [Gani, 2017] The pandemic brought wide effect to world economy on work conditions and delivery services. The domestic logistics performance ranking of Turkey 18th in 20 EU countries [Senir, 2021].

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Logistics and supply chain domains can be difficult, due to multiple tiers and the number of organizations involved [Grant & Shaw, 2021] especially in-service sector. First, organizations define the strategic objectives for accessible service and standards in delivery processes and then it allows all related parties. This study discusses the changes in business logistics that studied in three dimensions of accessibility because of their contributions to the global economy: sociological, technological, and economical. [Özbalcı, 2020].

THEORY AND HYPOTHESIS

The ideal design concept targets all people of all ages, sizes and abilities [Center for Universal Design, 2009] Universal Design Principles are necessary for dealing with reasonable adjustments which is the main frame of an equal workplace environment such as: "principle equitable, flexible, simple and intuitive use, perceptible information, tolerance for error, low physical effort, size and space for approach". The concept of equity is adopted by making equal "products, connections, communications and the built environment more usable by more people at little or no extra cost". [Michopoulou et al, 2015] In this case the person's impairment does not only disable them but the complex collection of practices and attitudes, which are imposed on top of a person's differences because the requirements depending on those specialties: the dimensions of access level for support needs, and the equity in logistics for adaptive/assistive equipment used for reasonable adjustments.

Domestic economy develops in an inclusive society (Yıldırım, 2021) that must provide fair and equitable access to excluded groups; "corruption has a high social cost; it enables higher levels of opportunity hoarding, both in terms of access to higher education and access to work opportunities" [WEF, 2020]. The economic model of disability sees the issue mainly as an equity problem for the work environment that excludes people from physical participation. It has been described by the terms as disabled/disability cost, easy access, barrier free environment, inclusive workplace, universal design, and recently social mobility [WEF, 2021]. When defining the disability through the World Health Organization (WHO) definitions on which national disability statistics are collected, disability scholars describe two main modes of disability in general: firstly, the medical or individual model; and secondly, the social model. These models include "people with permanent and temporary disabilities, seniors, obese, families with young children, and those working in safer and more socially sustainably designed environments" [Michopoulou et al, 2015]. On the other hand, there is a growing need on the equity of the work standards for people "who are committed to the organization's purpose and output" according to the Equity Effect Report (Henley Business School, 2020). It also points out that: "There is significant correlation between a more diverse and inclusive business environment and overall financial performance. Human logic and human experience prove that if you build a safe environment for people regardless of color, race, background, belief and all that sort of stuff, you give them an environment to express themselves. If you give people the environment to self-express, they will achieve, and they will feel good about themselves." These discussed in this paper with WEF access priorities.

MATERIALS AND METHODS

This study practices the priorities of the World Economic Forum (WEF, 2021), Global Social Mobility Pillars 10th for the inclusive institutions, which is based on the United Nations (UN, 2020) Sustainable Development Goals. As a new tool of WEF, Global Social Mobility Index (rankings for 2020 Turkey 64th, and Poland 30th) understanding and explaining the global system with new assessment of 82 global economies. It respects to human rights, the medical models of disability and embodiment, the examples of new market segments, environmental elements, universal design concepts for logistics, accessibility and aging in the first place. The inclusive effect as a social construct and examples of changing experience expectations amongst people with disabilities, as well as increased level of acceptance of people with special needs by other stakeholders in work environment opportunities around the world with the international validity of accessibility standards. It suggests that all developed sectors, support elements and services are interconnected with each other, as well as with communities and the natural environment. Therefore, an accessible environment also has a positive effect on global trade procedures. This means "perceived environmental uncertainty has a negative effect on performance and as a result, firms need to decide strategy to minimize the negative effect of the uncertainty on performance which has a role to change "a negative effect (a direct effect) with a positive effect (indirect and total effects) on the effect of perceived environmental uncertainty on performance". [Bae, 2017]

Accessibility is one of the most important human rights in the fight against discrimination enabling universal accessibility by the availability of national building codes, access and mobility standards and administrative procedures. Therefore, accessibility discussions are started with globalizing, universal integrity, and social disability. It means having a social dimension, constructed by barriers. These barriers affect participation at work by "creating disability on top of a person's impairment and discriminating against a person because of their impairment" [Buhalis and Darcy, 2011]. There is a growing literature on the needs of equity in the workplace. This article provides data research, which considers the economic effects of Covid-19 for adults (≥18 years of age and employed with high digital literacy) 100 Turkish businesspeople during lockdown. This research is drawing together the needs in the workplace by gathering people's reflections in Covid-19 process. Results are useful for an important request as a first kit for defining the concepts of the area for inclusive practices. A smart definition of economic accessibility is described and focused on the experiences of people while supporting logistic elements of the business field.

RESULTS

The survey on which findings are reported here, conducted in December 2020 among the people with distant working conditions. The response rate was %100 frequency distributions and other descriptive characteristics for each question. The design of the descriptive statistics such as means, standard divisions, and minimum-maximum values for each question were calculated and performed with SPSS. Also, there are questions on socio-demographic characteristics such as gender (40 male, 59 female, 1 other), age (min: 18, max: 65) educations (3 PhD, 35 faculty, 45 master, 17 high school & others), also being a disabled or having a relative with disability (Yes: 25, No: 75), interest of inclusive work (Yes, 95; No, 5).

Table 1. Inclusive Workplace Statistics

	As Coworker (%)			As Customer (%)		
Disability Type	Yes	Partly	No	Yes	Partly	No
Hearing	28	56	16	27	64	9
Visual	27	64	9	34	58	8
Physical	41	55	4	42	65	3
Mean	32	58	10	34	62	7

Digital technologies as an enabler of inclusive work are delivering the digital flow with Industry 4.0 by changing the way of logistic services function into another virtual transportation platform. Recent studies show that staff characteristics related to the knowledge, and experiences of the people play an influential role in trade activities (Unal & Metin, 2021). Experiences of the people during lockdowns examined to measure the economic impact of pandemic by logistic equity conditions. It shows that staying at home, online meetings etc. are affected their income level and family relations in medium level, the bills highly negative impacted, but job satisfaction and transportation costs are positively reacted to the situations. Asking participants if they can work with people with special needs as co-worker or customer, they replied figuratively eager to communicate with them, statistics are shown in Table 1. It is stated more than 50% they cannot contact in work environment people with special needs because of literacy of accessibility knowledge.

Participants shared their ability to understand people with specialities in these five levels:

1. 89% like to participate equity at work,
2. 68% cannot communicate PWS's,
3. 67% people have emergency support and first aid skills,
4. 58% able to be friends with people with disabilities,
5. 28% of them being aware of the co-workers' health status at workplace.

DISCUSSION

In this study the accessibility need is explained based on Maslow's hierarchy of needs which represents the pyramid of demand types: the continuum abilities. This is a good tool for dividing the needs into disability groups of people with similar needs. It also helps companies' top management and shareholders to understand what matters the most for creating an accessible workplace [Özbalcı, 2020]. Because the suppliers which are targeting these groups, they must change their accessibility level to achieve competitive advantages through differentiation with 4A+ status (Figure 1) which defined as; acceptable, adoptable, assitable, and affordable. While their special status is increasing the inclusive factors should reduce the care need in the workplace to help persons with special needs to accomplish their independence.

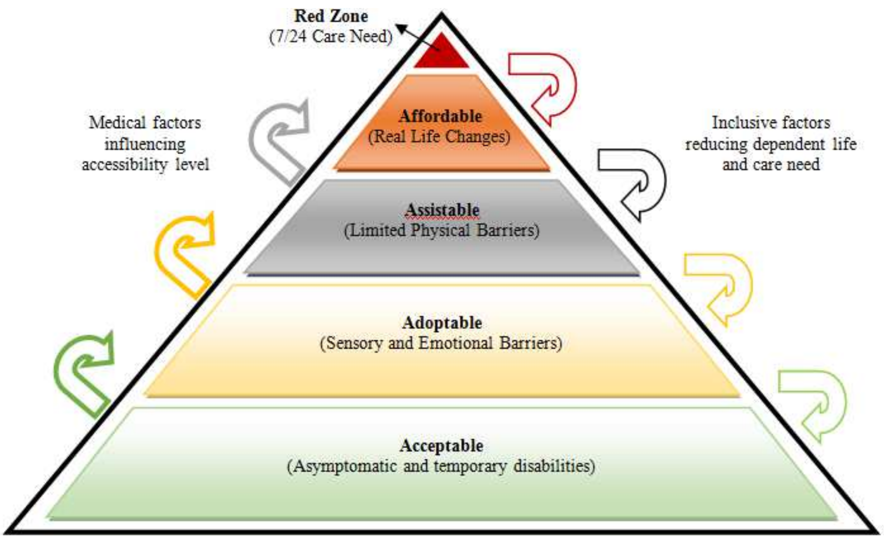

Fig. 1. Hierarchy of Accessibility

People with more moderate needs should be listed at the top of this hierarchy (Figure 1). On the other hand, access needs for distant work can be explained in five technological categories such as: visual, hearing, learning, age sensitivity and other. The mainstream providers who have utilized inclusive design in their facilities they reach this new market levels with differentiation of services and products. An accessibility product can be used as a business tool as a part of the service. Additionally, logistics involves storage and movement of products or information from the source of production to the end customer. Therefore, it covers two parallel platforms of production: physical and digital. The fact that it explains the defining key areas of the access need to be delivered for logistics in two scopes:

- Technological: Delivering & receiving devices (indoor & outdoor operations),
- Physical: Design of built environment (reasonable adjustments).

The social and environmental value of the company pulls a positive impact on the financial results in the long term [Palacio, 2021]. It is correlated with the physical and digital flow of logistics for the 3rd Party Business activities such as:

- Customer relations (sales and marketing),
- Transportation services (international logistics),
- Employment opportunities (human resources),
- Delivery options (documentary and reverse logistics).

Customer relations (sales and marketing)

This study points out the people with disabilities faced several delivery and transportation problems during Covid-19. It would be possible for logistic operations by seeking to incorporate social participation to understand the digitalization from a disability perspective for distant work and business cycle development. It concerns the digital transformation for the company's operational efficiency and positive customer experiences in capability of changing.

Transportation services (international logistics)

New logistics practices integrated approach [Martin et al., 2021], the operational availability [Zhao et al., 2021], success mission [Agarwal et al., 2019] and affordable life cycle costs [Baruffaldi et al., 2020] for defining the optimum budget for fast and accessible systems. This system draws a cycle related with accessibility levels [Özbalcı, 2020] explained by considering the supply chain flow as a sustainable process (Figure 2, Figure 3).

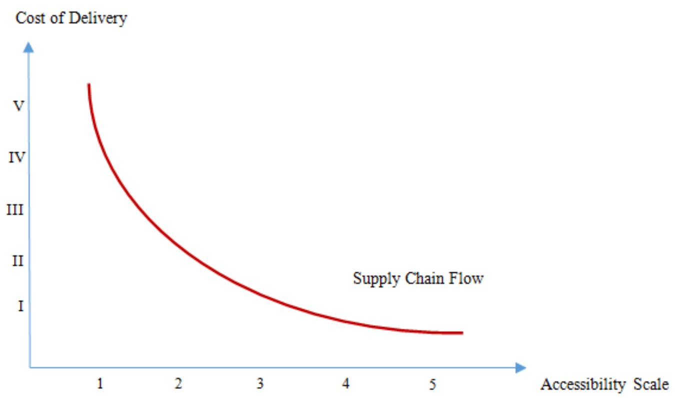

Fig. 2. Measuring Logistics with Accessibility Levels

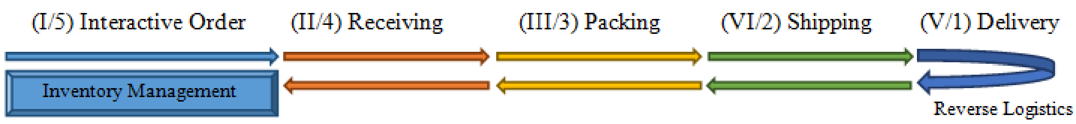

Fig. 3. Accessible Platforms of Supply Chain Flow

Logistics with constructed smart options such as drones, mobile phones result in minimizing the effort and costs. It helps building interactive business practices benefitable for everyone incorporate with planning, implementing, controlling the effective flow, storage, and inventory management for service operations such as (Figure 3): receiving, packing, shipping.

Employment opportunities (human resources)

The business cycle of logistics carries a quick tool for measuring the access levels. It explains the difficulties of accessing optimum delivery point with five levels because of problems with instruments and qualifications of delivery point; variance of service equality

[McInroy, 2018] and rapid response, employment opportunities [Mascarenhas& Barbosa, 2019] such as:

- Shortage of accessible order points,
- Insufficient support for related marking items,
- Inadequate training of workers,
- Unreliable transportation equipment,
- Lack of accessible tools and support.

Delivery options (documentary and reverse logistics)

The supply chain documentary tools are essential transportation proof between the sender and receiver with the aim of handling products in good and accessible condition. It means the customer services of the logistic performers' responsibility to moderate right goods, right places in right time and right quantity with the correct documents.

Digital logistics chain involves storage and movement of products or information from the source of production to the customer. The accessibility level in the content of packing list as a digital mark which traceable (SIoV, IoT, Blockchain, etc.) for the warehouse, vehicles [Roopa et al, 2021] and stock operations and defined by incoterms is an essential part of the chain as:

- Support accessible process of strategy & payment elements,
- Expanded maintenance planning with universal design influence,
- Equity of logistics acquisition,
- The life cycle of barrier free material management.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this study is analyzing the crucial part of the new methodology of WEF Global Social Mobility Index Pillars constructed on accessible logistic ecosystem environment (Figure 4) in the logistics which contains these three factors for five strategic moderation:

- Developing experiences of people: this reflects co-worker's attitudes to disability,
- Removing work barriers: understanding in both built environment and social life.
- Solving social dysfunctions resulting from physical barriers: enabling delivery options, building sufficient work conditions on abilities etc.

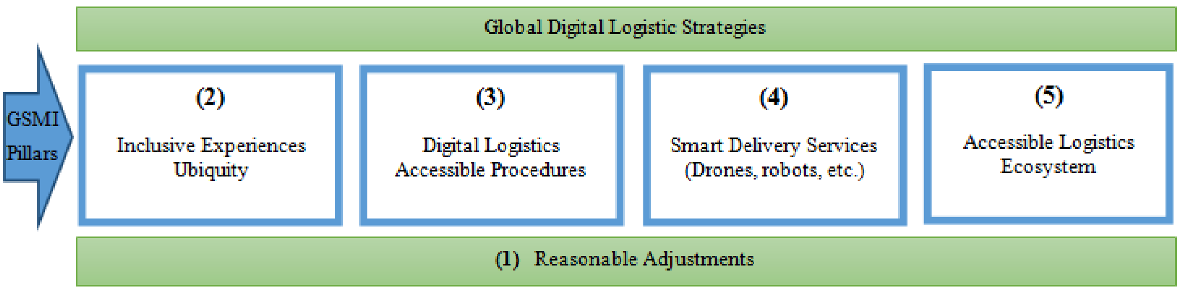

Fig. 4. Defining Accessibility Levels of Logistics Ecosystem

Economies with greater social mobility provide more opportunities (WEF, 2021) with the content of the accessible procedures which useful instrument for each procurement mode; operational, tactical, and strategic. It confirms the efficiency, effectiveness, and experiences of people with the digitalization technologies (SIoV, IoT, Blockchain, RPA, AI, Data Analytics, etc.) In this paper, with the aim of identifying future directions, more than 100 surveys reviewed focusing on inclusive workplace options. It is discussed and suggested in this study with the possibility of increasing the inclusive institutions (Pillar 10) level of Turkey from 75th with understanding the demand of accessibility regulations in the workplace (positive response rate 89%) and measurability of global logistics delivery options with the five levels of accessible supply chain performance. It is recommended that the levels explained in this study contribute to future studies by practicing with a product samples in accessible supply chain with inclusive work procedures. This study is a reference source for international literature, provides an inclusive perspective from Turkey that are well qualified information for researchers in the era which contributes unique studies about experiences of people who are eager to work in inclusive business practices, such as shareholders, company providers and international academicians from different disciplines. Understanding the impacts of accessibility on global economy with future studies on SME's and international organizations could be productive. It is suggested in this perspective that promoting inclusive culture and preventing discriminative behaviors in the workplace with the upcoming applied research and workshop ideas.

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REFERENCES

Agarwal S., Kant R., Shankar R., 2019. Humanitarian supply chain management frameworks: A critical literature review and framework for future development. Benchmarking 26, 6, 1749 - 1780, 31 Jul 2019, http://doi.org/10.1108/BIJ-08-2018-0245/

Bae H. S., 2017. Empirical relationships of perceived environmental uncertainty, supply chain collaboration and operational performance: analyses of direct, indirect and total effects. The Asian Journal of Shipping and Logistics, 33, 4, 263-272, ISSN 2092-5212, http://doi.org/10.1016/j.ajsl.2017.12.010/

Baruffaldi G., Accorsi R., Manzini R., Ferrari E., 2020. Warehousing process performance improvement: a tailored framework for 3PL. Business Process Management Journal, 26, 6, 1619-164116 Nov 2020, http://doi.org/10.1108/BPMJ-03-2019-0120/

Cassidy F., 2021. Equity pays: why pursuing workplace equality isn't enough. Raconteur, Content for business decision makers. Retrieved from, https://www.raconteur.net/hr/diversity-inclusion/workplace-racial-equity-bottom-line/

David B.G., Sarah S., 2021. Logistics and Supply Chain Management Performance Measures, International Encyclopedia of Transportation, Elsevier, 16-23, ISBN 9780081026724, http://doi.org/10.1016/B978-0-08-102671-7.10210-6/

Gani A., 2017. The logistics performance effect in international trade. The Asian Journal of Shipping and Logistics, Volume 33, 4, 2017, 279-288, ISSN 2092-5212, http://doi.org/10.1016/j.ajsl.2017.12.012/

Halassi S., Semeijn J., Kiratli N., 2019. From consumer to prosumer: a supply chain revolution in 3D printing. International Journal of Physical Distribution and Logistics Management, 49, 2, 200 – 216, 5 Mar 2019, http://doi.org/10.1108/IJPDLM-03-2018-0139/

Martin F., Hemmelmayr V.C., Wakolbinger T., 2021. Integrated express shipment service network design with customer choice and endogenous delivery time restrictions. European Journal of Operational ResearchOpen Access, 294, 2, 590 - 60316 October 2021, http://doi.org/10.1016/j.ejor.2021.02.014/

Mascarenhas A.O., Barbosa A.C.Q., 2019. Sustainable human resource management and social and environmental responsibility: An agenda for debate. RAE Revista de Administracao de Empresas Open Access, 59, 5, 353 - 3642019, http://doi.org/10.1590/S0034-759020190505/

McInroy N., 2018. Wealth for all: Building new local economies. Local Economy, 33, 6, 678 – 687, 1 September 2018, http://doi.org/10.1177/0269094218803084/

Michopoulou, E., Darcy S., Ambrose I. and Buhalis D., 2015. Accessible tourism futures: the world we dream to live in and the opportunities we hope to have, Journal of Tourism Futures, 1, 3, 179-188. http://doi.org/10.1108/JTF-08-2015-0043/

Özbalcı S., 2020. Economic Accessibility: Addressing Equality for Industry 4.0, Managing Global Trade in Industry 4.0: New Issues and Trends, Ankara: Gazi.

Palacio J.R.S., Climent V.C., Catala A.E., 2021. The organizational model of the Economy for the Common Good and its comparison with other approaches to Sustainability, CIRIEC-Espana Revista de Economia Publica, Social y Cooperativa,Open Access, 101, 143 - 163, http://doi.org/10.7203/CIRIEC-E.101.16399/

Roopa M.S., Ayesha S., Rajkumar B., Venugopal K.R., Iyengar S.S., Patnaik L.M., 2020. DTCMS: Dynamic traffic congestion management in Social Internet of Vehicles (SIoV), Internet of Things, http://doi.org/10.1016/j.iot.2020.100311/

Senir G., 2021. Comparison of domestic logistics performances of Turkey and European Union countries in 2018 with an integrated model. LogForum, 17 (2), 193-204. http://doi.org/10.17270/J.LOG.2021.576/

Unal T.D., Metin I.,2021. Do the factors affecting Incoterms® selection differ for exporters and importers? A Fuzzy Analytical Hierarchy Process (FAHP) application. LogForum 17 (2), 299-309, http://doi.org/10.17270/J.LOG.2021.585/

UN (2021) United Nations Development Programme, Human Development Index, Retrieved from, http://hdr.undp.org/en/content/human-development-index-hdi/

WEF (2021) World Economic Forum, Social Mobility Index, Retrieved From, https://www.weforum.org/reports/global-social-mobility-index-2020-why-economies-benefit-from-fixing-inequality/

Yıldırım E., 2021. Inclusive leadership and counseling in schools: asylum seekers students, Eğitimde Nitel Araştırmalar Dergisi, 9(1): 126-150, Retrieved from https://dergipark.org.tr/tr/pub/enad/issue/60131/871219/

Zhao Y., Leng L., Zhang C., 2021. A novel framework of hyper-heuristic approach and its application in location-routing problem with simultaneous pickup and delivery. Operational Research. 21, 2, 1299 – 1332, June 2021, http://doi.org/10.1007/s12351-019-00480-6/

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ORIGINAL PAPER

RISK MANAGEMENT TOOLS IN THE ROAD TRANSPORTATION INDUSTRY WITH MEDIATION AND MODERATION ANALYSIS

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ABSTRACT. **Background:** This study aims to shed light on risk-mitigating tools and strategies that can be used in third-party logistics (3PL) companies to increase performance. Risk and risk management tools are identified and classified according to the managers' feedback and the theoretical background. The most important risks for the road transportation industry are analyzed, their implications are discussed, and mitigating strategies are offered.
Methodology: The study used purposive sampling from international road freight forwarders that were members of the Association of International Forwarding and Logistics Service Providers (UTIKAD) or International Transporters' Association (UND). The data were collected by questionnaire method and analyzed with SPSS 22 and AMOS programs.
Results: The results show that the road transportation industry has important risks that managers have not effectively managed. According to the results, the main problems in 3PL companies are lack of coordination, lack of visibility, and poor service quality. The results support that delivery risk directly affects transportation quality and process risks.
Originality In this study, transportation-related risks are analyzed, showing their impact on a company's overall processes. Additionally, we examine whether the transportation quality creates a mediation effect or information sharing has a moderation effect on a company's process risks. Few studies exist on transportation risks and the role of mitigating strategies in reducing these risks, and this is also a limitation of our research from the risk perspective.

Keywords: risks, road freight transportation, transportation risks, risks of road freight transportation industry, mediation, moderation.

INTRODUCTION

In the last decade, globalization and technology developments have increased competition in the international arena and companies have begun to look for new ways to reduce their risks. To compete effectively nationally or internationally, companies must seek new solutions for the business environment. Outsourcing is one tool that companies use in this competitive environment. Outsourcing activity in logistics has increased significantly over time. The main reason for logistics outsourcing is to reduce costs and risks, thereby increasing a firm's performance. Transportation is one of the most important services of a third-party logistics (3PL) company. A firm's activities, partners, transfer volume, and number of employees directly affect the firm's performance, cost, profit, damage, and risks. Therefore, if a firm wants to manage and reduce its damage and risks, which have a direct effect on the firm's profitability and cost, it should add risk management tools for its processes. Many studies emphasize that risks are increasing in the supply chain context and mitigating strategies play an important role in managing supply chain risks [Wang et al., 2020a]. The modern concept of logistics dates to the second half of the twentieth century [Seyed-Alagheband et al., 2011]. Since the 2000s, logistics has become crucial for both industries and researchers and, thus, the field has expanded theoretically and practically. The

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development of logistics necessitates that managers have a comprehensive and current vision of the logistics concept. Logistics is essential for dealing with problems related to the transportation of goods without delays or damage, the on-time delivery of goods, and consumers'/customers' satisfaction with the service. The variety of logistics and supply chain activities (e.g., transportation, warehousing, handling, packaging) increases the complexity of the process and the risks for good decision making. In outsourcing, firms should analyze whether logistics activities provide efficiency and benefit the company. The benefit and efficiency can be related to increasing a firm's performance and profit and/or reducing costs. Third-party logistics activities include both transportation and warehousing activities; 3PL companies are also involved with packaging, order management, inventory management, finance, information-related activities, and value-added activities for customers, such as door-to-door services and custom operations [Wu, Chaipiyaphan, 2019]. These activities allow companies to manage transportation, delivery, and quality problems. In many cases, outsourcing is a main strategic decision for organizations that increasingly focus on a limited number of core competencies. For example, firms generally engage in outsourcing to improve service quality, provide effective communications with suppliers, reduce costs, and coordinate activities. Well-defined outsourcing strategies or strategic collaborations with partners can increase the overall performance of the organizations [Mclvor et al., 2009]. Some studies have shown that outsourcing in many European countries, Australia, the United States, and Japan is an important element for both public and private industries [Domberger, 1998]. Additionally, Gay and Eassinger [2000] show that outsourcing activities are important for reducing cost, increasing flexibility, having easy access to expertise, improving service quality, and focusing on the firm's main activities. Similarly, other studies have emphasized that outsourcing activities allow firms to focus on their core competencies, reduce logistics cost, increase flexibility in operations, improve productivity, access new technology and innovation, increase penetration into new markets, improve return on investment, reduce company risks, and improve company performance [Browne, Allen, 2017, Knemeyer, Murphy, 2004]. Other important benefits of outsourcing activities are improved firm performance and effectiveness. By outsourcing some activities, firms can focus on their main activities, their various businesses, and their core competencies and reduce their overall risks [Lankford, Parsa, 1999]. Firms are generally interested in outsourcing their logistics activities to achieve cost efficiency and mitigate bad outcomes. Outsourcing strategies provide efficiency, time saving, and money saving [Lankford, Parsa, 1999; Knemeyer, Murphy, 2004]. Despite its advantages, outsourcing also carries risks related to, for example, loss of control [Bardi, Tracey, 1991]. Also, a long-term contract can lead to a lack of flexibility, difficulty in reversing decisions [Shrivastava, 1995], a lack of volume, rigid systems, no understanding of value, and loss of in-house expertise [Bardi, Tracey, 1991].

Risk and performance are directly related to these dimensions, which in turn directly affect a company's managerial organization, a supplier's quality, and an organization's control [Lonsdale, Cox, 2000]. Therefore, risk management strategies are important for companies to mitigate risks and increase overall performance and profit.

The most important risks for transportation industries are distribution risks; these risks relate to late delivery and lead time, among other concerns. Transportation quality risk is related to the defect rate, accidents, and similar circumstances, and process risk is related to production processes and product quality. Different criteria are used to evaluate suppliers' performance. Researchers generally highlight risks associated with quality, delivery, performance, warranty policy, reliability, product, satisfaction, price, and technical skills [Tracey, Tan, 2001]. Ho et al. [2010] emphasize that delivery, product quality, service quality, and managerial risks are critical criteria for the performance evaluation process.

Many studies have emphasized the importance of risks related to quality, delivery, and processes, taking different perspectives and using different risks mitigating tools [e.g., Schoenherr et al., 2008; Sinrat, Atthirawong, 2013, Świerczek, 2019]. In this study, we limit the research to three types of risks that have the highest impact, as identified in the literature. The effects of delivery-related risks, process risks and transportation quality risks on a company's overall process risks are analyzed and recommendations are made to help companies reduce these risks.

Generally, studies in the literature have focused on supply chain-related risks; very few have investigated 3PL-related risks. Based on these gaps in the literature, this study aims to research and analyze 3PL-related risks and mitigating strategies that can be used to reduce the impact of these risks.

This paper continues with the following sections. In Section 2, we address the theoretical background of 3PL-related risks and the hypothesis development. Section 3 discusses the research method. Section 4 continues with analysis and results and Section 5 concludes the paper, details managerial implications, and suggests future research paths.

THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

Managing transportation risk, delivery risk, and quality-related risk is essential in supply chain processes. Agency theory concentrates on problems related to each other or to each member in the chain [Eisenhardt, 1989, Lassar, Kerr, 1996]. This theory emphasizes process coordination [Celly, Frazier, 1996], control [Anderson, Oliver, 1987], outsourcing [Bahli, Rvard, 2003], management [McMillan, 1990], supply chain [Zsidisin, Ellram, 2003], and managerial risk taking [Wiseman, Gomez-Mejia, 1998]. Additionally, quality-related problems represent another important risk that directly increases the supply chain process risks. Zsidisin and Ellram [2003] show that quality-related risks are generally related to suppliers, equipment, delivery failure, damage, or employee performance.

Improving information sharing by using risk management tools to reduce process-related risks and to develop closer relationships with suppliers is also part of this theory. Agency theory focuses on problems with partners and reducing the associated risks [Eisenhardt, 1989, Lassar, Kerr, 1996]. From the risk management perspective, the main purpose of this theory is to reduce misinformation or information asymmetries, align objectives, and encourage closer supplier relations [Zsidisin, Ellram, 2003]. All these efforts aim to reduce the impact of supply chain-related risks. Therefore, in our research, the theoretical reasoning in the interactions among transportation quality, delivery, and process risks is backed up by a well-established theoretical foundation.

Delivery Risks and Transportation Quality Risks

Delivery risks are associated with product damage, product loss, wrong delivery, or delivery to a wrong address. Wrong deliveries related to quantity include failures, demand problems, or irregular supplies [Zsidisin, 2003]. These types of risks cause transportation quality problems. Similarly, if firms' delivery risk decreases, the quality of transportation increases [Tuncel and Alpan, 2010]. Delivery and transportation risks are companies' main concerns. Transportation quality and delivery are important for companies to ensure that customers receive products in proper condition [Ghavamifar et al., 2018]. Delivery problems like wrong or late deliveries not only cause financial losses, but they also result in reduced product quality, loss of prestige in the eyes of customers, damage to property and equipment, suppliers, and the wider public, and delivery delays [Ahlert et al., 2009, Waters, 2011, Beneke et al., 2015]. Prior findings and rationales lead to our first hypothesis:

H_1= Delivery risks increase transportation quality risks.

Delivery Risks, Transportation Quality Risks, and Process Risks

The process starts when a customer orders something from the manufacturer and continues with delivery of the order. If all aspects of the process are in place (e.g., product availability, transportation, operations), the purchase process activities can start. The main concerns with the delivery process are delivery risks and transportation quality risks, both of which are important for transporting products in the desired condition [Tuncel, Alpan, 2010]. The risks involving this process include, in particular, consumers' fear that the product will be damaged during transportation. For this reason, it is important to manage the delivery process effectively and to select a suitable delivery system to reduce delivery- or process-related risks [Shi et al., 2014]. These risks especially relate to internal processes, distribution failures, or poor transportation quality [Sreedevi, Saranga, 2017]. Process risks arise when the delivery of goods or services is slow, delayed, irregular, or incorrect [Zhao et al., 2013] because the delivery process includes high uncertainty and high unreliability [Frohlich and Westbrook, 2002]. Delivery and operation risks can affect all transportation movements, as well as the quality of the process [Waters, 2011]. Delivery-related risks and transportation quality risks affect all process activities (e.g., sales, delivery, company reputation, operations, costs) [Garvey et.al, 2015; Globerman, Storer, 2015; Mesa-Arango, et. al., 2016].

Transportation quality affects all aspects of the supply chain (e.g., late delivery, disruption, flow interruption, product quality) [Zhen et.al., 2016]. These transportation quality problems cause operations breakdowns, lost sales, late delivery, and reputation problems [Garvey et al., 2015]. This confirms that transportation is an important dimension of supply chain operations and processes. Supply chain disruptions may cause problems such as, inability to meet customer requirements, stock outs, long lead times, and increasing costs [Svensson, 2000]. Risk in the supply chain may cause unexpected problems such as capacity problems, accidents, quality related problems or natural disasters at the supplier side [Yang, Yang, 2010, Blackhurst et al., 2005]. Globerman and Storer [2015] emphasized that transportation quality plays an important role in supply chain and process efficiency.

Giunipero and Eltantawy [2004] stressed that "transportation disruption caused a great risk and, if severe, could cripple the entire supply chain". Houshyar et al. [2013] argued that transportation disruption may cause a decrease in supply chain performance as it may result in delay production and late deliveries, leading to loss sales. Prior findings and rationales lead to our second and third hypotheses:

H_2= Delivery risks increase process risks.

H_3= Transportation quality risks increase process risks.

Transportation quality problems and risks arise from delays or unavailability of the product, in either inbound or outbound activities [Sheffi et al., 2003]. Transportation risks cause delays in the final delivery or the production delivery stages [Prakash et al., 2020]. Transportation risk directly affects customer satisfaction and quality of service; therefore, improving transportation quality with risk analysis tools plays an important role in processes [Christopher, Holweg, 2011].

Mediation and Moderation Effects

Sharing correct, reliable, relevant and timely information between members defined as information sharing [Ramanathan, 2013]. It is characterized by frequency, reliability, content, and validity [Neumann, Segev, 1979]. Shared information helps members to coordinate and standardize their activities to work together [Sodhi, Son, 2009]. Shared information among members can be related to strategic, operational or tactical plans and decisions [Huang et.al., 2003]. In addition, information sharing is an important tool for reducing process disruptions [Craighead et al., 2007, Sodhi, Tang, 2012], cost [Kahn et al., 2016], transparency [Jüttner, 2005], and supply chain visibility [Christopher, Lee, 2004]. Sharing risk and information with supply chain members has a significant and positive impact on a company's operational performance [Fan et al., 2017; Wang, et al., 2020b]. Lee and Lee's [2019] framework shows the importance of information sharing as a mediation between trust and long-term relationships, but without any analysis or results.

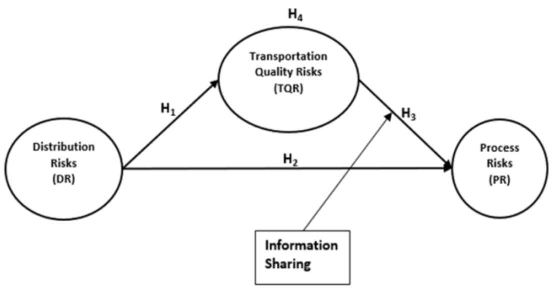

Fig. 1. Research Model

Our fourth hypothesis is as follows:

H_4= Transportation quality risks mediate delivery risks and process risks.

On time delivery is vital for satisfying production needs and reducing inventory cost. Delivery is evaluated via the differences between the planned and occurred arrival times [Li, Zeng, 2016]. Proper delivery conditions are important to customer satisfaction and product or production quality; quality risks can be related to the product or production process [Sinrat, Atthirawong, 2013]. These quality problems can increase a company's process risks. Information-related risks (e.g., product, quality, demand, cost, delivery) are extremely sensitive elements because information is directly related to a firm's performance [Min. et.al, 2007]. Additionally, information sharing between supply chain members plays an important role in a company's relationships. However, very few articles in the literature have examined the relationship between risk and information sharing, and the moderator effect of information sharing has not yet been studied.

RESEARCH METHOD

Sample and Data Collection

The proposed model validates with utilized a cross-sectional survey approach in this study empirically. The study used purposive sampling from international road freight forwarders that were members of the Association of International Forwarding and Logistics Service Providers (UTIKAD) or International Transporters' Association (UND). The questionnaire was pre-tested with three logistics managers and five general managers who worked in highly reputable international logistics companies to ensure the quality and validity of the questionnaire. The pilot survey was conducted using face-to-face interviews and pre-tested with 60 international road transportation firms' managers. The questions used for the pre-test and the participants' answers were analyzed with confirmatory factor analyses and some questions were deleted from the survey based on pre-test analyses. Final data were collected from 151 managers, executives, and logistics managers who were members of UTIKAD or UND. According to the survey results, the respondents' gender distribution was male dominated at 81.46%, with 18.54% being female. As predicted, the logistics industry is male dominated. Participants' position in the 3PL firms were Manager (35.8%), General Manager (25.2%), and Logistics Manager (18.5%). These three types of managers represented approximately 80% of all survey respondents. Generally speaking, well-educated managers answered the survey. To eliminate the impact of other factors on delivery and process risks, it is important to control factors such as firm size and experience. Two control variables were used in this research. Firm size and number of years doing business were selected as control variables. Firm size and experience are often used as control variables, with different results.

ANALYSIS AND RESULTS

Analyses of the measurement and structural model of our research follow Anderson and Gerbing's [1988] procedures. All items in the model distribution risks, transportation quality risks, and process risks load with a high alpha coefficient, greater than 0.5, and all eigenvalues are greater than 1.00; thus, the results fulfill the convergent validity criteria. Items with a low alpha coefficient (lower than 0.70) and loading related to dependent and independent variables are rejected. The measurement items load with their respective construct and factor loadings range from 0.70 to 0.90, providing convergent validity of the theoretical constructs. The average variance extracted (AVE) value of the construct is greater than the recommended value of 0.50 [Bagozzi et.al., 1981], so the model construct shows strong convergent validity. Composite reliability (CR) values of each construct are greater than 0.85, which shows that all measurement scales demonstrate high reliability [Nunnally and Bernstein, 1994]. Distribution risk (DR) and transportation quality risk (TQR) scales are adapted from Ersoy [2014] and the process risk (PR) scale is adapted from Ersoy [2014] and Moeinzadeh and Hajfathaliha [2009].

Amos 24 is applied to verify the internal consistency and reliability of the measurement model and to check factor structures using Confirmatory Factor Analysis (CFA) and relationships between the dependent and independent variables. The total variance explained with these three constructs is greater than 75%. The measurement model's CFA results show a good fit to our three-factor solution ($\chi 2$/df= 1.52, CFI= 0.991, IFI= 0.991, TLI= 0.981, NFI= 0.975, and RMSEA=0.042), and the fit indexes show a good fit for our model [Hu and Bentler, 1999]. Table A in the appendix, displays detailed information on the constructs, Cronbach's alpha, composite reliability, and average variance extracted. Correlations among the constructs are shown in Table B (in the appendix). The AVE values of all constructs are greater than the correlation among all constructs, for this reason discriminant validity is provided among the constructs [Fornell, Larcker, 1981]. The Harman's one-factor test conducted by performing factor analysis on the items of the dependent and independent variables and designed questionnaire with separating dependent and independent variables [Podsakoff, et al.,2003]. The unrotated solutions yield three factors with eigenvalues greater than 1.0 and explain 59.34% of the total variance. Single factor loading accounts for less than 35% of the total explained variance [Malhotra et al., 2006]. The single factor model fit indices are very poor ($\chi 2$ /df= 8.804, GFI= 0.67, CFI= 0.68, IFI=0.70, TLI=0.69, RMSEA=0.304). The results show that common method bias is not an issue in this research.

Hypotheses Testing and Results

The structural model and model fit indices tested with using Amos 24. The model indices are a good fit ($\chi 2$/df= 2.582, CFI= 0.97, IFI= 0.98, TLI= 0.96, NFI= 0.97, RMSEA=0.052) and the structural model is acceptable. Table 1 shows the estimated results of the hypothesized model. H_1 and H_2 address distribution risk (DR), which affects transportation quality risk and process risk. For H_1, the result (β=0.3354, p=0.0000) shows that distribution risk has a positive effect on transportation risk; thus, H_1 is supported. Similarly, a positive relationship exists between distribution risk and transportation quality (β=0.3501, p=0.0000); thus, H_2 is supported. Hypothesis 3 addresses the effects of transportation quality risk on a company's process risk; transportation quality risk has a positive and significant effect on process risk (β=0.4459, p=0.0000), and H_3 is supported.

Table 1. Structural Model Results

Hypothesis	Hypothesis path	Proposed Effect	*p* Value	Path coefficient	Results
H_1	Distribution Risk → Transportation Quality Risk	Positive	0.0000	0.3354	Supported
H_2	Distribution Risk → Process Risk	Positive	0.0000	0.3501	Supported
H_3	Transportation Quality Risk → Process Risk	Positive	0.0000	0.4459	Supported

Mediation and Moderation Analysis

Researchers use mediation analysis to understand how an independent variable (X) affects a dependent variable (Y) with or without an extra variable. To measure the mediation effect of transportation quality risk as formulated in H_4, the recommended bootstrapping bias-corrected confidence interval procedure in structural equation modeling is applied [Preacher and Hayes, 2008]. Using AMOS 24, we apply 2,000 samples to obtain the confidence intervals. This procedure generated 95% confidence intervals, Table 2 describes the mediation effect results and shows a significant indirect effect of distribution risk on process risk through transportation quality risk, supporting H_4 ($\beta=0.4996$, $p<0.0000$). Thus, transportation quality-related risks may increase a company's process risks. With a third variable, strength of the relationship between dependent and independent variables, the moderation effect occurs [Preacher et al., 2007]. H_5 addresses the moderation effect of information sharing on transportation quality risks and process risks ($\beta=0.0327$, $p<0.0000$). The result shows that sharing information through the delivery process may help companies reduce their process risks.

Table 2. Moderated Mediation Analysis Results

Hypo thesis	Paths	Variable	Varia ble Type	Direct with mediator/ moderator (β)	Direct without mediator/ moderator (β)	p-value	Boot 95% CI		Relation Type	Propose d Effect	Results
							LL	UL			
H_4	DR →PR	TQR	Mediator	0.4996	0.3501	p<0.000	0.3993	0.6000	Media tion	Positive	Supported
H_5	TQR →PR	Informa tion Sharing	Moderator	0.0327	0.4459	p<0.001	0.0124	0.0541	Modera tion	Positive	Supported

Notes. CI= Confidence Interval; LL= Lower Limit; UL= Upper Limit

CONCLUSIONS

The structural model and moderated mediation result tables show the results of our research. The results support that delivery risk directly affects transportation quality and process risks. Therefore, companies should manage their distribution options, delivery frequencies, packaging lines, and storage accordingly. Additionally, transportation quality risks directly affect a company's process risks. For this reason, companies should improve their transportation quality with additional employee seminars and training, thereby improving their service quality and solving routing problems via software. The mediation result shows that transportation quality problems directly increase process risks. Thus, improving their transportation quality may help companies improve their processes. The moderation effect demonstrates that sharing information during the delivery process or increasing transparency between members helps to reduce process-related risks.

Similarly, Piltan and Sowlati [2015] showed that monitoring the performance of partnerships directly affects whole process performance. This research empirically analyzed the relationship between a firm's delivery and transportation quality risks and their impact on the firm's process risks. In which conditions these risks can be mitigated is the main concern of this study. The researchers found a limited number of studies on transportation risks and the role of mitigating strategies for reducing these risks. Delivery risks always affect a firm's internal and external logistics activities [Sreedevi, Saranga, 2017]. To reduce delivery, product, or time problems, companies can develop new strategies such as routing, employee training, and enhancing communication between chain members. New solutions and strategies are inevitable in this competitive environment.

Managerial Implications

The research findings will help company managers form a new perspective to mitigate their delivery-related risks. First, the findings show that delivery-related risks can include mitigating distribution varieties, training employees, selecting alternative routes, and improving transportation services. Increasing flexibility during the delivery process or choosing alternative routes can help managers mitigate delivery-related risks. Additionally, managers can reduce distribution uncertainty, lead time, and systems problems by increasing process transparency and flexibility. These solutions not only reduce existing risks but also develop better service quality and long-run company sustainability. Our results provide alternative solutions for companies to identify their risks and reduce their potential impact. As seen from the results, process risks are directly related to transportation quality and delivery problems; for this reason, managers should focus on these problems to improve the company's overall performance and reduce its potential losses.

Limitations and Future Research

Despite its important findings, as with any study, several limitations arise from our research design. In this study, we limited risks to delivery, transportation, and process risks. Other supply chain risks can be used in future studies to find new mitigating strategies. In this study, we used information sharing as a moderator; in future studies, other control variables such as age, education level, and gender can be used and control as a moderator. On the other hand, dependent variables like service-related risks or procurement-related risks can be used as a mediator and their impacts can be analyzed. This study was conducted on road freight transportation and, specifically, 3PL firms. The study can also be applied to industries to define their specific risks. For generalization of the findings, the solutions can be tested in different industries and countries.

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REFERENCES

Ahlert D., Olbrich R., Kenning P., Schroeder H., Glynn M.S., Chen S., 2009. Consumer-factors moderating private label brand success: further empirical results. International Journal of Retail & Distribution Management. http://doi.org/10.1108/09590550910999343

Anderson J.C., Gerbing D.W., 1988. Structural equation modeling in practice: A review and recommended two-step approach. Psychological bulletin, 103(3), 411.

Anderson E., Oliver R.L., 1987. Perspectives on behavior-based versus outcome-based salesforce control systems. Journal of Marketing, 51(4), 76-88.

Bagozzi R.P., Fornell C., Larcker D.F., 1981. Canonical correlation analysis as a special case of a structural relations model. Multivariate Behavioral Research, 16(4), 437-454. http://doi.org/10.1207/s15327906mbr1604_2

Bahli B., Rivard S., 2003. The information technology outsourcing risk: a transaction cost and agency supply chain-based perspective. Journal of information technology, 18(3), 211-221. http://doi.org/10.1080/0268396032000130214

Bardi E.J., Tracey M., 1991. Transportation outsourcing: a survey of US practices. International Journal of Physical Distribution & Logistics Management. http://doi.org/10.1108/09600039110134986

Beneke J., Brito A., Garvey K.A., 2015. Propensity to buy private label merchandise. International Journal of Retail & Distribution Management. http://doi.org/10.1108/IJRDM-09-2013-0175

Blackhurst J., Craighead C.W., Elkins D., Handfield R.B., 2005. An empirically derived agenda of critical research issues for managing supply-chain disruptions. International journal of production research, 43(19), 4067-4081. http://doi.org/10.1080/00207540500151549

Browne M., Allen J., 2017. Logistics outsourcing. In Handbook of logistics and supply-chain management. Emerald Group Publishing Limited. http://doi.org/10.1108/9780080435930-016

Celly K.S., Frazier G.L., 1996. Outcome-based and behavior-based coordination efforts in channel relationships. Journal of marketing research, 33(2), 200-210. http://doi.org/10.1177/002224379603300207

Christopher M., Holweg M., 2011. Supply Chain 2.0: managing supply chains in the era of turbulence. International journal of physical distribution & logistics management, 41(1), 63-82. http://doi.org/10.1108/09600031111101439

Craighead C.W., Blackhurst J., Rungtusanatham M.J., Handfield R.B., 2007. The severity of supply chain disruptions: design characteristics and mitigation capabilities. Decision Sciences, 38(1), 131-156. http://doi.org/10.1111/j.1540-5915.2007.00151.x

Domberger S., 1998. The contracting organization: a strategic guide to outsourcing: a strategic guide to outsourcing. OUP Oxford.

Eisenhardt K.M., 1989. Agency theory: An assessment and review. Academy of management review, 14(1), 57-74. http://doi.org/10.5465/amr.1989.4279003

Ersoy P., 2014. Risk Management Strategies in Supply Chain: An Application on International Road Transportation Industry in Turkey. Dokuz Eylül University, Business Management PhD. Program, Published PhD. Thesis.

Fan H., Li G., Sun H., Cheng T.C.E., 2017. An information processing perspective on supply chain risk management: Antecedents, mechanism, and consequences. International Journal of Production Economics, 185, 63-75. http://doi.org/10.1016/j.ijpe.2016.11.015

Fornell C., Larcker D.F., 1981. Structural equation models with unobservable variables and measurement error: Algebra and statistics. http://doi.org/10.1177/002224378101800313

Frohlich M.T., Westbrook R., 2002. Demand chain management in manufacturing and services: web-based integration, drivers and performance. Journal of operations Management, 20(6), 729-745. http://doi.org/10.1016/S0272-6963(02)00037-2

Garvey M.D., Carnovale S., Yeniyurt S., 2015. An analytical framework for supply network risk propagation: A Bayesian network approach. European Journal of Operational Research, 243(2), 618-627. http://doi.org/10.1016/j.ejor.2014.10.034

Gay C.L., Eassinger J., 2000. Inside outsourcing: an insider's guide to managing strategic sourcing. Nicholas Brealey Pub.

Ghavamifar A., Makui A., Taleizadeh A.A., 2018. Designing a resilient competitive supply chain network under disruption risks: A real-world application. Transportation research part E: logistics and transportation review, 115, 87-109. http://doi.org/10.1016/j.tre.2018.04.014

Giunipero L.C., Eltantawy R.A., 2004. Securing the Upstream Supply Chain: A Risk Management Approach. International Journal of Physical Distribution & Logistics Management 34 (9): 698–713. http://doi.org/10.1108/09600030410567478

Globerman S., Storer P., 2015. Transportation costs and trade clusters: Some empirical evidence from US customs districts. Research in transportation business & management, 16, 67-73. http://doi.org/10.1016/j.rtbm.2015.05.004

Ho W., Xu X., Dey P.K., 2010. Multi-criteria decision-making approaches for supplier evaluation and selection: A literature review. European Journal of operational research, 202(1), 16-24. http://doi.org/10.1016/j.ejor.2009.05.009

Houshyar A.N., Baghdadabad M.R.T., Hoshyar A.N., Bin Sulaiman R., 2013. Simulating Effects of Transportation Disruption on Supply Chain based on Vendor Managed Inventory Approach. International Journal of Modeling and Optimization 3 (2): 116–119.

Hu L.T., Bentler P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural equation modeling: a multidisciplinary journal, 6(1), 1-55. http://doi.org/10.1080/10705519909540118

Huang G.Q., Lau J.S., Mak K.L., 2003. The impacts of sharing production information on supply chain dynamics: a review of the literature. International journal of production research, 41(7), 1483-1517. http://doi.org/10.1080/0020754031000069625

Jüttner U., 2005. Supply chain risk management. The international journal of logistics management. http://doi.org/10.1108/09574090510617385

Kahn C.M., Liñares-Zegarra J.M., 2016. Identity theft and consumer payment choice: Does security really matter?. Journal of Financial Services Research, 50(1), 121-159. http://doi.org/10.1007/s10693-015-0218-x

Knemeyer A.M., Murphy P.R., 2004. Evaluating the performance of third-party logistics arrangements: a relationship marketing perspective. Journal of supply chain management, 40(4), 35-51. http://doi.org/10.1111/j.1745-493X.2004.tb00254.x

Lankford W.M., Parsa F., 1999. Outsourcing: a primer. Management Decision. http://doi.org/10.1108/00251749910269357

Lassar W.M., Kerr J.L., 1996. Strategy and control in supplier–distributor relationships: An agency perspective. Strategic Management Journal, 17(8), 613-632. http://doi.org/10.1002/(SICI)1097-0266(199610)17:8<613::AID-SMJ836>3.0.CO;2-B

Lee H., Lee S.H., 2019. The Impact of Corporate Social Responsibility on Long-Term Relationships in the Business-to-Business Market. Sustainability, 11(19), 5377. http://doi.org/10.3390/su11195377

Li S., Zeng W., 2016. Risk analysis for the supplier selection problem using failure modes and effects analysis (FMEA). Journal of Intelligent Manufacturing, 27(6), 1309-1321. http://doi.org/10.1007/s10845-014-0953-0

Lonsdale C., Cox A., 2000. The historical development of outsourcing: the latest fad?. Industrial management & data systems. http://doi.org/10.1108/02635570010358384

Malhotra N.K., Kim S.S., Patil A., 2006. Common method variance in IS research: A comparison of alternative approaches and a reanalysis of past research. Management science, 52(12), 1865-1883. http://doi.org/10.1287/mnsc.1060.0597

McIvor R., 2009. How the transaction cost and resource-based theories of the firm inform outsourcing evaluation. Journal of Operations management, 27(1), 45-63. http://doi.org/10.1016/j.jom.2008.03.004

McMillan J., 1990. Managing suppliers: Incentive systems in Japanese and US industry. California Management Review, 32(4), 38-55. http://doi.org/10.2307/41166627

Mesa-Arango R., Zhan X., Ukkusuri S.V., Mitra A., 2016. Direct transportation economic impacts of highway networks disruptions using public data from the United States. Journal of Transportation Safety & Security, 8(1), 36-55. http://doi.org/10.1080/19439962.2014.978962

Min S., Mentzer J.T., Ladd R.T., 2007. A market orientation in supply chain management. Journal of the Academy of Marketing Science, 35(4), 507. http://doi.org/10.1007/s11747-007-0020-x

Moeinzadeh P., Hajfathaliha A., 2009. A combined fuzzy decision-making approach to supply chain risk assessment. World Academy of Science, Engineering and Technology, 60(2), 519-528.

Neumann S., Segev E., 1979. A case study of user evaluation of information characteristics for systems improvement. Information & Management, 2(6), 271-278. http://doi.org/10.1016/0378-7206(79)90025-9

Nunnally J.C., 1994. Psychometric theory 3E. Tata McGraw-hill education.

Piltan M., Sowlati T., 2016. Multi-criteria assessment of partnership components. Expert Systems with Applications, 64, 605-617. http://doi.org/10.1016/j.eswa.2016.08.006

Podsakoff P.M., MacKenzie S.B., Lee J.Y., Podsakoff N.P., 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. Journal of applied psychology, 88(5), 879. http://doi.org/10.1037/0021-9010.88.5.879

Prakash S., Kumar S., Soni G., Jain V., Rathore A.P.S., 2020. Closed-loop supply chain network design and modelling under risks and demand uncertainty: an integrated robust optimization approach. Annals of Operations Research, 290(1), 837-864. http://doi.org/10.1007/s10479-018-2902-3

Preacher K.J., Hayes A.F., 2008. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior research methods, 40(3), 879-891. http://doi.org/10.3758/BRM.40.3.879

Preacher K.J., Rucker D.D., Hayes A.F., 2007. Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. Multivariate behavioral research, 42(1), 185-227. http://doi.org/10.1080/00273170701341316

Ramanathan U., 2013. Aligning supply chain collaboration using Analytic Hierarchy Process. Omega, 41(2), 431-440. http://doi.org/10.1016/j.omega.2012.03.001

Schoenherr T., Tummala V.R., Harrison T.P., 2008. Assessing supply chain risks with the analytic hierarchy process: Providing decision support for the offshoring decision by a US manufacturing company. Journal of purchasing and supply management, 14(2), 100-111. http://doi.org/10.1016/j.pursup.2008.01.008

Seyed-Alagheband S.A., Farahani L.R., Rezapour S., 2011. Logistics parties (pp. 71-92). New York: Elsevier.

Sheffi Y., Rice J.B., Fleck J.M., Caniato F., 2003. Supply Chain Response to Global Terrorism : A Situation Scan. EurOMA POMS Joint International Conference, 1–6.

Shi Q., Zhou Y., Xiao C., Chen R., Zuo J., 2014. Delivery risk analysis within the context of program management using fuzzy logic and DEA: a China case study. International Journal of Project Management, 32(2), 341-349. http://doi.org/10.1016/j.ijproman.2013.05.002

Shrivastava P., 1995. Environmental technologies and competitive advantage. Strategic management journal, 16(S1), 183-200. http://doi.org/10.1002/smj.4250160923

Sinrat S., Atthirawong W., 2013. A conceptual framework of an integrated fuzzy ANP and TOPSIS for supplier selection based on supply chain risk management. In 2013 IEEE International Conference on Industrial Engineering and Engineering Management (pp. 1607-1611). IEEE. https://doi.org/10.1109/IEEM.2013.6962681

Sodhi M.S., Son B.G., 2009. Supply-chain partnership performance. Transportation Research Part E: Logistics and Transportation Review, 45(6), 937-945. http://doi.org/10.1016/j.tre.2009.05.004

Sodhi M.S., Tang C.S., 2012. Managing supply chain risk (Vol. 172). Springer Science & Business Media.

Sreedevi R., Saranga H., 2017. Uncertainty and supply chain risk: The moderating role of supply chain flexibility in risk mitigation. International Journal of Production Economics, 193, 332-342. http://doi.org/10.1016/j.ijpe.2017.07.024

Svensson G., 2000. A conceptual framework for the analysis of vulnerability in supply chains. International journal of physical distribution & logistics management. http://doi.org/10.1108/09600030010351444

Świerczek A., 2019. The effects of demand planning on the negative consequences of operational risk in supply chains. LogForum, 15. http://doi.org/10.17270/J.LOG.2019.340

Tracey M., Tan C.L., 2001. Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance. Supply Chain Management: An International Journal. http://doi.org/10.1108/EUM0000000005709

Tuncel G., Alpan G., 2010. Risk assessment and management for supply chain networks: A case study. Computers in industry, 61(3), 250-259. http://doi.org/10.1016/j.compind.2009.09.008

Wang M., Asian S., Wood L.C., Wang B., 2020a. Logistics innovation capability and its impacts on the supply chain risks in the Industry 4.0 era. Modern Supply Chain Research and Applications. http://doi.org/10.1108/MSCRA-07-2019-0015

Wang Q., Huo B., Zhao X., 2020b. What Makes Logistics Integration More Effective? Governance from Contractual and Relational Perspectives. Journal of Business Logistics. http://doi.org/10.1111/jbl.12236

Waters D., 2011. Supply chain risk management: vulnerability and resilience in logistics. Kogan Page Publishers.

Wiseman R. M., Gomez-Mejia L.R., 1998. A behavioral agency model of managerial risk taking. Academy of management Review, 23(1), 133-153. http://doi.org/10.5465/amr.1998.192967

Wu P.J., Chaipiyaphan P., 2019. Diagnosis of delivery vulnerability in a logistics system for logistics risk management. The International Journal of Logistics Management. http://doi.org/10.1108/IJLM-02-2019-0069

Yang B., Yang Y., 2010. Postponement in supply chain risk management: a complexity perspective. International Journal of Production Research, 48(7), 1901-1912. http://doi.org/10.1080/00207540902791850

Zhao L., Huo B., Sun L., Zhao X., 2013. The impact of supply chain risk on supply chain integration and company performance: a global investigation. Supply Chain Management: An International Journal, 18(2), 115-131. http://doi.org/10.1108/13598541311318773

Zhen X., Li Y., Cai G.G., Shi D., 2016. Transportation disruption risk management: business interruption insurance and backup transportation. Transportation Research Part E: Logistics and Transportation Review, 90, 51-68. http://doi.org/10.1016/j.tre.2016.01.005

Zsidisin G.A., 2003. A grounded definition of supply risk. Journal of purchasing and supply management, 9(5-6), 217-224.7. http://doi.org/10.1016/j.pursup.2003.07.002

Zsidisin G.A., Ellram L.M., 2003. An agency theory investigation of supply risk m anagement. Journal of supply chain management, 39(2), 15-27. http://doi.org/10.1111/j.1745-493X.2003.tb00156.x

Appendix

Table A. Individual Constructs and Validity Measures

Author/s	**Construct**	**Item**	**Cronbach Alpha**	**AVE**	**CR**	**Construct Reliability (α)**
Ersoy, P. (2014)	**Distribution and Delivery Risks**	Distribution network variety increases a company's delivery-related risk Delivery problems (e.g., frequency of delivery) increase a company's delivery-related risk Network variety increases a company's delivery-related risk Packaging line variety increases a company's delivery-related risk.	0.790 0.858 0.848 0.771	0.668	0.889	0.834
Ersoy, P. (2014); Moeinzadeh & Hajfathaliha (2009)	**Process Risks**	Distribution uncertainty increases a company's process-related risk Problems with system integration increase a company's process-related risk Lack of process visibility increases a company's process-related risk Lead time problems increase a company's process-related risk	0.813 0.865 0.841 0.774	0.679	0.894	0.858
Ersoy, P. (2014)	**Transportation Quality Risks**	Lack of education seminars for employees increases a company's transportation quality-related risks. Routing problems or choosing the wrong route increases a company's transportation quality-related Complaints about transportation service increase a company's transportation quality-related risks	0.815 0.833 0.829	0.682	0.865	0.767

Note: Likert scale: 1 = Completely disagree; 7 = Completely agree
GFI= 0.977
CFI=0.991
IFI= 0.991
NFI= 0.975
TLI=0.981
RMSEA= 0.042
X^2/df = 39,612/26= 1.52

Table B. Correlations and Descriptive Statistics

Construct	**Mean**	**Std. Dev.**	**Distribution Risks**	**Transportation Quality Risks**	**Process Risks**
Distribution Risks	3.49	0.98	1		
Transportation Quality Risks	3.34	0.99	0.344	1	
Process Risks	3.42	0.95	0.492	0.547	1

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ORIGINAL PAPER

MANAGING INDUSTRY 4.0 INTEGRATION - THE INDUSTRY 4.0 KNOWLEDGE & TECHNOLOGY FRAMEWORK

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ABSTRACT. **Background:** This paper has the aim to address the key area of managing complex Industry 4.0 production systems to support a successful adoption and integration of Industry 4.0. This is achieved by approaching methodological research challenges of Industry 4.0 in the form of lacking reference models and the need to establish common definitions of fundamental concepts. The general underlying challenge this paper aims to contribute to solve can therefore be defined as how the technological advances, like CPS, IoT, Big Data or CC can be best linked with each other on different levels of perspective and how they can be used by decision-makers to generate economic value and to improve existing processes. This is achieved through the introduction of the Industry 4.0 Knowledge & Technology Framework (IKTF).

Methods: The Industry 4.0 Knowledge Framework (IKTF) is based on the concept of the micro-meso-macro analysis framework and consequently is representative for the approach of micro-meso-macro analysis in managerial practice. It proposes three categories of factors and places them in three basic levels layering them on top of each other. The macro-level includes the financial, political and sociocultural factors that influence Industry 4.0. The meso-level includes the technical and organizational factors. The micro-level refers to individual factors, particularly individual companies' intention to use Industry 4.0 in practical economic contexts.

Results: The Industry 4.0 Knowledge & Technology Framework (IKTF) provides guidance to corporate decision makers by providing a comprehensive, multi-level sequential integration framework for Industry 4.0 based on a sequential micro, meso and macro perspective analysis of the individual corporate context. The aim of the IKTF is to support an informed and successful managerial decision-making process and therefore enable the integration of Industry 4.0 in a corporate context.

Conclusion: As a first step, the structure, and contents of the IKTF are sequentially introduced and described. In a second and final step the functionality and applicability of the IKTF are demonstrated and discussed on a theoretical and practical level with the help of a case study.

Keywords: Industry 4.0, Smart Factory, exponential technological change, cyber-human systems, cyber-physical systems.

INTRODUCTION

Accelerating technological developments and the changes induced by the so-called exponential disruptive technologies lead to the necessity for companies to integrate new manufacturing methods in the form of Industry 4.0. This development is expected to allow companies to anticipate and utilize the potency of current and upcoming technological advancements in production technology and to leverage existing competitive advantages while unlocking new progress. The rising potency of technology in areas like general computer processing power, sensors, artificial intelligence, machine learning algorithms, robotics and automation technology breaks through the limits of the anticipated growth rates of traditional technologies and manifests in more radical visions for changes in industrial production systems [McAfee and Brynjolfsson, 2014, Fraunhofer IPT, 2019]. Underlying drivers for the possible exponential

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development of technology are the often mentioned "Moore´s Law" which shows that the number of transistors per microchip increased by the power of 10 in the last 40 years , "Metcalf´s Law" can also be mentioned which states that computing hardware becomes more powerful, small and more embedded over time and the vastly increased and ever increasing speed of technology adoption by users. "Butter´s Law of photonics" says that the amount of data one can transmit using optical fiber is doubling every nine months. "Rose´s Law", which states that the number of qubits in quantum computers is growing exponentially and the concept of "Big Data" referring to the exponential growth of information generated by modern information systems. [McAfee and Brynjolfsson, 2014, Gimple, Röglinger, 2015]. In addition to the accelerating impact of disruptive exponential technologies, industrial production is driven by a hyper-competitive rivalry for market shares between formerly separated industries caused by a more global, digital and interconnected market environment [Turgay, Emeagwali, 2012]. Technology induced market disruption and the resulting volatile and complex market environments are expressed through constantly changing, more individualized customer requirements and shorter product lifecycles. These developments can be regarded as the determining factors for the successful development process of a market-oriented industrial production with a high-tech methodology that can fulfill the requirements of current and future market environments [Vaidya, Ambad, Bhosle, 2018 Lee, Bagheri, 2015]. These aspects are furthermore accelerated by the COVID-19 pandemic, a global "black swan" event which inflicts high and rising human and economic costs world-wide and as a result enforced a global partial or total lockdown of most facilities of production [Congressional Research Service, 2020, World Economic Outlook, 2020]. The vision of Industry 4.0 can be regarded as a potential answer to overcome the described current and future technological, social and economic challenges that disrupt the functionality of the traditional manufacturing paradigm of embedded production systems, computer systems that have a dedicated function within a larger technical system, as the primary systemic approach for industrial mass production in traditional market environments [Rojko, 2017, Pilloni, 2018]. The concept of Industry 4.0 requires a converging combination of digitized, intelligent systems of production through the means of emerging enabling technologies primarily in the form of cyber-physical systems (CPS), Internet of Things (IoT) and cloud computing (CC) [Rojko, 2017, Pilloni, 2018, Xu, Ling, 2018, Morrar, Arman, Moussa, 2017, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016]. The concept of Industry 4.0, therefore, represents, in theory, a transformative, evolutionary advancement from traditional embedded systems in manufacturing to smart industrial production systems defined by autonomous, interconnected CPS. This transformation is expected to allow the successful change from a more standardized mass-production system to a customizable, flexible, cost-efficient and demand responsive production that can efficiently fulfill the requirements of volatile market environments [Rojko, 2017, Pilloni, 2018, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko and Krapez, 2016]. Even though the vision and the concept of Industry 4.0. are already well-described on a theoretical level, several unsolved challenges on the technological, integrative, and general level of understanding remain to be better understood and captivated [Savastano, Amendola, Bellini and D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016]. These challenges effectively inhibit a successful integration of the concept of Industry 4.0 in applied manufacturing systems and that until now, only a limited number of companies achieved performance increases through the integration of aspects of Industry 4.0. [Roblek, Mesko, Krapez, 2016]. It can therefore be concluded that the concept of Industry 4.0 while still not fully developed, is ambiguously connected to a variety of other meta-concepts or sub-concepts, like VUCA environments (Volatility, Uncertainty, Complexity and Ambiguity) [Gimpel, Röglinger, 2015]. This requires further academic investigation to explore possible trajectories of development and to enhance the overall understanding of the contained inherent characteristics of decision-making in a VUCA and Industry 4.0 context [Rojko, 2017, Pilloni, 2018, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016].

MOTIVATION

This paper has the aim to address the key area of managing complex Industry 4.0 production systems to support a successful adoption and integration of Industry 4.0. This is achieved by approaching methodological research challenges of Industry 4.0 in the form of lacking reference models and the need to establish common definitions of fundamental concepts. The general underlying challenge this paper aims to contribute to solve can therefore be defined as how the technological advances, like CPS, IoT, Big Data or CC can be best linked with each other on different levels of perspective and how they can be used by decision-makers to generate economic value and to improve existing processes [Thoben, Wiesner, Wuest, 2016].

The paper furthermore presents an improved version of the Industry 4.0 Knowledge & Technology Framework (IKTF) developed by Freund & Al-Majeed [Freund and Al-Majeed, 2020] and is build upon the research conducted by Freund & Al-Majeed and Millard in the area of complex systems management and cyber-physical systems [Freund and Al-Majeed, 2021, Freund, Al-Majeed & Millard].

The IKTF has the vision to guide decision makers to better understand the concept of Industry 4.0, its core concepts and how these concepts are related to each other in a coherent, sequential manner on three levels represented by a micro, meso and macro level of analysis. By achieving this the IKTF allows decision-makers to pinpoint their company's integration status and to support the overall proactive integration of Industry 4.0. One application example is the retrospective analysis of historical cases, as demonstrated in the final section of this paper. The aim of IKTF is to represent a coherent and logical analytical overview and support tool for the initial phases of Industry 4.0 integration thought process in a corporate context. In a next step, the core concepts and technological manifestations contained in IKTF are introduced and explained in further detail.

IKTF CORE CONCEPTS

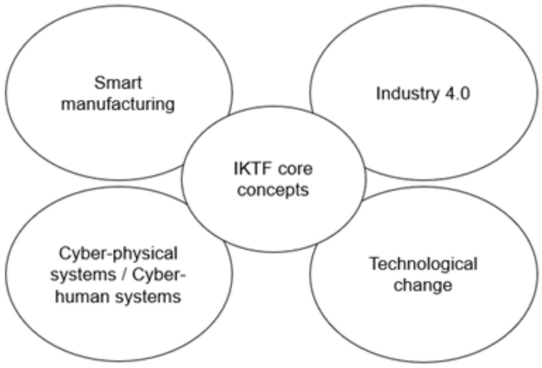


Fig. 1. IKTF core concepts

Figure 1 displays the underlying core-concepts of the IKTF. The core-concepts of IKTF, Industry 4.0, Smart Manufacturing and cyber-physical system architecture, cyber-physical systems, cyber-human system and technological change are now defined in more detail and provide a basis for the introduction of the IKTF in a later section of this paper.

INDUSTRY 4.0

Industry 4.0 is a manufacturing approach based on the integration of emerging technologies, like CC, CPS or IoT, in the business and manufacturing processes to achieve superior production capacities. The economic potential of Industry 4.0 is thus expected to be significant; for example, the German gross value is assumed to be increased by 267 billion euros by 2025 after the introduction of Industry 4.0. [Lee, Bagheri, 2015]. The technical aspects of the requirements of a successful integration are primarily addressed by the application of the concepts of Cyber-Physical Systems (CPS) [Rojko, 2017, Pilloni, 2018]. Any Industry 4.0 concept is therefore based on the connections of autonomous CPS building blocks. The CPS blocks are potentially heterogenous embedded systems equipped with intelligent, decentralized control and advanced connectivity. These blocks have the central ability to collect and exchange real-time information with the goal of monitoring and optimizing the production processes [Rojko, 2017, Pilloni, 2018, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016]. The technologies introduced by Industry 4.0 thus enable autonomous intelligent communication and cooperation among CPS, so that a higher level of intelligence, and therefore a higher level of flexibility and performance, can be achieved in industrial manufacturing processes. Industry 4.0 is thus assumed to enable three core aspects namely digitization of production, automatization of production and intelligent data interchange. As a logical consequence, the manifestation of Industry 4.0 is often exemplified through the concept of a smart factory. (SF) [Nagorny, Limo-Monteiro, Barata and Colombo, 2017].

SMART FACTORY

Smart manufacturing systems are largely autonomous, non-hierarchical physical and logical capsulated systems based on the Industry 4.0 concept that form a complex manufacturing ecosystem. These systems are often summarized under the term smart factory (SF). SF systems are heterogeneous, loosely coupled, cyber-physical systems that again accumulate in a cyber-physical system architecture, a cyber-physical system of systems, the smart factory. SF uses information to continuously maintain and improve performance and can be expected to be producing a high variety and volume of data due to the interconnected nature of the contained CPS [Mittal et.al., 2019, Freund, Al-Majeed, 2020]. Traditionally, manufacturing was defined as a sequence of processes through which raw materials were converted into finished goods for a fixed market. SF aims to integrate the properties of self-assembly to produce complex and customized products to exploit the new and existing markets [Gaham, Bouzouia, Achour, 2013].

CYBER-PHYSICAL SYSTEM ARCHITECTURE

A cyber-physical system architecture describes the overall integration approach of CPS to construct and achieve value creation in a manufacturing system.

CYBER-PHYSICAL SYSTEM

A CPS can be described as a new generation of systems that blend the knowledge of physical artifacts and engineered systems due to integrated computational and physical capabilities. CPS are established in order to produce a global intelligent behaviour featuring autonomy, self-control and self-optimization and are expected to be a decisive driving force for advances in different applicative domains including manufacturing control and for opening up new areas of innovation [Horvarth and Gerritsen, 2012, Schiliro, 2017]. CPS are characterized by advanced connectivity that ensures real-time data acquisition from the physical world and information feedback from the cyber space and intelligent data management, analytics and computational capability that constructs the cyber space. (Lee and Bagheri, 2015) CPS are also connected with high system complexity and contains an inherent trade-off relationship between the drawbacks of complexity and the performance increases gained [Freund and Al-Majeed, 2020].

CYBER-HUMAN SYSTEM

A CHS means that humans have an increasingly interconnected relationship with digitized and digital systems and represents an integral factor to establish a functioning CPS. This development is exemplified in the increasing human-machine interaction through new computer systems, the internet, mobile devices, improved sensor technology and possible future applications like brain-machine interfaces and leads to human lives and decision-making increasingly merging with technology [Gimpel and Röglinger, 2015, Horvarth and Gerritsen 2012].

Figure 2 now illustrates the concept of CPS and CHS [Freund & Al-Majeed, 2020].

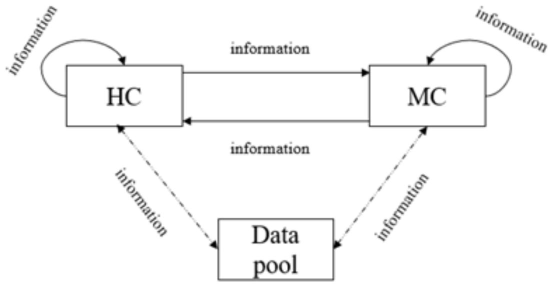


Fig. 2. CPS example

Figure 2 shows that an exemplary CPS architecture can be described as a closed loop heterogeneous system of a constellation of machine (MC) and human (HC) units with data interaction enabled through a reflexive and irreflexive multi-directional information flow with a shared data pool [Freund and Al-Majeed, 2020]. As a result, the illustrated structure of a CPS is characterized by highly interconnected constellation of heterogeneous agent types situated in reinforcing information diffusion and generation feedback loops.

TECHNOLOGICAL CHANGE

The term technological change is a positive transition of a system from a technological level (A) to a more advanced technological level (B) in a given transition time period (t). If the transition time periods between a series of technological levels Δ(t) decreases in an exponential manner exponential technological change can be identified. The transitioning from a technological level (A) to technological level (B) shall furthermore encompass the emergence of new and more potent technologies, like more productive and efficient tools, facilities or services (for example robotics or the internet) and the diminishment of less potent technologies. It also contains the habitual and institutional adjustments conducted by the society employing and interacting with the technologies. It shall therefore be assumed that technological change can be regarded for a company as a main impact factor of corporate structural change responding to external market incentives that drive competition and economic growth [Romer, 1990, Hochwallner and Ribeiro, 2018].

METHOD

The Industry 4.0 Knowledge Framework (IKTF) is based on the concept of the micro-meso-macro analysis framework and consequently is representative for the approach of micro-meso-macro analysis in managerial practice [Dopfer, Foster, Potts, 2004]. The micro–meso–macro analytical framework represents a proven method of analysis in the social sciences and economics and can greatly enhance the focus, clarity and strength of decision quality in many decision-making contexts [Serpa, Ferreira, 2019]. It proposes three categories of factors and places them in three basic levels layering them on top of each other. The macro-level includes the financial, political and sociocultural factors that influence Industry 4.0. The meso-level includes the technical and organizational factors. The micro-level refers to individual factors, particularly individual companies' intention to use Industry 4.0 in practical economic contexts. This framework is useful in that it affords insight into the various factors that influence the integration and usage of Industry 4.0. It is also suggested that there is interaction between, and interdependence of the different factors. It also proposes different points of high relevancy for decision makers and planners when developing Industry 4.0 integration initiatives. The applied micro-meso-macro framework is an adaption of the model presented by Ly et. al and is now illustrated in Figure 3 [Serpa, Ferreira, 2019].

Figure 3 shows, that change is the defining property of meso (i.e. the origination of new rules and the technological dynamics), and coordination occurs as micro and macro structures adapt and change according to the meso-level dynamics. This makes visible that the micro level refers to the individual carriers of rules and decision makers in the organization and the systems they organize, and the macro level consists of the aggregated effect of the system dynamics of the meso level. The micro level is thus positioned between the elements of the meso, and the macro level is positioned between meso elements [Dopfer, Foster, Potts, 2004].

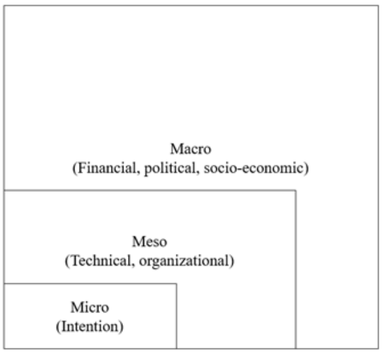


Fig. 3. Micro-Meso-Macro Analysis

THEORY SYNTHESIS

The definitions and concepts presented in this study are largely based on secondary sources and research, meaning a systematic foundational review of relevant literature. Information on the core research complexes “information”, “complexity” and “systems” is mostly available in (academic) books, professional journals, academic journals, reports or internet sources, mainly published in the research fields of philosophy, information technology, physics, engineering and business studies, as demonstrated by the following sections of this chapter. This paper quotes a wide range of sources in the form of basic theoretical considerations, expressed though the introduction and discussion of relevant definitions to allow a coherent pursuit of the previously mentioned aim of research through summarizing and synthesizing previous sources to develop a set of hypotheses out which directions for new future research may be derived. To allow the establishment of the IKTF core concepts in a coherent approach, a systematic review of relevant literature was conducted for this paper and in total 125 sources matching the scope of this article, in the form of academic journals and academic books of the mentioned academic fields, published between 2012 and 2021, were selected, individually read and reviewed by the authors and reduced by careful author selection to 29 key sources which served as the basis for theory synthesis of the presented framework. Theory synthesis has then be applied to define the in Figure 1 shown IKTF core concepts in more detail on the micro-meso and macro level.

After describing the applied methods for this paper, the Industry 4.0 Knowlegde & Technology Framework can now be presented in detail.

INDUSTRY 4.0 KNOWLEGDE & TECHNOLOGY FRAMEWORK

The Industry 4.0 Knowledge Roadmap (IKTF) can now be introduced and is based on the concept of the micro-meso-macro analysis framework presented in Figure 3 and consequently is representative for the approach of micro-meso-macro framework and its benefits for decision makers [Dopfer, Foster, Potts, 2004].

Figure 4 now illustrates the basic structure of the IKTF.

Figure 4 shows, that the basic structure of the IKTF follows an inverted Micro-Meso-Macro logic in which the macro-development level (M) is positioned at the bottom, followed by the meso level in the form of the framework level (F) and the micro level in the form of the integration level (I) at the top with transition indicators between each level. Each level follows the three-step (M1-M3, F1-F3, I1-I3) one-directional logic of displaying the most relevant Industry 4.0 concept for this level, followed by the resulting technological manifestations and the specific attributes in the form of socio-economic and technological impacts for the level. When the level internal logic chain ends a transition to the next level is implemented, as indicated by the arrows. It is also shown that the transition from (M) to (F) implicates a transition from the company external macro-environment to a company internal perspective, while (F) to (I) remain company internal. The external environment consists of an organization’s external factors that affect its business operations in an indirect manner. Thus, the organization has no or little control over these factors; that means, the external environment is generally assumed to be non-controllable and represented by (M). The internal environment describes forces or conditions or surroundings within the boundary of the organization represented by (F) and (I). The internal environment includes all assets contained within the boundaries of the organization. Some of these assets are tangible, such as the physical facilities, the plant capacity technology, proprietary technology, or know-how; some are intangible, such as information processing and communication capabilities. Consequently, decision makers can only use company internal assets in (F) and (I) as resources to make decisions in response to (M). In a next step, all IKTF levels are presented and described in more detail. The Macro Development Level (M) shall be defined as the larger and abstract level of understanding that stands above the other two levels of the framework. As already mentioned, (M) represents the company external world and the trends that impact Industry 4.0. (M) shall now be defined as the following level structure.

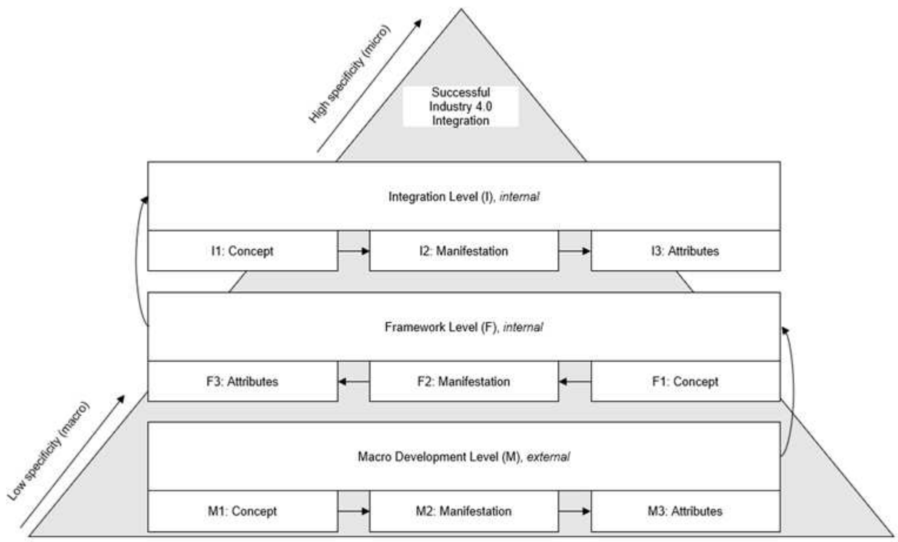


Fig. 4. IKTF basic structure

Figure 5 shows, that the core concept of (M) is defined as the already described core concept exponential technological change, which results in the manifestations as described in Table 1.

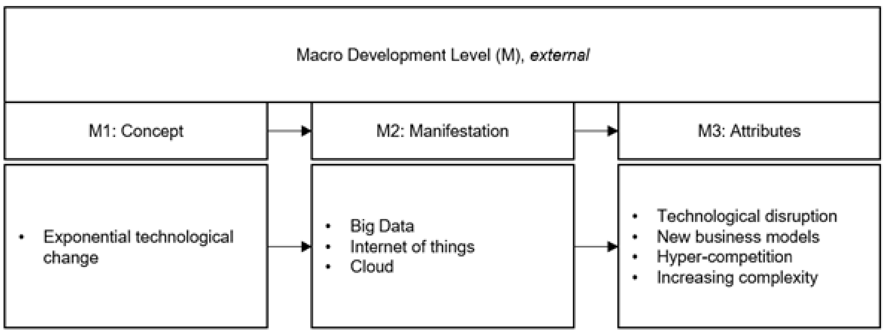


Fig. 5. IKTF basic structure

Table 1. Macro Level (M) Manifestations

Manifestation (M)	Description
M.2 Big Data	The increased usage of networked machines and sensors generates high-volume data. High-tech technology, like advanced machine learning, is necessary that can analyze and leverage large data sets including real-time data that are difficult to analyze by traditional methods. (Lee and Bagheri, 2015, Gaham, Bouzouia and Achour, 2013)
M.2 Internet of Things	The IoT enables the communication between physical and Internet-enabled devices through connecting physical objects through the virtual realm. (Mittal, Limo-Monteiro, Barata and Colombo, 2017)
M.2 Cloud	Cloud-based IT-platform serves as a technical backbone for the connection and communication of manifold elements of Industry 4.0. and IoT as they, for example, allow flexible and cost-efficient data storage upscaling. (Rojko, 2018)

Table 2. Macro Level (M) Attributes

Attributes (M)	Description
M.3 Technological disruption	The combination of technologies like IoT, cloud and Big Data in the Industry 4.0 is disruptive and leads to significant paradigm shifts in manufacturing. CPS for example derive from important technical advances on the internet, embedded systems, computer science and artificial intelligence. (Morrar, Arman and Moussa, 2017, Roblek, Mesko and Krapez, 2016)
M.3 New business models	Industry 4.0 and its embedded technology diffusion progress is expected to grow exponentially in terms of technical change and socioeconomic impact and allow for new types of business models, for example platform business. Benefiting of such a transformation requires a holistic approach of value creation that integrates innovative and sustainable business and technology solutions which modify or replace existing business models. (Morrar, Arman and Moussa, 2017, Roblek, Mesko and Krapez, 2016, Thoben, Wiesner and Wuest, 2016)
M.3 Hyper-competition	As explained in the introduction, industrial production is driven by a hyper-competitive rivalry for market shares between formerly separated industries generated caused by a more global, digital, and interconnected market environment. (Turgay and Emeagwali, 2012)
M.3 Increasing complexity	Cyber-physical system architectures are characterized by unprecedented scale and interconnectedness and are thus highly complex. Managing this complexity is a challenging task, as traditional analysis tools are unable to cope with the full complexity of CPS or adequately predict system behavior. One barrier to progress is the lack of appropriate science and technology to conceptualize and design the deep interdependencies among engineered systems of the Industry 4.0 concept and the changes manifesting in the company external environment. (Rojko, 2017, Pilloni, 2018, Thoben, Wiesner and Wuest, 2016)

These manifestations can now be attributed with the following properties as shown in Table 2.

After describing the macro-level manifestations and attributes, the framework level can now be defined in detail.

The Framework Level (F) represents the meso level that lies between the macro and micro level of the framework. the company internal reaction to (M). (F) shall now be defined as the following.

Figure 6 shows, that the concept of (F) is defined by the company internal concept Industry 4.0, which results in the already described manifestation Smart Factory and the attributes described in Table 3.

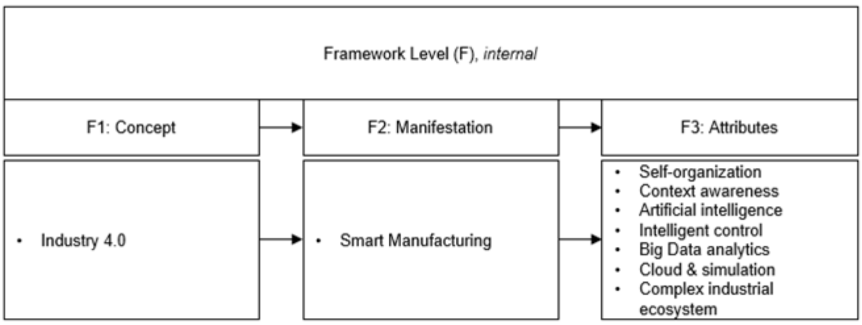


Fig. 6. Framework Level

Table 3. Framework Level (F) Attributes

Attributes (F)	Description
F.3 Self-organization	Manufacturing processes will be interconnected across corporate boundaries via CPS. These changes in supply and manufacturing chains require greater decentralization from existing traditional manufacturing systems. This results in a decomposition of the classic, centralized production hierarchy and a paradigm shift toward decentralized self-organization. (Lee and Bagher, 2015, Pilloni, 2018, Roblek, Mesko and Krapez, 2016)
F.3 Context awareness	Context awareness is an important intelligent characteristic of an SF and its underlying CPS and it is a combination of the following attributes: Awareness of identity, location, status, time. (Horvarth and Gerritsen, 2012)
F.3 Intelligent control, artificial intelligence	With the help of intelligent technology and context awareness, a CPS is expected to be able to change its actions based on its own experience and is thus self-learning and capable of evolutionary self-adapting to external changes. If it possesses intelligent control technology, it can make use of, for example, artificial intelligence techniques, like machine learning, to control its mechanisms via decision algorithms and is able to perform more reliable and accurate in a less stable environment. (Thoben, Wiesner and Wuest, 2016, Mittal, Khan, Romero and Wuest, 2019)
F.3 Big Data analytics	The collection and comprehensive evaluation of data from many different sources like production equipment and systems as well as enterprise and customer-management systems will become standard to support real-time decision making. (Pilloni, 2018, Morrar, Arman and Moussa, 2017)
F.3 Cloud & simulation	With Industry 4.0, organization needs increased data sharing across the sites and companies, achieving superior reaction times in milliseconds or even faster. This leads to the idea of having the connections of different devices to the same cloud to share information to one another. This can be extended to set of machines from a shop floor as well as the entire manufacturing system. Simulations will be used more extensively in plant operations to leverage real-time data to mirror the physical world in a virtual model via double representation. This includes machines, products, and humans, reducing machine setup times and increasing quality. Decision making quality can also be improved with the help of simulations, as possible system trajectories can be featured into the decision-making process. (Rojko, 2017, Pilloni, 2018, Xu and Ling, 2018)
F.3 Complex industrial ecosystem	Designing Industry 4.0 systems involves high complexity, which mainly originates from the high dimensionality and the internal complexity of components. As, for example, the IoT scales to billions of connected devices – with the capacity to sense, control, and otherwise interact with the human and the physical world – the requirements for dependability, security, safety, and privacy grow significantly and must be managed accurately. (Savastano, Amendola, Bellini and D´Ascenzo, 2019, Freund and Al-Majeed, 2020)

After describing the framework level manifestations and attributes, the integration level can now be defined in detail.

The Integration Level (I) represents micro level the company internal reaction to (F). (I) shall now be defined as the following.

Figure 7 shows, that the concept of (I) is defined by the already described company internal core concept cyber-physical system architecture, which results in the manifestations cyber-physical system and cyber-human system and the attributes shown in Table 4.

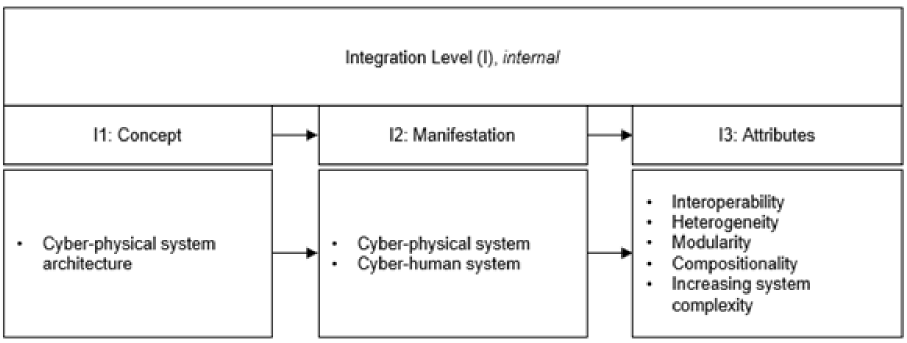


Fig. 7. Integration Level

Table 4. Integration Level (I) Attributes

Attributes (I)	Description
I.3 Interoperability	Interoperability is the characteristic due to which, system units are able to exchange and share information with each other. With the help of networkability, systems can collaborate in different process-related aspects, and for this collaboration, they have to allow each other to share and exchange information. Similarly, distributed systems allow the information and data of one system to be accessed by other systems in the network. (Nagorny, Limo-Moneteiro, Barata and Colombo, 2017, Gaham, Bouzouia and Achour, 2013)
I.3 Heterogeneity	Heterogeneity considers the diversity and dissimilarities in the units and components. (Thoben, Wiesner and Wuest, 2016, Gaham, Bouzouia and Achour, 2013)
I.3 Modularity	Modularity is the property of a system by which a unit can be decomposed into components that can be recombined to form different configurations. (Mittal, Khan, Romero and Wuest, 2019, Gaham, Bouzouia and Achour, 2013)
I.3 Compositionality	Compositionality is the property that deals with the understanding of the whole system based on the definition of its components and the combination of the constituents.(Mittal, Khan, Romero and Wuest, 2019, Gaham, Bouzouia and Achour, 2013)
I.3 Increasing complexity	CPS emerge through networking and integration of embedded systems, application systems, and infrastructure, enabled by human machine interaction. In comparison to conventional systems used for production such a system is expected to be increasingly more complex. (Thoben, Wiesner and Wuest, 2016, Camarinha-Matos, Fornasiero, and Asfarmanesh, 2017)

After presenting all levels of the IKTF in detail, it is now possible to present the complete IKTF framework..

COMPLETE FRAMEWORK

The complete IKTF framework results and is displayed in Figure 8.

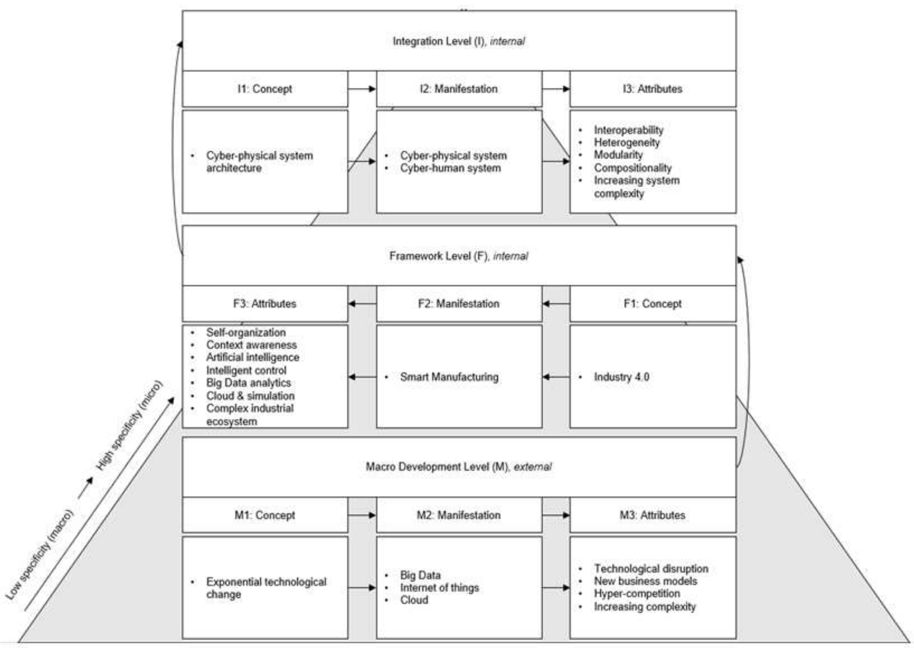


Fig. 8. IKTF - Complete Framework

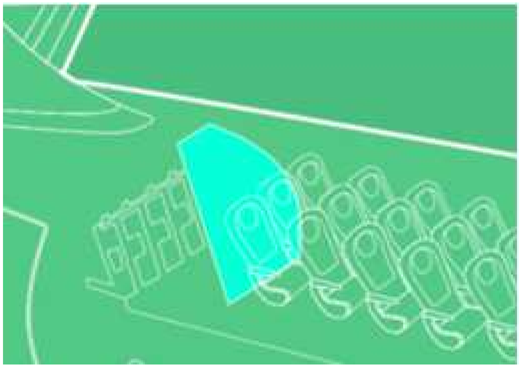
After presenting the complete IKTF framework, the resulting implications for decision-makers and the overall functionality can now be discussed on the basis of a case study.

IMPLICATIONS FOR DECISION-MAKERS

The IKTF shows, that decision makers must acquire sufficient knowledge in the macro-level, with low context specificity (M) about the concept, manifestations and attributes of exponential technological change and its disruptive effects on the financial, political, and socio-economic external environment of the company. This can be achieved through understanding analyzing the manifestations of Big Data, Internet of Things and Cloud and their attributes of technological disruption, new business models, hyper-competition and increasing complexity in the individual corporate context. A response through the utilization of company assets in the internal framework level (F) can then be formulated as a reaction by analyzing the applicability of the concept of Industry 4.0 with its manifestation smart factory and the attributes of self-organization, context awareness, intelligent control, artificial intelligence, Big Data analytics, cloud & simulation and the complexity of industrial ecosystems under the resource constraints and macro influence factors of the individual company. If this is achieved an integration approach can formulated by analyzing the applicability of cyber-physical system architectures, their manifestations cyber-physical systems and cyber-human systems with the attributes of interoperability, heterogeneity, modularity, compositionality and increasing complexity under the identified constraints on the framework level and macro level. This makes visible that a successful integration of Industry 4.0 is an extensive, difficult to achieve task which requires extensive knowledge, reflection and insights on all levels of specificity. According to the IKTF no level of the framework can be skipped or only partially understood. Only a comprehensive understanding of the framework levels and the successful application on the individual corporate context allow a successful integration of industry 4.0. This highlights the importance of informed and analytical decision making on all corporate areas in the context of Industry 4.0 integration. In the final step of this paper, the IKTF is applied to case study to further display the functionality and practical applicability of the line of argument and the framework.

CASE STUDY: AIRCRAFT PARTITION REDESIGN FOR AIRBUS 320

After presenting the theoretical foundation of the IKTF, the framework is now applied to a rudimentary case study to showcase its functionality. The case utilized is taken from [26,27]. European aircraft manufacturer Airbus collaborated with Autodesk to rethink the design of aircraft partitions of the Airbus A320 cabin, as part of creating a vision for future aircraft design. This vision includes the overarching goals of a more eco-friendly, lighter plane designs and a more customizable customer experience. The partitions used to separate the cabin crew's workstation from the rest of the cabin represents a major engineering conundrum, especially to the aircraft manufacturers, who want these partitions to be as small and light as humanly possible.



Source: Autodesk, 2021

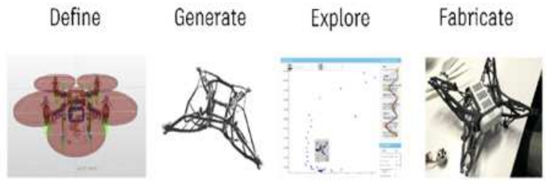
Fig. 9. Aircraft partition

This new partition was planned to be:

- significantly lighter than the current partition, meeting the goal of reducing the weight of the plane,
- strong enough to anchor two jump seats for flight attendants during take-offs and landings
- have a cutout to pass wide items in and out of the cabin
- no more than an inch thick
- attached to the plane's airframe in just four places.

To meet the outlined requirements, it was decided to leave traditional manufacturing and design paradigms behind and to start working with the company Autodesk Research on the so-called "Bionic Partition", based on generative design, that mimics the evolutionary design approaches found in nature.

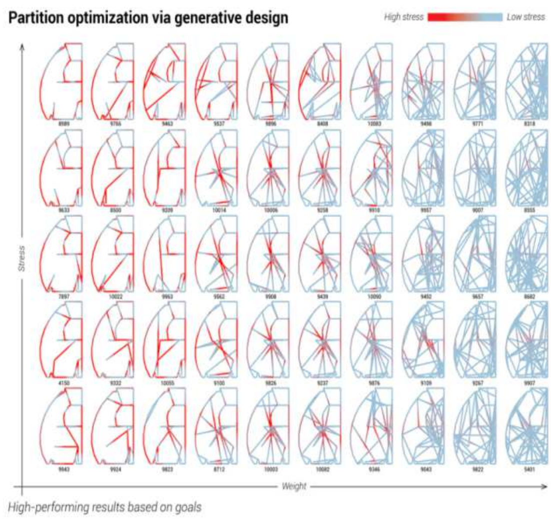
Engineering design software (Autodesk Dreamcatcher), machine learning techniques and additive manufacturing based on 3D Printing were used to generate a new partition based on bionic, generative design principles. To allow a better understanding of the case the rudimentary concept of Autodesk Dreamcatcher is now illustrated in Figure 10.



Source: Autodesk, 2021

Fig. 10. Autodesk Dreamcatcher

Figure 11 now illustrates a sample of the partition optimization in the generative design process based on the parameters stress and high-performing results based on system goals.



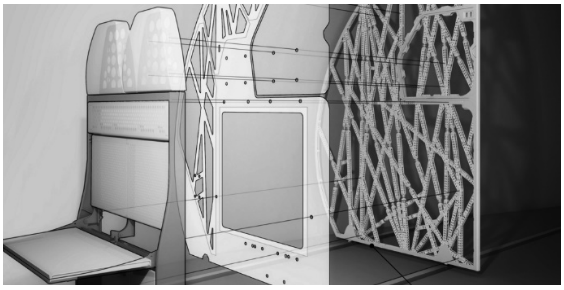
Source: Autodesk, 2021

Fig. 11. Partition optimization via generative design

The new partition was 3-D printed using new innovative, generative design algorithms based on bionics, represented by the interconnectivity found in slime-mold singular-celled organism and grid structures of mammal bone growth dynamics in biological systems. Over 10,000 design options were created by the software in the process and checked for applicability. More than 100 separate pieces were 3D printed and assembled in a process of additive manufacturing. Figure 12 now shows a final 3D printed piece of the partition, while Figure 13 shows the final product.

Source: Autodesk, 2021

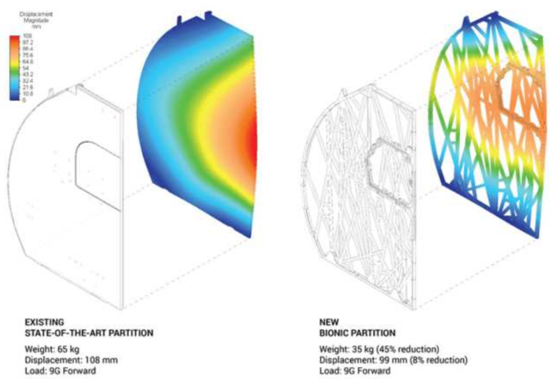
Fig. 12. Final printed piece– part of a bionic aircraft partition by Airbus



Source: Autodesk, 2021

Fig. 13. Bionic aircraft partition by Airbus

Figure 14 now illustrates a comparison between the bionic partition and the standard partition.



Source: Autodesk, 2021

Fig. 14. Bionic aircraft partition by Airbus compared to standard partition

The new partition weighs in at 35 kg, significantly lighter than Airbus's original partitions that weighed 65 kg apiece, which represents a 45% weight reduction. This results in (if all four partitions in an Airbus 320 were replaced) 500kg overall weight reduction of the aircraft, reduced fuel consumption, reduction of CO_2 emissions. Due to the usage of 3D printing and additive manufacturing material consumption is reduced by 95% in comparison to traditional manufacturing processes [Autodesk, 2021]. Moreover, because the designs created by the generative design software are so complex, classical manufacturing techniques were out of the question when it came to building the part [Skillton, Hoysepian, 2018].

After describing the case, the IKTF can now be applied for further analysis.

CASE STUDY: IKTF APPLICATION

The IKTF is now applied to the presented case as shown in Figure 15.

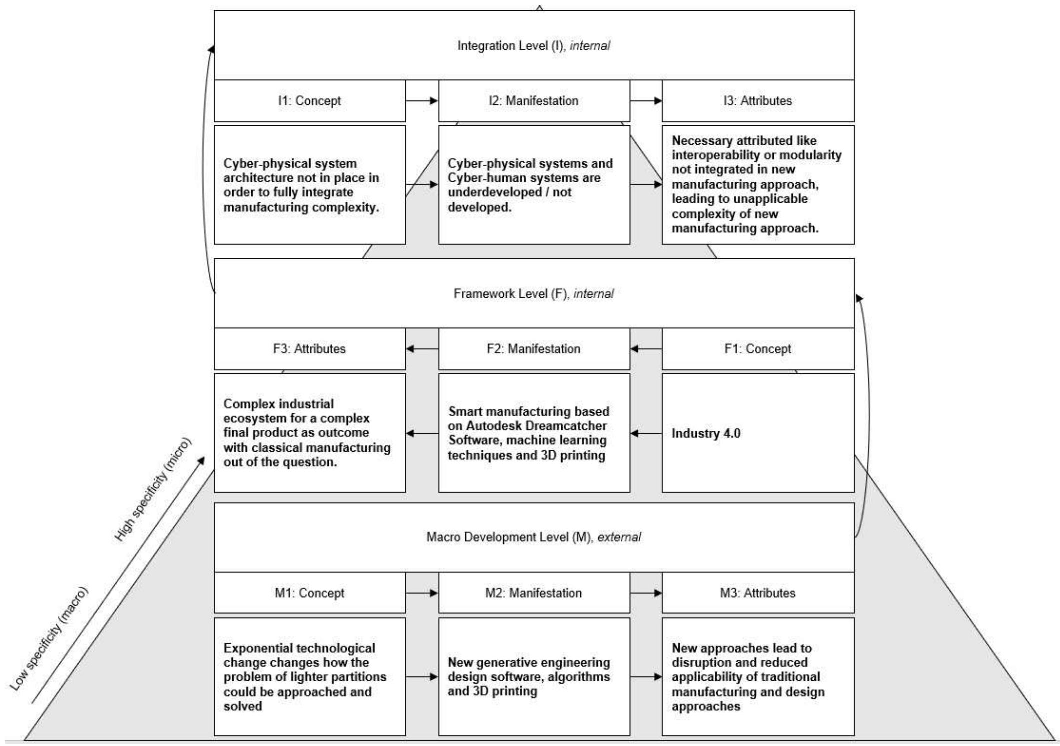


Fig. 15. IKTF – Case study application

After integrating the case in the IKTF the different levels of the framework can now be described in Tables 5, 6 and 7.

Table 5. Macro Level (M) Application

Macro Level (M)	Case Application
M1	Exponential technological change changes how the problem of lighter partitions could be approached and solved in general on the technological level.
M2	Big Data, Internet of things, Cloud can be applied as enablers in the form of new generative engineering design software, algorithms, and 3D printing.
M3	Technological disruption, increasing complexity manifest themselves in new approaches that lead to disruption and reduced applicability of traditional manufacturing and design approaches.

After describing (M) for the case in Table 5 a transition to the framework level is now possible.

After describing (F) in Table 6 for the case a transition to the integration level is now possible.

Table 6. Framework Level (F) Application

Framework Level (F)	Case Application
F1	Industry 4.0 can be described as the necessary framework concept to capitalize of the macro level developments.
F2	Industry 4.0 manifests in the concept of smart manufacturing which itself is based on the 3D printing, the generative design software Autodesk Dreamcatcher software and machine learning techniques.
F3	The attributes artificial intelligence, self-organization, cloud and simulation, context awareness and Big Data analytics can now be identified in F3 for F2 and already indicate the necessity of a complex industrial ecosystem to allow the production of the new product.

Table 7. Integration Level (I) Application

Integration Level (I)	Case Application
I1	Appropriate cyber-physical system architecture proportional to final product complexity is not in place, while classical manufacturing approaches are no option for production.
I2	Cyber-physical and cyber-human systems are necessary, but not in place, to manifest to fully capitalize on the benefit of the new, highly complex product
I3	The attributes of interoperability, heterogeneity, modularity, compositionality, and an overall production system of higher complexity should be integrated in a potential production approach for the new product.

After describing (M) in Table 5, (F) in Table 6 and (I) in Table 7 it is now possible to interpret the results of the IKTF in the next chapter..

INTERPRETATION

Figure 16 now shows the interpretation of the presented case in the IKTF format.

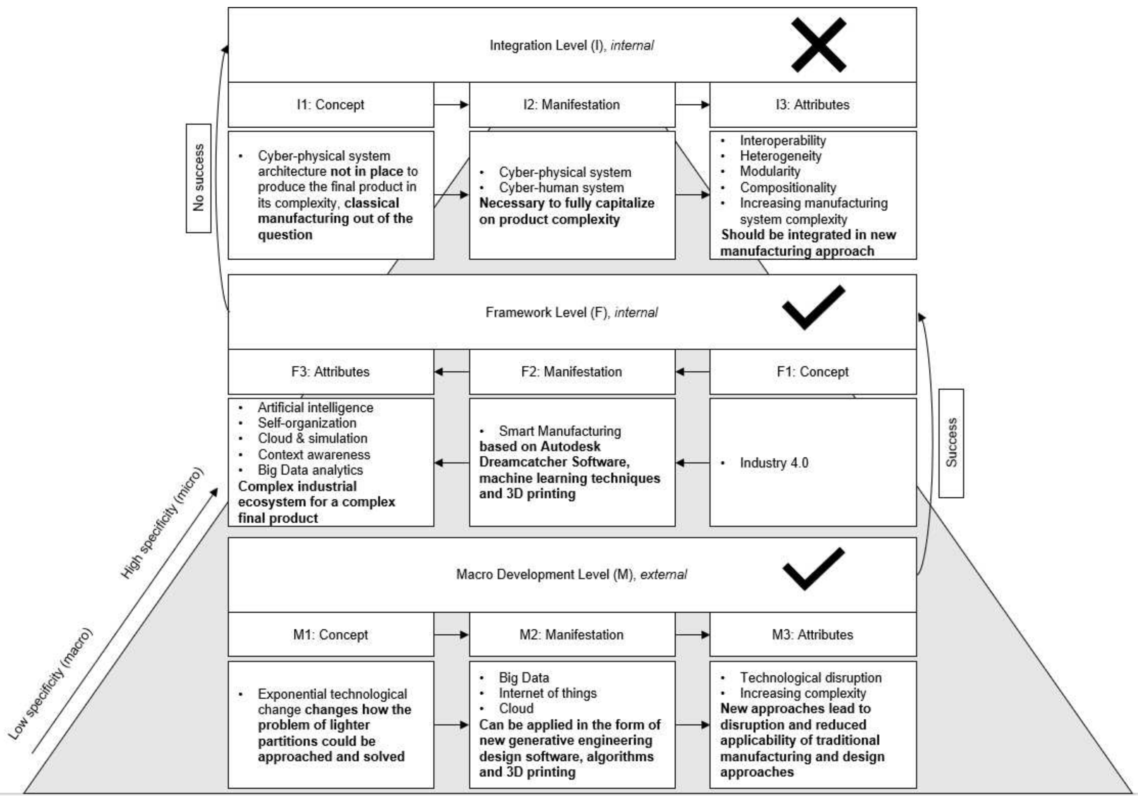


Fig. 16. IKTF – Case study interpretation

Figure 16 shows, that the Airbus project can be described to capitalize of the external level (M) can achieve a successful transition of from (M) to the internal framework level (F). (F) can be completed, but no transition to the integration level (I) is in place and whether a sufficient understanding of the required concept, manifestations and attributes is in place to allow full capitalization of a successful completion of (M) and (F).

The final IKTF of the described case allows to conclude that the newly developed bionic aircraft partition cannot be a successful product unless the integration level is completed. The IKTF thus recommends that it is necessary to translate the requirements of an complex industrial ecosystem for a product of high complexity into an adequate cyber-physical system architecture for production which is itself characterized by a combination of interoperable, heterogenous, modular cyber-physical and cyber-human systems which itself represent a highly complex system with compositionality. These recommendations, even though not specific, allow to question the economic viability of the new product designed and its applicability for mass production overall. This conclusion to the IKTF is in line with the presented case, which can be regarded as a lighthouse project of Airbus to explore technological not economic feasibility and presents a first proof of concept for the framework.

DISCUSSION OF RESULTS

The IKTF shows that the successful integration of Industry 4.0 is dependent from many layers of understanding which are sequentially connected on the micro-meso-macro levels of analysis. The IKTF furthermore proposes that decision makers follow the shown bottom-up approach when aiming for integration and identify how every concept applies for the individual corporate context and project they want to implement. As already mentioned in the introduction, the integration of Industry 4.0 is accompanied by a large variety of research and development issues, for example the management of system complexity in a VUCA environment and the development of universally applicable reference models and foundational definitions of fundamental concepts for Industry 4.0. As shown by the provided case study, the IKTF can serve decision makers in the context of management of system complexity, definitions and reference models by providing three functions:

- Obtain a multi-level understanding of Industry 4.0
- Definition of the corporate context in the framework of Industry 4.0
- Pinpoint the position and integration status of a given project in IKTF relative to the framework levels
- Show potential “weak zones” in the integration process
- Provide first implications for the scalability and economic validity of a given Industry 4.0 integration project

As argued by Camarinha-Matos, Fornasiero and Asfarmanesh the concept of Industry 4.0 has turned into a buzzword and an “everything fits” catalyzer for various technologies and manufacturing approaches. The “everything fits” mentality, making the concept difficult to understand, is additionally supported by companies and their respective managers utilizing their own descriptions and concepts, leading to a decreased diffusion of best practice methodologies [Camarinha-Matos, Fornasiero and Asfarmanesh, 2017]. The IKTF can contribute to avoid such a mindset and helps to replace it with a consistent and coherent analytical approach, as illustrated by the provided case study. Nevertheless, the IKTF is to be regarded as a foundational managerial decision-making tool that predominantly focusses on providing insight for decision-makers in the context of their respective company and on overcoming the challenge of developing Industry 4.0 reference and application models for integration processes and is thus limited in applicative value when applied out of this scope.

CONCLUSION

The IKTF analyzes Industry 4.0 on several levels of abstraction in a micro-meso-macro framework and introduces the different positions of different core concepts in a coherent and logically consistent framework that represents relevant Industry 4.0 core concepts, manifestations and attributes on three interdependent levels. These levels can then be applied to a given managerial decision-making problem, for example the integration of a new technology, in an analytical way. While doing this, the levels of the IKTF and their respective internal logical chains cannot be seen isolated from each other since every level and builds on the concept, manifestation, and attributes of the previous level. Hence, the practical integration of Industry 4.0 requires decision makers to have insights into company external and internal interconnected knowledge and technology fields on different levels of abstraction to be successful, as shown by the provided case study. The IKTF, therefore, proposes a well-structured solution to the complex nature of Industry 4.0 and shows a path to informed managerial decision making.

OUTLOOK

To advance the applicability and theoretical foundation of the proposed framework, future work focuses on verifying, expanding, modifying, and applying the ITKF via extensive case study research in European companies.

CONFLICT OF INTEREST

The authors of this study have no conflict of interest to declare.

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REFERENCES

Autodesk.,2021. website: www.autodesk.com/customer-stories/airbus

Camarinha-Matos L., Fornasiero R., Asfarmanesh H., 2017. Collaborative Networks as a Core Enabler of Industry 4.0, Collaboration in a Data-Rich World, Springer, PRO-VE 2017. IFIP Advances in Information and Communication Technology, 506: 3-17, http://doi.org/10.1007/978-3-319-65151-4_1

Congressional Research Service, 2020. Global Economic Effects of COVID-19. World Economic Outlook. International Monetary Fund. April 2020.

Dopfer K., Foster J., Potts J., 2004. micro-meso-macro. Journal of Evolutionary Economics, 14(3):263–279, http://doi.org/10.1007/s00191-004-0193-0

Fraunhofer IPT. 2019., INDUSTRIE 4.0 – Vernetzte, Adaptive Produktion. Frauenhofer Institut für Produktionstechnologie: 3-7.

Freund L., Al-Majeed S., 2020. The Industry 4.0 Knowledge & Technology Framework. PalArch's Journal of Archaeology of Egypt / Egyptology, 17(9), 6321 – 6339, ISSN 1567-214x

Freund L., Al-Majeed S., 2020. Cyber-physical systems as sources of dynamic complexity in cyber-physical systems of systems. 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), Sakheer, Bahrain, 2020, 1-5, http://doi.org/10.1109/3ICT51146.2020.9312015

Freund L., Al-Majeed S., 2021., Hypotheses concerning complexity surges in modern and future industrial information systems . Logforum 17 (3), 1. http://doi.org/10.17270/J.LOG.2021.3.1

Freund L., Al-Majeed S., Millard A., 2021. Case Studies Key-Findings of a Strategic

Complexity Management Framework for Industrial Manufacturing Systems. 2021 16th International Conference of System of Systems Engineering (SoSE), 2021, 55-60, http://doi.org/10.1109/SOSE52739.2021.9497489.

Gaham M., Bouzouia B., Achour N., 2013. Human-in-the-Loop Cyber-Physical Production Systems [Control HiLCP2sC) A Multi-objective interactive framework Proposal. in: Service Orientation in Holonic and Multi-agent Manufacturing, Springer-Verlag Berlin Heidelberg: 315-325, http://doi.org/10.1007/978-3-319-15159-5_29

Gimpel H., Röglinger M., 2015. Digital transformation: changes and chances. Project Group Business and Information Systems Engineering (BISE) of the Fraunhofer Institute for Applied Information Technology FIT: 1-20

Hochwallner M., Ribeiro L., 2018. On the Design Complexity of Cyberphysical Production Systems. Complexity, Vol.18, http://doi.org/10.1155/2018/4632195

Horvarth I., Gerritsen B., 2012. Cyber physical systems: concepts, technologies and implementations. Proceedings of TMCE 2012, 1:19-22, ISBN 978-90-5155-082-5

Lee J., Bagheri B., 2015. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. Manufacturing Letters 2015 3:18-23, http://doi.org/10.1016/j.mfglet.2014.12.001

McAfee A., Brynjolfsson E., 2014. The second machine age. W.W. Norton & Company, New York: 26-34, ISBN: 978-0-393-35064-7

Mittal S., Khan M., Romero D., Wuest T., 2019. Smart Manufacturing: Characteristics, Technologies and Enabling Factors. Proceedings of the Institution of Mechanical Engineers 2017 Part B Journal of Engineering Manufacture, 233(5): 1342-1361, http://doi.org/10.1177/0954405417736547

Morrar R., Arman H., Moussa S., 2017. The Fourth Industrial Revolution (Industry 4.0): A Social Innovation Perspective. Technology Innovation Management Review, 7 (11):14-18, http://doi.org/10.22215/TIMREVIEW/1117

Nagorny K., Limo-Monteiro P., Barata J., Colombo A., 2017. Big Data Analysis in Smart Manufacturing: A Review. International Journal of Communication, Network and System Sciences, 10: 31-58., http://doi.org/10.4236/ijcns.2017.103003

Pillioni V., 2018. How Data Will Transform Industrial Processes: Crowdsensing, Crowdsourcing and Big Data as Pillars of Industry 4.0. Future Internet, 10 (3), http://doi.org/10.3390/fi10030024

Roblek V., Mesko M., Krapez A., 2016. A Complex View of Industry 4.0. Sage Open April-June 2016, 1 (11), http://doi.org/10.1177/2158244016653987

Rojko A., 2017. Industry 4.0 Concept: Background and overview. International Journal of Interactive Mobile Technologies, 11(5), http://doi.org/10.3991/ijim.v11i5.7072

Turgay T., Emeagwali O., 2012. Hypercompetition: the driving force behind successful business innovations? A critical review of literature, Investment Management and Financial Innovations. 9 (3):111-113, Corpus ID: 55387401

Romer P., 1990. Endogenous Technological Change. The Journal of Political Economy. 98(5): 71-102

Savastano M., Amendola C., Bellini F., D´Ascenzo F., 2019. Contextual Impacts on Industrial Processes Brought by the Digital Transformation of Manufacturing: A Systematic Review. Sustainability. 11 (3):1-3, http://doi.org/10.3390/su11030891

Schiliro D. ,2017. A glance at Solow’s growth theory. MPRA Paper No. 84531

Serpa S., Ferreira C., 2019. Micro, Meso and Macro Levels of Social Analysis. International Journal of Social Science Studies, 7 (3): 121-131, ISSN 2324-8033

Skillton M., Hovsepian F., 2018. The 4th Industrial Revolution, Springer: 282-284

Thoben K., Wiesner S., Wuest T., 2016. Industrie 4.0 and Smart Manufacturing –A

Review of Research Issues and Application Examples. International Journal of Automation Technology, 11(1):4-19, http://doi.org/10.20965/ijat.2017.p0004

Vaidya S., Ambad P., Bhosle S., 2018. Industry 4.0 – A Glimpse. Procedia Manufacturing Volume 20: 233–238, http://doi.org/10.1016/j.promfg.2018.02.034

Xu L., Ling L., 2018. Industry 4.0: state of the art and future trends. International journal of production research, 8 (56): 2941-2962, http://doi.org/10.1080/00207543.2018.1444806

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ORIGINAL PAPER

MANAGING INDUSTRY 4.0 INTEGRATION - THE INDUSTRY 4.0 KNOWLEDGE & TECHNOLOGY FRAMEWORK

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ABSTRACT. **Background:** This paper has the aim to address the key area of managing complex Industry 4.0 production systems to support a successful adoption and integration of Industry 4.0. This is achieved by approaching methodological research challenges of Industry 4.0 in the form of lacking reference models and the need to establish common definitions of fundamental concepts. The general underlying challenge this paper aims to contribute to solve can therefore be defined as how the technological advances, like CPS, IoT, Big Data or CC can be best linked with each other on different levels of perspective and how they can be used by decision-makers to generate economic value and to improve existing processes. This is achieved through the introduction of the Industry 4.0 Knowledge & Technology Framework (IKTF).

Methods: The Industry 4.0 Knowledge Framework (IKTF) is based on the concept of the micro-meso-macro analysis framework and consequently is representative for the approach of micro-meso-macro analysis in managerial practice. It proposes three categories of factors and places them in three basic levels layering them on top of each other. The macro-level includes the financial, political and sociocultural factors that influence Industry 4.0. The meso-level includes the technical and organizational factors. The micro-level refers to individual factors, particularly individual companies' intention to use Industry 4.0 in practical economic contexts.

Results: The Industry 4.0 Knowledge & Technology Framework (IKTF) provides guidance to corporate decision makers by providing a comprehensive, multi-level sequential integration framework for Industry 4.0 based on a sequential micro, meso and macro perspective analysis of the individual corporate context. The aim of the IKTF is to support an informed and successful managerial decision-making process and therefore enable the integration of Industry 4.0 in a corporate context.

Conclusion: As a first step, the structure, and contents of the IKTF are sequentially introduced and described. In a second and final step the functionality and applicability of the IKTF are demonstrated and discussed on a theoretical and practical level with the help of a case study.

Keywords: Industry 4.0, Smart Factory, exponential technological change, cyber-human systems, cyber-physical systems.

INTRODUCTION

Accelerating technological developments and the changes induced by the so-called exponential disruptive technologies lead to the necessity for companies to integrate new manufacturing methods in the form of Industry 4.0. This development is expected to allow companies to anticipate and utilize the potency of current and upcoming technological advancements in production technology and to leverage existing competitive advantages while unlocking new progress. The rising potency of technology in areas like general computer processing power, sensors, artificial intelligence, machine learning algorithms, robotics and automation technology breaks through the limits of the anticipated growth rates of traditional technologies and manifests in more radical visions for changes in industrial production systems [McAfee and Brynjolfsson, 2014, Fraunhofer IPT, 2019]. Underlying drivers for the possible exponential

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development of technology are the often mentioned "Moore´s Law" which shows that the number of transistors per microchip increased by the power of 10 in the last 40 years , "Metcalf´s Law" can also be mentioned which states that computing hardware becomes more powerful, small and more embedded over time and the vastly increased and ever increasing speed of technology adoption by users. "Butter´s Law of photonics" says that the amount of data one can transmit using optical fiber is doubling every nine months. "Rose´s Law", which states that the number of qubits in quantum computers is growing exponentially and the concept of "Big Data" referring to the exponential growth of information generated by modern information systems. [McAfee and Brynjolfsson, 2014, Gimple, Röglinger, 2015]. In addition to the accelerating impact of disruptive exponential technologies, industrial production is driven by a hyper-competitive rivalry for market shares between formerly separated industries caused by a more global, digital and interconnected market environment [Turgay, Emeagwali, 2012]. Technology induced market disruption and the resulting volatile and complex market environments are expressed through constantly changing, more individualized customer requirements and shorter product lifecycles. These developments can be regarded as the determining factors for the successful development process of a market-oriented industrial production with a high-tech methodology that can fulfill the requirements of current and future market environments [Vaidya, Ambad, Bhosle, 2018 Lee, Bagheri, 2015]. These aspects are furthermore accelerated by the COVID-19 pandemic, a global "black swan" event which inflicts high and rising human and economic costs world-wide and as a result enforced a global partial or total lockdown of most facilities of production [Congressional Research Service, 2020, World Economic Outlook, 2020]. The vision of Industry 4.0 can be regarded as a potential answer to overcome the described current and future technological, social and economic challenges that disrupt the functionality of the traditional manufacturing paradigm of embedded production systems, computer systems that have a dedicated function within a larger technical system, as the primary systemic approach for industrial mass production in traditional market environments [Rojko, 2017, Pilloni, 2018]. The concept of Industry 4.0 requires a converging combination of digitized, intelligent systems of production through the means of emerging enabling technologies primarily in the form of cyber-physical systems (CPS), Internet of Things (IoT) and cloud computing (CC) [Rojko, 2017, Pilloni, 2018, Xu, Ling, 2018, Morrar, Arman, Moussa, 2017, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016]. The concept of Industry 4.0, therefore, represents, in theory, a transformative, evolutionary advancement from traditional embedded systems in manufacturing to smart industrial production systems defined by autonomous, interconnected CPS. This transformation is expected to allow the successful change from a more standardized mass-production system to a customizable, flexible, cost-efficient and demand responsive production that can efficiently fulfill the requirements of volatile market environments [Rojko, 2017, Pilloni, 2018, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko and Krapez, 2016]. Even though the vision and the concept of Industry 4.0. are already well-described on a theoretical level, several unsolved challenges on the technological, integrative, and general level of understanding remain to be better understood and captivated [Savastano, Amendola, Bellini and D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016]. These challenges effectively inhibit a successful integration of the concept of Industry 4.0 in applied manufacturing systems and that until now, only a limited number of companies achieved performance increases through the integration of aspects of Industry 4.0. [Roblek, Mesko, Krapez, 2016]. It can therefore be concluded that the concept of Industry 4.0 while still not fully developed, is ambiguously connected to a variety of other meta-concepts or sub-concepts, like VUCA environments (Volatility, Uncertainty, Complexity and Ambiguity) [Gimpel, Röglinger, 2015]. This requires further academic investigation to explore possible trajectories of development and to enhance the overall understanding of the contained inherent characteristics of decision-making in a VUCA and Industry 4.0 context [Rojko, 2017, Pilloni, 2018, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016].

MOTIVATION

This paper has the aim to address the key area of managing complex Industry 4.0 production systems to support a successful adoption and integration of Industry 4.0. This is achieved by approaching methodological research challenges of Industry 4.0 in the form of lacking reference models and the need to establish common definitions of fundamental concepts. The general underlying challenge this paper aims to contribute to solve can therefore be defined as how the technological advances, like CPS, IoT, Big Data or CC can be best linked with each other on different levels of perspective and how they can be used by decision-makers to generate economic value and to improve existing processes [Thoben, Wiesner, Wuest, 2016].

The paper furthermore presents an improved version of the Industry 4.0 Knowledge & Technology Framework (IKTF) developed by Freund & Al-Majeed [Freund and Al-Majeed, 2020] and is build upon the research conducted by Freund & Al-Majeed and Millard in the area of complex systems management and cyber-physical systems [Freund and Al-Majeed, 2021, Freund, Al-Majeed & Millard].

The IKTF has the vision to guide decision makers to better understand the concept of Industry 4.0, its core concepts and how these concepts are related to each other in a coherent, sequential manner on three levels represented by a micro, meso and macro level of analysis. By achieving this the IKTF allows decision-makers to pinpoint their company's integration status and to support the overall proactive integration of Industry 4.0. One application example is the retrospective analysis of historical cases, as demonstrated in the final section of this paper. The aim of IKTF is to represent a coherent and logical analytical overview and support tool for the initial phases of Industry 4.0 integration thought process in a corporate context. In a next step, the core concepts and technological manifestations contained in IKTF are introduced and explained in further detail.

IKTF CORE CONCEPTS

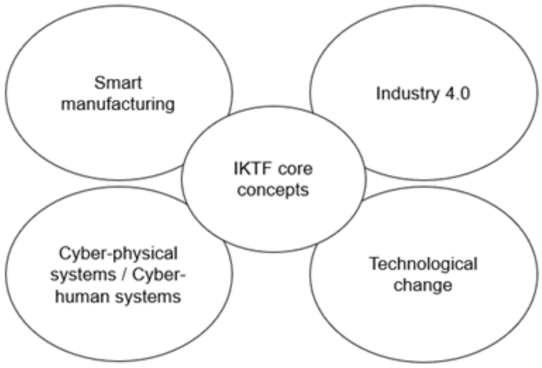


Fig. 1. IKTF core concepts

Figure 1 displays the underlying core-concepts of the IKTF. The core-concepts of IKTF, Industry 4.0, Smart Manufacturing and cyber-physical system architecture, cyber-physical systems, cyber-human system and technological change are now defined in more detail and provide a basis for the introduction of the IKTF in a later section of this paper.

INDUSTRY 4.0

Industry 4.0 is a manufacturing approach based on the integration of emerging technologies, like CC, CPS or IoT, in the business and manufacturing processes to achieve superior production capacities. The economic potential of Industry 4.0 is thus expected to be significant; for example, the German gross value is assumed to be increased by 267 billion euros by 2025 after the introduction of Industry 4.0. [Lee, Bagheri, 2015]. The technical aspects of the requirements of a successful integration are primarily addressed by the application of the concepts of Cyber-Physical Systems (CPS) [Rojko, 2017, Pilloni, 2018]. Any Industry 4.0 concept is therefore based on the connections of autonomous CPS building blocks. The CPS blocks are potentially heterogenous embedded systems equipped with intelligent, decentralized control and advanced connectivity. These blocks have the central ability to collect and exchange real-time information with the goal of monitoring and optimizing the production processes [Rojko, 2017, Pilloni, 2018, Savastano, Amendola, Bellini, D`Ascenzo, 2019, Roblek, Mesko, Krapez, 2016]. The technologies introduced by Industry 4.0 thus enable autonomous intelligent communication and cooperation among CPS, so that a higher level of intelligence, and therefore a higher level of flexibility and performance, can be achieved in industrial manufacturing processes. Industry 4.0 is thus assumed to enable three core aspects namely digitization of production, automatization of production and intelligent data interchange. As a logical consequence, the manifestation of Industry 4.0 is often exemplified through the concept of a smart factory. (SF) [Nagorny, Limo-Monteiro, Barata and Colombo, 2017].

SMART FACTORY

Smart manufacturing systems are largely autonomous, non-hierarchical physical and logical capsulated systems based on the Industry 4.0 concept that form a complex manufacturing ecosystem. These systems are often summarized under the term smart factory (SF). SF systems are heterogeneous, loosely coupled, cyber-physical systems that again accumulate in a cyber-physical system architecture, a cyber-physical system of systems, the smart factory. SF uses information to continuously maintain and improve performance and can be expected to be producing a high variety and volume of data due to the interconnected nature of the contained CPS [Mittal et.al., 2019, Freund, Al-Majeed, 2020]. Traditionally, manufacturing was defined as a sequence of processes through which raw materials were converted into finished goods for a fixed market. SF aims to integrate the properties of self-assembly to produce complex and customized products to exploit the new and existing markets [Gaham, Bouzouia, Achour, 2013].

CYBER-PHYSICAL SYSTEM ARCHITECTURE

A cyber-physical system architecture describes the overall integration approach of CPS to construct and achieve value creation in a manufacturing system.

CYBER-PHYSICAL SYSTEM

A CPS can be described as a new generation of systems that blend the knowledge of physical artifacts and engineered systems due to integrated computational and physical capabilities. CPS are established in order to produce a global intelligent behaviour featuring autonomy, self-control and self-optimization and are expected to be a decisive driving force for advances in different applicative domains including manufacturing control and for opening up new areas of innovation [Horvarth and Gerritsen, 2012, Schiliro, 2017]. CPS are characterized by advanced connectivity that ensures real-time data acquisition from the physical world and information feedback from the cyber space and intelligent data management, analytics and computational capability that constructs the cyber space. (Lee and Bagheri, 2015) CPS are also connected with high system complexity and contains an inherent trade-off relationship between the drawbacks of complexity and the performance increases gained [Freund and Al-Majeed, 2020].

CYBER-HUMAN SYSTEM

A CHS means that humans have an increasingly interconnected relationship with digitized and digital systems and represents an integral factor to establish a functioning CPS. This development is exemplified in the increasing human-machine interaction through new computer systems, the internet, mobile devices, improved sensor technology and possible future applications like brain-machine interfaces and leads to human lives and decision-making increasingly merging with technology [Gimpel and Röglinger, 2015, Horvarth and Gerritsen 2012].

Figure 2 now illustrates the concept of CPS and CHS [Freund & Al-Majeed, 2020].

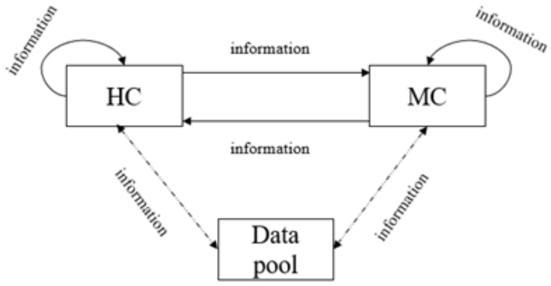


Fig. 2. CPS example

Figure 2 shows that an exemplary CPS architecture can be described as a closed loop heterogeneous system of a constellation of machine (MC) and human (HC) units with data interaction enabled through a reflexive and irreflexive multi-directional information flow with a shared data pool [Freund and Al-Majeed, 2020]. As a result, the illustrated structure of a CPS is characterized by highly interconnected constellation of heterogeneous agent types situated in reinforcing information diffusion and generation feedback loops.

TECHNOLOGICAL CHANGE

The term technological change is a positive transition of a system from a technological level (A) to a more advanced technological level (B) in a given transition time period (t). If the transition time periods between a series of technological levels Δ(t) decreases in an exponential manner exponential technological change can be identified. The transitioning from a technological level (A) to technological level (B) shall furthermore encompass the emergence of new and more potent technologies, like more productive and efficient tools, facilities or services (for example robotics or the internet) and the diminishment of less potent technologies. It also contains the habitual and institutional adjustments conducted by the society employing and interacting with the technologies. It shall therefore be assumed that technological change can be regarded for a company as a main impact factor of corporate structural change responding to external market incentives that drive competition and economic growth [Romer, 1990, Hochwallner and Ribeiro, 2018].

METHOD

The Industry 4.0 Knowledge Framework (IKTF) is based on the concept of the micro-meso-macro analysis framework and consequently is representative for the approach of micro-meso-macro analysis in managerial practice [Dopfer, Foster, Potts, 2004]. The micro–meso–macro analytical framework represents a proven method of analysis in the social sciences and economics and can greatly enhance the focus, clarity and strength of decision quality in many decision-making contexts [Serpa, Ferreira, 2019]. It proposes three categories of factors and places them in three basic levels layering them on top of each other. The macro-level includes the financial, political and sociocultural factors that influence Industry 4.0. The meso-level includes the technical and organizational factors. The micro-level refers to individual factors, particularly individual companies' intention to use Industry 4.0 in practical economic contexts. This framework is useful in that it affords insight into the various factors that influence the integration and usage of Industry 4.0. It is also suggested that there is interaction between, and interdependence of the different factors. It also proposes different points of high relevancy for decision makers and planners when developing Industry 4.0 integration initiatives. The applied micro-meso-macro framework is an adaption of the model presented by Ly et. al and is now illustrated in Figure 3 [Serpa, Ferreira, 2019].

Figure 3 shows, that change is the defining property of meso (i.e. the origination of new rules and the technological dynamics), and coordination occurs as micro and macro structures adapt and change according to the meso-level dynamics. This makes visible that the micro level refers to the individual carriers of rules and decision makers in the organization and the systems they organize, and the macro level consists of the aggregated effect of the system dynamics of the meso level. The micro level is thus positioned between the elements of the meso, and the macro level is positioned between meso elements [Dopfer, Foster, Potts, 2004].

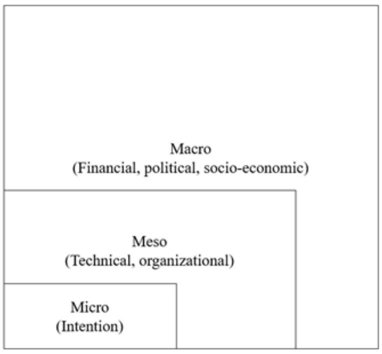


Fig. 3. Micro-Meso-Macro Analysis

THEORY SYNTHESIS

The definitions and concepts presented in this study are largely based on secondary sources and research, meaning a systematic foundational review of relevant literature. Information on the core research complexes “information”, “complexity” and “systems” is mostly available in (academic) books, professional journals, academic journals, reports or internet sources, mainly published in the research fields of philosophy, information technology, physics, engineering and business studies, as demonstrated by the following sections of this chapter. This paper quotes a wide range of sources in the form of basic theoretical considerations, expressed though the introduction and discussion of relevant definitions to allow a coherent pursuit of the previously mentioned aim of research through summarizing and synthesizing previous sources to develop a set of hypotheses out which directions for new future research may be derived. To allow the establishment of the IKTF core concepts in a coherent approach, a systematic review of relevant literature was conducted for this paper and in total 125 sources matching the scope of this article, in the form of academic journals and academic books of the mentioned academic fields, published between 2012 and 2021, were selected, individually read and reviewed by the authors and reduced by careful author selection to 29 key sources which served as the basis for theory synthesis of the presented framework. Theory synthesis has then be applied to define the in Figure 1 shown IKTF core concepts in more detail on the micro-meso and macro level.

After describing the applied methods for this paper, the Industry 4.0 Knowlegde & Technology Framework can now be presented in detail.

INDUSTRY 4.0 KNOWLEGDE & TECHNOLOGY FRAMEWORK

The Industry 4.0 Knowledge Roadmap (IKTF) can now be introduced and is based on the concept of the micro-meso-macro analysis framework presented in Figure 3 and consequently is representative for the approach of micro-meso-macro framework and its benefits for decision makers [Dopfer, Foster, Potts, 2004].

Figure 4 now illustrates the basic structure of the IKTF.

Figure 4 shows, that the basic structure of the IKTF follows an inverted Micro-Meso-Macro logic in which the macro-development level (M) is positioned at the bottom, followed by the meso level in the form of the framework level (F) and the micro level in the form of the integration level (I) at the top with transition indicators between each level. Each level follows the three-step (M1-M3, F1-F3, I1-I3) one-directional logic of displaying the most relevant Industry 4.0 concept for this level, followed by the resulting technological manifestations and the specific attributes in the form of socio-economic and technological impacts for the level. When the level internal logic chain ends a transition to the next level is implemented, as indicated by the arrows. It is also shown that the transition from (M) to (F) implicates a transition from the company external macro-environment to a company internal perspective, while (F) to (I) remain company internal. The external environment consists of an organization’s external factors that affect its business operations in an indirect manner. Thus, the organization has no or little control over these factors; that means, the external environment is generally assumed to be non-controllable and represented by (M). The internal environment describes forces or conditions or surroundings within the boundary of the organization represented by (F) and (I). The internal environment includes all assets contained within the boundaries of the organization. Some of these assets are tangible, such as the physical facilities, the plant capacity technology, proprietary technology, or know-how; some are intangible, such as information processing and communication capabilities. Consequently, decision makers can only use company internal assets in (F) and (I) as resources to make decisions in response to (M). In a next step, all IKTF levels are presented and described in more detail. The Macro Development Level (M) shall be defined as the larger and abstract level of understanding that stands above the other two levels of the framework. As already mentioned, (M) represents the company external world and the trends that impact Industry 4.0. (M) shall now be defined as the following level structure.

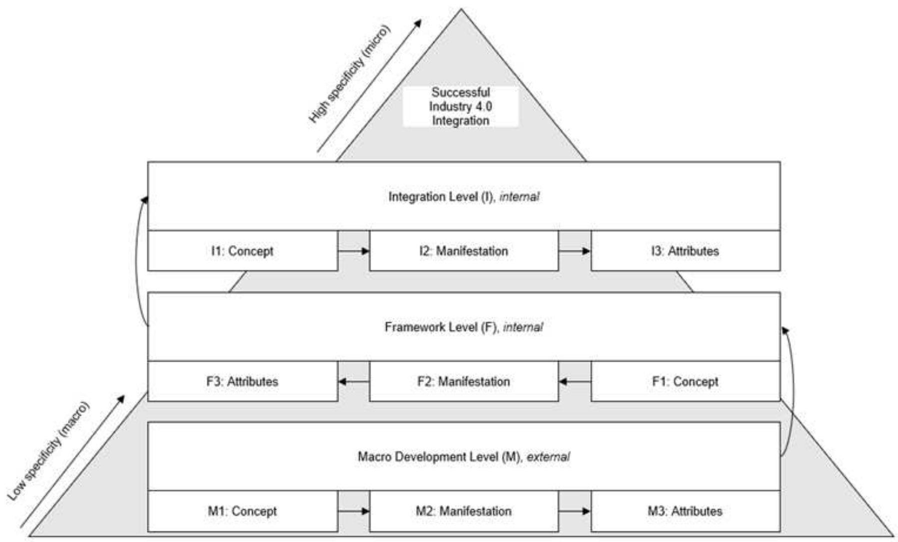


Fig. 4. IKTF basic structure

Figure 5 shows, that the core concept of (M) is defined as the already described core concept exponential technological change, which results in the manifestations as described in Table 1.

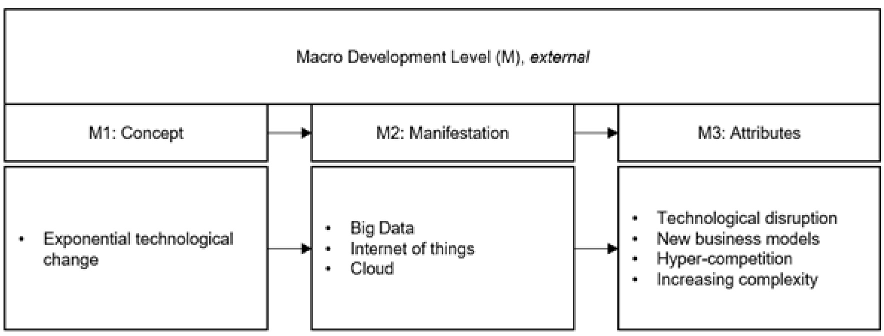


Fig. 5. IKTF basic structure

Table 1. Macro Level (M) Manifestations

Manifestation (M)	Description
M.2 Big Data	The increased usage of networked machines and sensors generates high-volume data. High-tech technology, like advanced machine learning, is necessary that can analyze and leverage large data sets including real-time data that are difficult to analyze by traditional methods. (Lee and Bagheri, 2015, Gaham, Bouzouia and Achour, 2013)
M.2 Internet of Things	The IoT enables the communication between physical and Internet-enabled devices through connecting physical objects through the virtual realm. (Mittal, Limo-Monteiro, Barata and Colombo, 2017)
M.2 Cloud	Cloud-based IT-platform serves as a technical backbone for the connection and communication of manifold elements of Industry 4.0. and IoT as they, for example, allow flexible and cost-efficient data storage upscaling. (Rojko, 2018)

Table 2. Macro Level (M) Attributes

Attributes (M)	Description
M.3 Technological disruption	The combination of technologies like IoT, cloud and Big Data in the Industry 4.0 is disruptive and leads to significant paradigm shifts in manufacturing. CPS for example derive from important technical advances on the internet, embedded systems, computer science and artificial intelligence. (Morrar, Arman and Moussa, 2017, Roblek, Mesko and Krapez, 2016)
M.3 New business models	Industry 4.0 and its embedded technology diffusion progress is expected to grow exponentially in terms of technical change and socioeconomic impact and allow for new types of business models, for example platform business. Benefiting of such a transformation requires a holistic approach of value creation that integrates innovative and sustainable business and technology solutions which modify or replace existing business models. (Morrar, Arman and Moussa, 2017, Roblek, Mesko and Krapez, 2016, Thoben, Wiesner and Wuest, 2016)
M.3 Hyper-competition	As explained in the introduction, industrial production is driven by a hyper-competitive rivalry for market shares between formerly separated industries generated caused by a more global, digital, and interconnected market environment. (Turgay and Emeagwali, 2012)
M.3 Increasing complexity	Cyber-physical system architectures are characterized by unprecedented scale and interconnectedness and are thus highly complex. Managing this complexity is a challenging task, as traditional analysis tools are unable to cope with the full complexity of CPS or adequately predict system behavior. One barrier to progress is the lack of appropriate science and technology to conceptualize and design the deep interdependencies among engineered systems of the Industry 4.0 concept and the changes manifesting in the company external environment. (Rojko, 2017, Pilloni, 2018, Thoben, Wiesner and Wuest, 2016)

These manifestations can now be attributed with the following properties as shown in Table 2.

After describing the macro-level manifestations and attributes, the framework level can now be defined in detail.

The Framework Level (F) represents the meso level that lies between the macro and micro level of the framework. the company internal reaction to (M). (F) shall now be defined as the following.

Figure 6 shows, that the concept of (F) is defined by the company internal concept Industry 4.0, which results in the already described manifestation Smart Factory and the attributes described in Table 3.

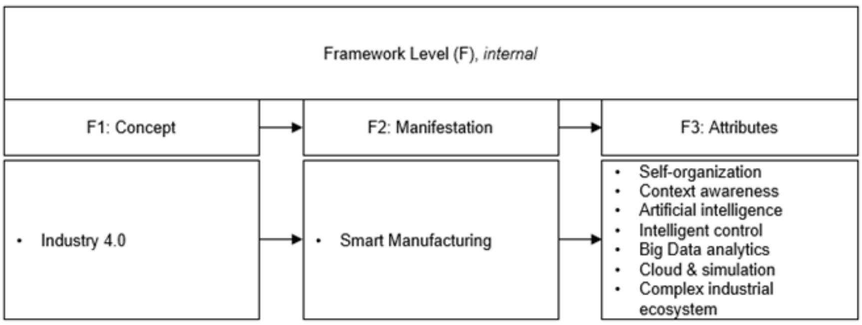


Fig. 6. Framework Level

Table 3. Framework Level (F) Attributes

Attributes (F)	**Description**
F.3 Self-organization	Manufacturing processes will be interconnected across corporate boundaries via CPS. These changes in supply and manufacturing chains require greater decentralization from existing traditional manufacturing systems. This results in a decomposition of the classic, centralized production hierarchy and a paradigm shift toward decentralized self-organization. (Lee and Bagher, 2015, Pilloni, 2018, Roblek, Mesko and Krapez, 2016)
F.3 Context awareness	Context awareness is an important intelligent characteristic of an SF and its underlying CPS and it is a combination of the following attributes: Awareness of identity, location, status, time. (Horvarth and Gerritsen, 2012)
F.3 Intelligent control, artificial intelligence	With the help of intelligent technology and context awareness, a CPS is expected to be able to change its actions based on its own experience and is thus self-learning and capable of evolutionary self-adapting to external changes. If it possesses intelligent control technology, it can make use of, for example, artificial intelligence techniques, like machine learning, to control its mechanisms via decision algorithms and is able to perform more reliable and accurate in a less stable environment. (Thoben, Wiesner and Wuest, 2016, Mittal, Khan, Romero and Wuest, 2019)
F.3 Big Data analytics	The collection and comprehensive evaluation of data from many different sources like production equipment and systems as well as enterprise and customer-management systems will become standard to support real-time decision making. (Pilloni, 2018, Morrar, Arman and Moussa, 2017)
F.3 Cloud & simulation	With Industry 4.0, organization needs increased data sharing across the sites and companies, achieving superior reaction times in milliseconds or even faster. This leads to the idea of having the connections of different devices to the same cloud to share information to one another. This can be extended to set of machines from a shop floor as well as the entire manufacturing system. Simulations will be used more extensively in plant operations to leverage real-time data to mirror the physical world in a virtual model via double representation. This includes machines, products, and humans, reducing machine setup times and increasing quality. Decision making quality can also be improved with the help of simulations, as possible system trajectories can be featured into the decision-making process. (Rojko, 2017, Pilloni, 2018, Xu and Ling, 2018)
F.3 Complex industrial ecosystem	Designing Industry 4.0 systems involves high complexity, which mainly originates from the high dimensionality and the internal complexity of components. As, for example, the IoT scales to billions of connected devices – with the capacity to sense, control, and otherwise interact with the human and the physical world – the requirements for dependability, security, safety, and privacy grow significantly and must be managed accurately. (Savastano, Amendola, Bellini and D´Ascenzo, 2019, Freund and Al-Majeed, 2020)

After describing the framework level manifestations and attributes, the integration level can now be defined in detail.

The Integration Level (I) represents micro level the company internal reaction to (F). (I) shall now be defined as the following.

Figure 7 shows, that the concept of (I) is defined by the already described company internal core concept cyber-physical system architecture, which results in the manifestations cyber-physical system and cyber-human system and the attributes shown in Table 4.

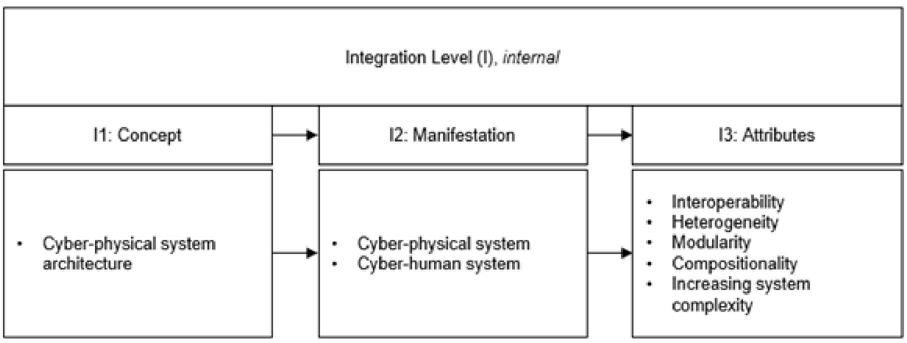


Fig. 7. Integration Level

Table 4. Integration Level (I) Attributes

Attributes (I)	Description
I.3 Interoperability	Interoperability is the characteristic due to which, system units are able to exchange and share information with each other. With the help of networkability, systems can collaborate in different process-related aspects, and for this collaboration, they have to allow each other to share and exchange information. Similarly, distributed systems allow the information and data of one system to be accessed by other systems in the network. (Nagorny, Limo-Moneteiro, Barata and Colombo, 2017, Gaham, Bouzouia and Achour, 2013)
I.3 Heterogeneity	Heterogeneity considers the diversity and dissimilarities in the units and components. (Thoben, Wiesner and Wuest, 2016, Gaham, Bouzouia and Achour, 2013)
I.3 Modularity	Modularity is the property of a system by which a unit can be decomposed into components that can be recombined to form different configurations. (Mittal, Khan, Romero and Wuest, 2019, Gaham, Bouzouia and Achour, 2013)
I.3 Compositionality	Compositionality is the property that deals with the understanding of the whole system based on the definition of its components and the combination of the constituents.(Mittal, Khan, Romero and Wuest, 2019, Gaham, Bouzouia and Achour, 2013)
I.3 Increasing complexity	CPS emerge through networking and integration of embedded systems, application systems, and infrastructure, enabled by human machine interaction. In comparison to conventional systems used for production such a system is expected to be increasingly more complex. (Thoben, Wiesner and Wuest, 2016, Camarinha-Matos, Fornasiero, and Asfarmanesh, 2017)

After presenting all levels of the IKTF in detail, it is now possible to present the complete IKTF framework..

COMPLETE FRAMEWORK

The complete IKTF framework results and is displayed in Figure 8.

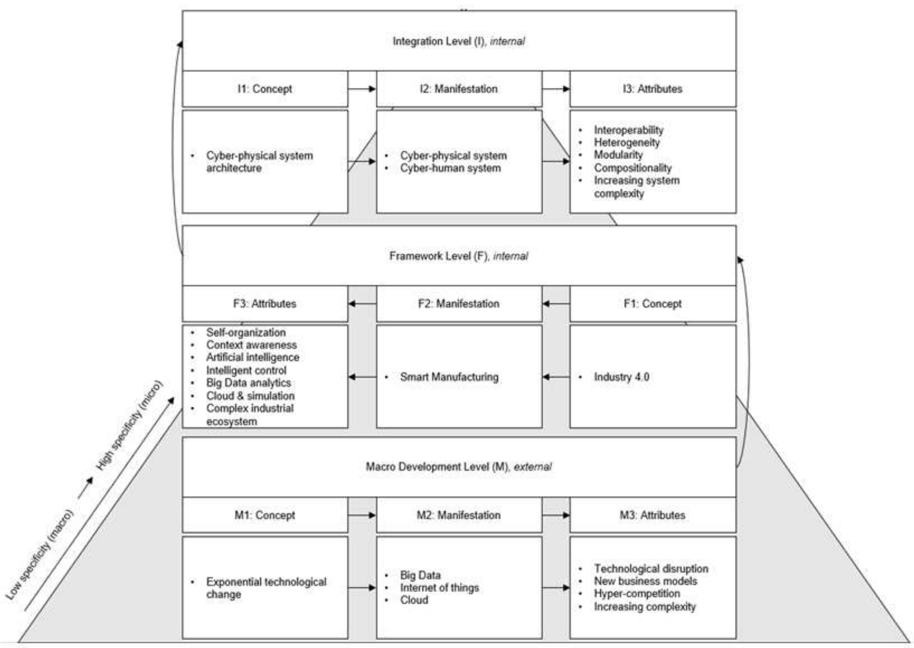


Fig. 8. IKTF - Complete Framework

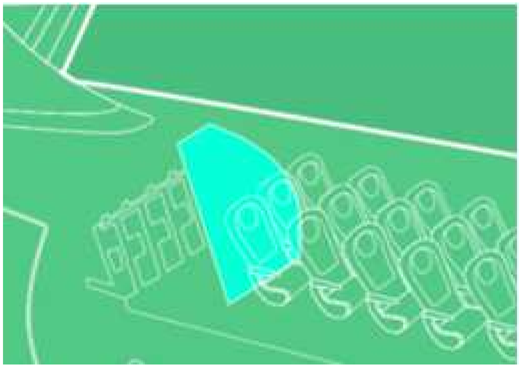
After presenting the complete IKTF framework, the resulting implications for decision-makers and the overall functionality can now be discussed on the basis of a case study.

IMPLICATIONS FOR DECISION-MAKERS

The IKTF shows, that decision makers must acquire sufficient knowledge in the macro-level, with low context specificity (M) about the concept, manifestations and attributes of exponential technological change and its disruptive effects on the financial, political, and socio-economic external environment of the company. This can be achieved through understanding analyzing the manifestations of Big Data, Internet of Things and Cloud and their attributes of technological disruption, new business models, hyper-competition and increasing complexity in the individual corporate context. A response through the utilization of company assets in the internal framework level (F) can then be formulated as a reaction by analyzing the applicability of the concept of Industry 4.0 with its manifestation smart factory and the attributes of self-organization, context awareness, intelligent control, artificial intelligence, Big Data analytics, cloud & simulation and the complexity of industrial ecosystems under the resource constraints and macro influence factors of the individual company. If this is achieved an integration approach can formulated by analyzing the applicability of cyber-physical system architectures, their manifestations cyber-physical systems and cyber-human systems with the attributes of interoperability, heterogeneity, modularity, compositionality and increasing complexity under the identified constraints on the framework level and macro level. This makes visible that a successful integration of Industry 4.0 is an extensive, difficult to achieve task which requires extensive knowledge, reflection and insights on all levels of specificity. According to the IKTF no level of the framework can be skipped or only partially understood. Only a comprehensive understanding of the framework levels and the successful application on the individual corporate context allow a successful integration of industry 4.0. This highlights the importance of informed and analytical decision making on all corporate areas in the context of Industry 4.0 integration. In the final step of this paper, the IKTF is applied to case study to further display the functionality and practical applicability of the line of argument and the framework.

CASE STUDY: AIRCRAFT PARTITION REDESIGN FOR AIRBUS 320

After presenting the theoretical foundation of the IKTF, the framework is now applied to a rudimentary case study to showcase its functionality. The case utilized is taken from [26,27]. European aircraft manufacturer Airbus collaborated with Autodesk to rethink the design of aircraft partitions of the Airbus A320 cabin, as part of creating a vision for future aircraft design. This vision includes the overarching goals of a more eco-friendly, lighter plane designs and a more customizable customer experience. The partitions used to separate the cabin crew's workstation from the rest of the cabin represents a major engineering conundrum, especially to the aircraft manufacturers, who want these partitions to be as small and light as humanly possible.



Source: Autodesk, 2021

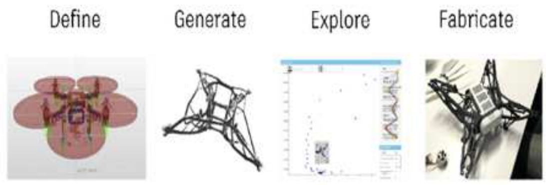
Fig. 9. Aircraft partition

This new partition was planned to be:

- significantly lighter than the current partition, meeting the goal of reducing the weight of the plane,
- strong enough to anchor two jump seats for flight attendants during take-offs and landings
- have a cutout to pass wide items in and out of the cabin
- no more than an inch thick
- attached to the plane's airframe in just four places.

To meet the outlined requirements, it was decided to leave traditional manufacturing and design paradigms behind and to start working with the company Autodesk Research on the so-called "Bionic Partition", based on generative design, that mimics the evolutionary design approaches found in nature.

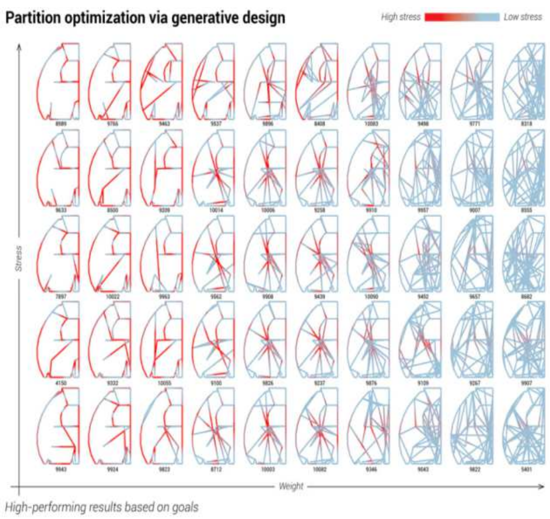
Engineering design software (Autodesk Dreamcatcher), machine learning techniques and additive manufacturing based on 3D Printing were used to generate a new partition based on bionic, generative design principles. To allow a better understanding of the case the rudimentary concept of Autodesk Dreamcatcher is now illustrated in Figure 10.



Source: Autodesk, 2021

Fig. 10. Autodesk Dreamcatcher

Figure 11 now illustrates a sample of the partition optimization in the generative design process based on the parameters stress and high-performing results based on system goals.



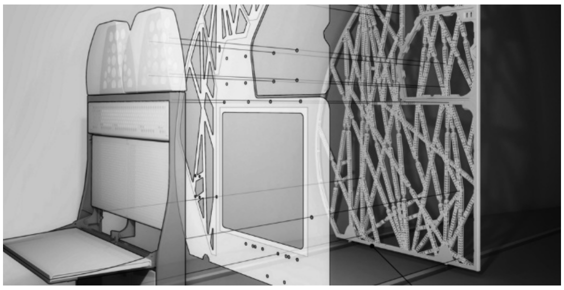
Source: Autodesk, 2021

Fig. 11. Partition optimization via generative design

The new partition was 3-D printed using new innovative, generative design algorithms based on bionics, represented by the interconnectivity found in slime-mold singular-celled organism and grid structures of mammal bone growth dynamics in biological systems. Over 10,000 design options were created by the software in the process and checked for applicability. More than 100 separate pieces were 3D printed and assembled in a process of additive manufacturing. Figure 12 now shows a final 3D printed piece of the partition, while Figure 13 shows the final product.

Source: Autodesk, 2021

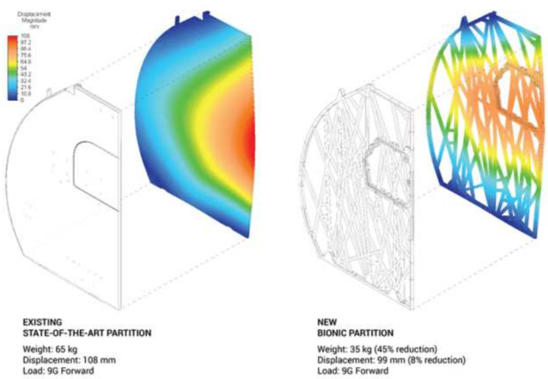
Fig. 12. Final printed piece– part of a bionic aircraft partition by Airbus



Source: Autodesk, 2021

Fig. 13. Bionic aircraft partition by Airbus

Figure 14 now illustrates a comparison between the bionic partition and the standard partition.



Source: Autodesk, 2021

Fig. 14. Bionic aircraft partition by Airbus compared to standard partition

The new partition weighs in at 35 kg, significantly lighter than Airbus's original partitions that weighed 65 kg apiece, which represents a 45% weight reduction. This results in (if all four partitions in an Airbus 320 were replaced) 500kg overall weight reduction of the aircraft, reduced fuel consumption, reduction of CO_2 emissions. Due to the usage of 3D printing and additive manufacturing material consumption is reduced by 95% in comparison to traditional manufacturing processes [Autodesk, 2021]. Moreover, because the designs created by the generative design software are so complex, classical manufacturing techniques were out of the question when it came to building the part [Skillton, Hoysepian, 2018].

After describing the case, the IKTF can now be applied for further analysis.

CASE STUDY: IKTF APPLICATION

The IKTF is now applied to the presented case as shown in Figure 15.

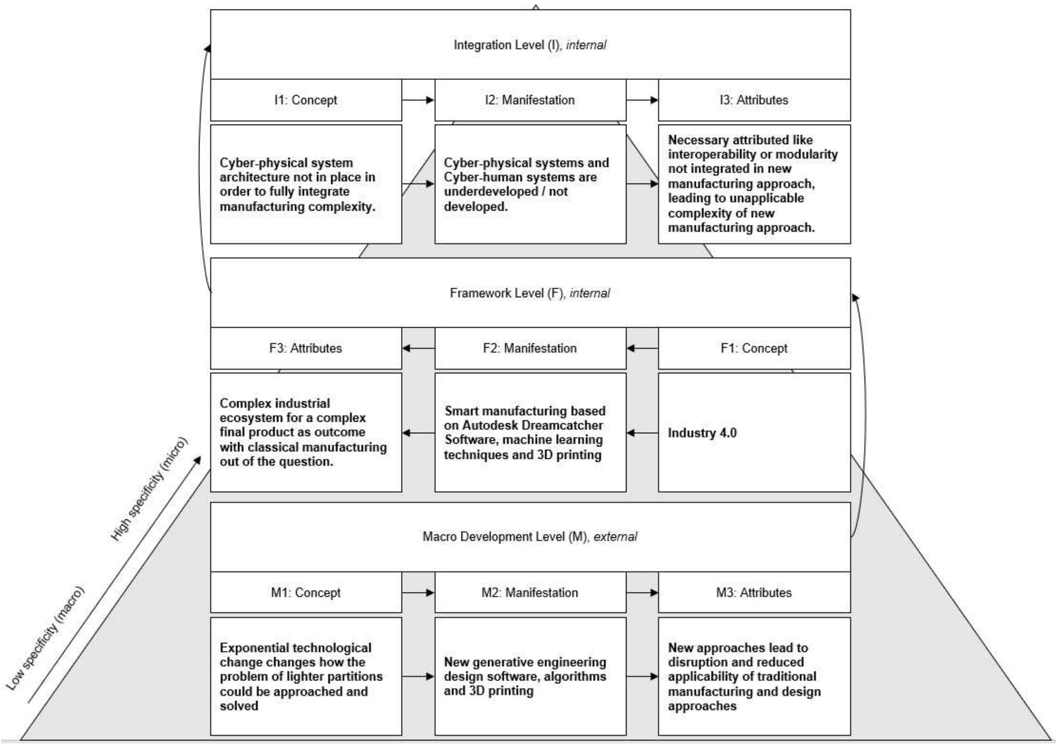


Fig. 15. IKTF – Case study application

After integrating the case in the IKTF the different levels of the framework can now be described in Tables 5, 6 and 7.

Table 5. Macro Level (M) Application

Macro Level (M)	Case Application
M1	Exponential technological change changes how the problem of lighter partitions could be approached and solved in general on the technological level.
M2	Big Data, Internet of things, Cloud can be applied as enablers in the form of new generative engineering design software, algorithms, and 3D printing.
M3	Technological disruption, increasing complexity manifest themselves in new approaches that lead to disruption and reduced applicability of traditional manufacturing and design approaches.

After describing (M) for the case in Table 5 a transition to the framework level is now possible.

After describing (F) in Table 6 for the case a transition to the integration level is now possible.

Table 6. Framework Level (F) Application

Framework Level (F)	Case Application
F1	Industry 4.0 can be described as the necessary framework concept to capitalize of the macro level developments.
F2	Industry 4.0 manifests in the concept of smart manufacturing which itself is based on the 3D printing, the generative design software Autodesk Dreamcatcher software and machine learning techniques.
F3	The attributes artificial intelligence, self-organization, cloud and simulation, context awareness and Big Data analytics can now be identified in F3 for F2 and already indicate the necessity of a complex industrial ecosystem to allow the production of the new product.

Table 7. Integration Level (I) Application

Integration Level (I)	Case Application
I1	Appropriate cyber-physical system architecture proportional to final product complexity is not in place, while classical manufacturing approaches are no option for production.
I2	Cyber-physical and cyber-human systems are necessary, but not in place, to manifest to fully capitalize on the benefit of the new, highly complex product
I3	The attributes of interoperability, heterogeneity, modularity, compositionality, and an overall production system of higher complexity should be integrated in a potential production approach for the new product.

After describing (M) in Table 5, (F) in Table 6 and (I) in Table 7 it is now possible to interpret the results of the IKTF in the next chapter..

INTERPRETATION

Figure 16 now shows the interpretation of the presented case in the IKTF format.

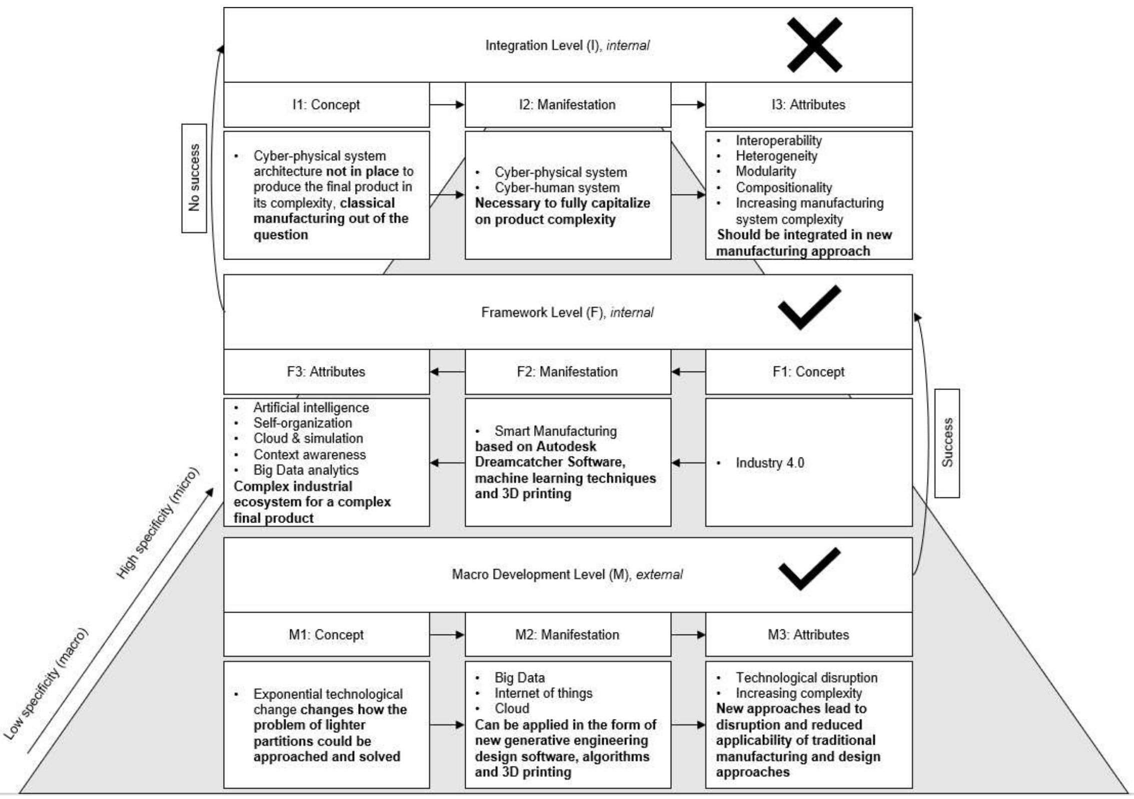


Fig. 16. IKTF – Case study interpretation

Figure 16 shows, that the Airbus project can be described to capitalize of the external level (M) can achieve a successful transition of from (M) to the internal framework level (F). (F) can be completed, but no transition to the integration level (I) is in place and whether a sufficient understanding of the required concept, manifestations and attributes is in place to allow full capitalization of a successful completion of (M) and (F).

The final IKTF of the described case allows to conclude that the newly developed bionic aircraft partition cannot be a successful product unless the integration level is completed. The IKTF thus recommends that it is necessary to translate the requirements of an complex industrial ecosystem for a product of high complexity into an adequate cyber-physical system architecture for production which is itself characterized by a combination of interoperable, heterogenous, modular cyber-physical and cyber-human systems which itself represent a highly complex system with compositionality. These recommendations, even though not specific, allow to question the economic viability of the new product designed and its applicability for mass production overall. This conclusion to the IKTF is in line with the presented case, which can be regarded as a lighthouse project of Airbus to explore technological not economic feasibility and presents a first proof of concept for the framework.

DISCUSSION OF RESULTS

The IKTF shows that the successful integration of Industry 4.0 is dependent from many layers of understanding which are sequentially connected on the micro-meso-macro levels of analysis. The IKTF furthermore proposes that decision makers follow the shown bottom-up approach when aiming for integration and identify how every concept applies for the individual corporate context and project they want to implement. As already mentioned in the introduction, the integration of Industry 4.0 is accompanied by a large variety of research and development issues, for example the management of system complexity in a VUCA environment and the development of universally applicable reference models and foundational definitions of fundamental concepts for Industry 4.0. As shown by the provided case study, the IKTF can serve decision makers in the context of management of system complexity, definitions and reference models by providing three functions:

- Obtain a multi-level understanding of Industry 4.0
- Definition of the corporate context in the framework of Industry 4.0
- Pinpoint the position and integration status of a given project in IKTF relative to the framework levels
- Show potential “weak zones” in the integration process
- Provide first implications for the scalability and economic validity of a given Industry 4.0 integration project

As argued by Camarinha-Matos, Fornasiero and Asfarmanesh the concept of Industry 4.0 has turned into a buzzword and an “everything fits” catalyzer for various technologies and manufacturing approaches. The “everything fits” mentality, making the concept difficult to understand, is additionally supported by companies and their respective managers utilizing their own descriptions and concepts, leading to a decreased diffusion of best practice methodologies [Camarinha-Matos, Fornasiero and Asfarmanesh, 2017]. The IKTF can contribute to avoid such a mindset and helps to replace it with a consistent and coherent analytical approach, as illustrated by the provided case study. Nevertheless, the IKTF is to be regarded as a foundational managerial decision-making tool that predominantly focusses on providing insight for decision-makers in the context of their respective company and on overcoming the challenge of developing Industry 4.0 reference and application models for integration processes and is thus limited in applicative value when applied out of this scope.

CONCLUSION

The IKTF analyzes Industry 4.0 on several levels of abstraction in a micro-meso-macro framework and introduces the different positions of different core concepts in a coherent and logically consistent framework that represents relevant Industry 4.0 core concepts, manifestations and attributes on three interdependent levels. These levels can then be applied to a given managerial decision-making problem, for example the integration of a new technology, in an analytical way. While doing this, the levels of the IKTF and their respective internal logical chains cannot be seen isolated from each other since every level and builds on the concept, manifestation, and attributes of the previous level. Hence, the practical integration of Industry 4.0 requires decision makers to have insights into company external and internal interconnected knowledge and technology fields on different levels of abstraction to be successful, as shown by the provided case study. The IKTF, therefore, proposes a well-structured solution to the complex nature of Industry 4.0 and shows a path to informed managerial decision making.

OUTLOOK

To advance the applicability and theoretical foundation of the proposed framework, future work focuses on verifying, expanding, modifying, and applying the ITKF via extensive case study research in European companies.

CONFLICT OF INTEREST

The authors of this study have no conflict of interest to declare.

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REFERENCES

Autodesk.,2021. website: www.autodesk.com/customer-stories/airbus

Camarinha-Matos L., Fornasiero R., Asfarmanesh H., 2017. Collaborative Networks as a Core Enabler of Industry 4.0, Collaboration in a Data-Rich World, Springer, PRO-VE 2017. IFIP Advances in Information and Communication Technology, 506: 3-17, http://doi.org/10.1007/978-3-319-65151-4_1

Congressional Research Service, 2020. Global Economic Effects of COVID-19. World Economic Outlook. International Monetary Fund. April 2020.

Dopfer K., Foster J., Potts J., 2004. micro-meso-macro. Journal of Evolutionary Economics, 14(3):263–279, http://doi.org/10.1007/s00191-004-0193-0

Fraunhofer IPT. 2019., INDUSTRIE 4.0 – Vernetzte, Adaptive Produktion. Frauenhofer Institut für Produktionstechnologie: 3-7.

Freund L., Al-Majeed S., 2020. The Industry 4.0 Knowledge & Technology Framework. PalArch's Journal of Archaeology of Egypt / Egyptology, 17(9), 6321 – 6339, ISSN 1567-214x

Freund L., Al-Majeed S., 2020. Cyber-physical systems as sources of dynamic complexity in cyber-physical systems of systems. 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), Sakheer, Bahrain, 2020, 1-5, http://doi.org/10.1109/3ICT51146.2020.9312015

Freund L., Al-Majeed S., 2021., Hypotheses concerning complexity surges in modern and future industrial information systems . Logforum 17 (3), 1. http://doi.org/10.17270/J.LOG.2021.3.1

Freund L., Al-Majeed S., Millard A., 2021. Case Studies Key-Findings of a Strategic

Complexity Management Framework for Industrial Manufacturing Systems. 2021 16th International Conference of System of Systems Engineering (SoSE), 2021, 55-60, http://doi.org/10.1109/SOSE52739.2021.9497489.

Gaham M., Bouzouia B., Achour N., 2013. Human-in-the-Loop Cyber-Physical Production Systems [Control HiLCP2sC) A Multi-objective interactive framework Proposal. in: Service Orientation in Holonic and Multi-agent Manufacturing, Springer-Verlag Berlin Heidelberg: 315-325, http://doi.org/10.1007/978-3-319-15159-5_29

Gimpel H., Röglinger M., 2015. Digital transformation: changes and chances. Project Group Business and Information Systems Engineering (BISE) of the Fraunhofer Institute for Applied Information Technology FIT: 1-20

Hochwallner M., Ribeiro L., 2018. On the Design Complexity of Cyberphysical Production Systems. Complexity, Vol.18, http://doi.org/10.1155/2018/4632195

Horvarth I., Gerritsen B., 2012. Cyber physical systems: concepts, technologies and implementations. Proceedings of TMCE 2012, 1:19-22, ISBN 978-90-5155-082-5

Lee J., Bagheri B., 2015. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. Manufacturing Letters 2015 3:18-23, http://doi.org/10.1016/j.mfglet.2014.12.001

McAfee A., Brynjolfsson E., 2014. The second machine age. W.W. Norton & Company, New York: 26-34, ISBN: 978-0-393-35064-7

Mittal S., Khan M., Romero D., Wuest T., 2019. Smart Manufacturing: Characteristics, Technologies and Enabling Factors. Proceedings of the Institution of Mechanical Engineers 2017 Part B Journal of Engineering Manufacture, 233(5): 1342-1361, http://doi.org/10.1177/0954405417736547

Morrar R., Arman H., Moussa S., 2017. The Fourth Industrial Revolution (Industry 4.0): A Social Innovation Perspective. Technology Innovation Management Review, 7 (11):14-18, http://doi.org/10.22215/TIMREVIEW/1117

Nagorny K., Limo-Monteiro P., Barata J., Colombo A., 2017. Big Data Analysis in Smart Manufacturing: A Review. International Journal of Communication, Network and System Sciences, 10: 31-58., http://doi.org/10.4236/ijcns.2017.103003

Pillioni V., 2018. How Data Will Transform Industrial Processes: Crowdsensing, Crowdsourcing and Big Data as Pillars of Industry 4.0. Future Internet, 10 (3), http://doi.org/10.3390/fi10030024

Roblek V., Mesko M., Krapez A., 2016. A Complex View of Industry 4.0. Sage Open April-June 2016, 1 (11), http://doi.org/10.1177/2158244016653987

Rojko A., 2017. Industry 4.0 Concept: Background and overview. International Journal of Interactive Mobile Technologies, 11(5), http://doi.org/10.3991/ijim.v11i5.7072

Turgay T., Emeagwali O., 2012. Hypercompetition: the driving force behind successful business innovations? A critical review of literature, Investment Management and Financial Innovations. 9 (3):111-113, Corpus ID: 55387401

Romer P., 1990. Endogenous Technological Change. The Journal of Political Economy. 98(5): 71-102

Savastano M., Amendola C., Bellini F., D´Ascenzo F., 2019. Contextual Impacts on Industrial Processes Brought by the Digital Transformation of Manufacturing: A Systematic Review. Sustainability. 11 (3):1-3, http://doi.org/10.3390/su11030891

Schiliro D. ,2017. A glance at Solow's growth theory. MPRA Paper No. 84531

Serpa S., Ferreira C., 2019. Micro, Meso and Macro Levels of Social Analysis. International Journal of Social Science Studies, 7 (3): 121-131, ISSN 2324-8033

Skillton M., Hovsepian F., 2018. The 4th Industrial Revolution, Springer: 282-284

Thoben K., Wiesner S., Wuest T., 2016. Industrie 4.0 and Smart Manufacturing –A

Review of Research Issues and Application Examples. International Journal of Automation Technology, 11(1):4-19, http://doi.org/10.20965/ijat.2017.p0004

Vaidya S., Ambad P., Bhosle S., 2018. Industry 4.0 – A Glimpse. Procedia Manufacturing Volume 20: 233–238, http://doi.org/10.1016/j.promfg.2018.02.034

Xu L., Ling L., 2018. Industry 4.0: state of the art and future trends. International journal of production research, 8 (56): 2941-2962, http://doi.org/10.1080/00207543.2018.1444806

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