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SUPPLY CHAINS IN CONTEXT OF KNOWLEDGE OF BUSINESS NETWORKS

Marek Ciesielski

Poznań University of Economics, Poznan, Poland

ABSTRACT. Background: Supply chains are a kind of business networks although both of these concepts are still defined in different ways in Poland. It seems that the paradigms of economics subdisciplines absorbed the knowledge of business networks in various ways and on various levels. In Poland, the networks are still treated as a novelty in many areas of management science.
Methods: The paradigms of four subdisciplines (logistics, marketing, strategic management and international economic relations) were analyzed and compared.
Results: The level of the integration between economic subdisciplines is low. There are significant differences among paradigms of subdisciplines, the concept of network is treated in different way in different subdisciplines, and therefore, the concept of strategy is in particular disciplines is treated differently.
Conclusions: The formation of interdisciplinary research teams should be intensified as well as the methodological discussions on different levels (from the unification of concepts up to grouping and unification of paradigms) should be induced.

Key words: network, supply chain, logistics, paradigm.

INTRODUCTION

The strange signs of the Logistics Development of the logistics can be observed in Poland. They concern the speed of elimination of gaps in the economic science and in the degree of the integration of subdisciplines of this field of the science. Although the rate of the transformations of the general paradigm of economics and management studies in Poland is big (which means the elimination of the gap between Polish and world science), the level of the integration of subdisciplines and their paradigms do not increase and therefore it inhibits the flows between them. The attempt to highlight this problem is the aim of this paper. It can be the basis to prepare the preliminary thesis about the level of the integration, although it concerns only a small part of this problem – the recognition of one selected concept in various areas of the knowledge of management and economics. Therefore, it is also a call to continue this research by other scientists.

The "network", one of the most important categories among modern economic sciences, was chosen for the purpose of this research. In the areas described by this concept, the degree of the integration among paradigms of four subdisciplines: logistics, marketing, strategic management and international economic relations were evaluated. The question will of course arise, whether in case of such disciplines, especially logistics and marketing, i.e. fully practical ones, is it possible to talk about a paradigm, i.e. achievements, scientific trends, theories, etc. Despite of that, such issues seem to be reasonable and appropriate. Definitely, the word "paradigm" can be used as "a model of a research" and maybe (will be shown later) in the meaning given by T.S.Kuhn. The reasoning scheme adopted in

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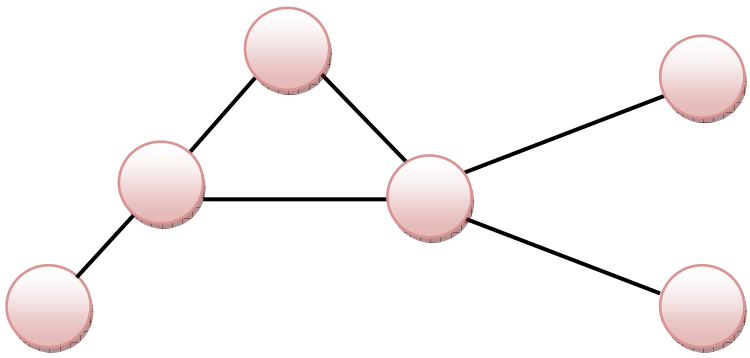
this research is very close to the view, where the various parts of paradigm of economics sciences are assigned to various subdisciplines.

The logistics is a starting point for these researches and the aim of them is to determine the level of the integration, with putting the special emphasis on the networks in strategies. If the assumptions of this researches turn to be true and the statement could be made that the fast development of economics sciences is accompanied by excessive disintegration of paradigms of its subdisciplines, the appropriate steps towards the integration could be undertaken.

SUPPLY CHAINS AND BUSINESS NETWORKS

The economic networks, called also business networks, are understood in two ways in Polish literature. According to first one, the networks are the relations. In this case, the following definition can be found: "the set of connections between two or more subjects, having interactions among them..." [Ratajczak 2010]. According to second one, the definition of networks is simple: "a set of connections between companies" [Leksykon zarządzania 2004]. According to the description given by A.Noga: "the business networks are groups of companies related to each other. Those links can be of vertical nature (such connections are identified by a permanent exchange of goods or services) or of horizontal one (in this case, they are understood as the mechanism to create and regulate the external effects within a group of objects" [Noga 2009]. The similar situation occurs in case of supply chains and supply networks. Some authors consider the supply chains as sets of organizations, others for sets of flows or interactions. J.Witkowski writes: "supply chains are various, cooperating with each other, companies (active in such areas like mining, production, commerce or services) and their customers, among them the goods, information and financial flows occur, starting at the mining of raw materials up to final customers" [Witkowski 2005]. Although such definitions can be found, which describe the supply chains as a set of flows and relations, the supply networks could be also both sets of flows or sets of companies. It is really difficult to understand the ambiguity of concepts. The issue is here only to clearly label circles and lines on the figure 1. The reference to the graph theory can be made here, where the organizations are the nodes and the relations are the lines.



Source: own work

Fig. 1. Network
Rys. 1. Sieć

The reason of this conceptual chaos is an important phenomenon. The issues related to networks are researched within the scope of the four (mainly) economic subdisciplines: marketing, logistics, strategic management and international economic relations. The researches and publications of these subdisciplines in Poland are poorly penetrated by each other as well as they do not refer sufficiently to the network theory, so-called network approach. (It would be interesting to determine whether such problems exist also in others key categories of modern economy, e.g. computerization, globalization,

customization). The above-mentioned conceptual confusion can be than related directly to the phenomenon, which requires in-depth researches. However, for now, only the expression "could be" is allowed to be used in this context. It seems that the concept of the network has not so far had the sufficient impact on the terminology and theories of these four subdisciplines, and maybe even on the entire field of economic sciences. What is even more important, the paradigms of these four subdisciplines have not been changed so far. It is very evident in the publications related to logistics issues. There are books about supply chains, where the business networks are not even mentioned. There are also publications in strategic management, which refer to some "networks in the logistics", which are a kind of business networks.

The papers of the world literature indicate that there is a crisis of a traditional corporate organizational model, based on the vertical integration, the hierarchical functional management, the technological, social and exact system of the work-sharing in a company, the organization of "management and production line" type [Castells 2010a]. The future belongs to networks. There are many types of them: networks of companies, of different types, context or culture, based on a family, on Chinese community, of a type occurring in Northern Italy, emerged from the centres of technological development like Silicon Valley, hierarchical communities of Japanese *keiretsu* type, networks of decentralized corporate units, derived from old vertically organized corporations, which now are forced to adapt to the requirements of time, business networks of customers of a company and suppliers of this company together with this company and finally international networks developed from strategical alliances of companies and networks which support them [Castells 2010b]. It is also worth to reconsider the previously mentioned issue: whether the network approach has found an appropriate response in Poland in the form of a change of paradigms of already mentioned four subdisciplines.

The big interest of networks and partly of a change of part of a paradigm is observed in case of the logistics and marketing - but it concerns only distribution channels, marketing relations and supply chains. In case of two other subdisciplines, the networks are still treated as a novelty and the completion of paradigms, used for years. The various types of understanding of a network concept and a network approach can be easily found. Once these concepts refer to spontaneous relationships among companies and organizations and otherwise it is understood as a conscious creating and shaping of cooperation forms. In case of logistics, the researches refer mainly to such concepts like transaction, cooperation, configuration and such theories like: the theory of transaction costs, networks models, modular approach and business theories. The concepts of a product, a life cycle, relations and marketing mix are emphasized in the case of marketing.

The issue of the network is usually ignored in Polish literature in the field of a strategic analysis. Even the presentations of Porter's model still emphasize the competitive attitude of companies, their suppliers and customers to each other, although the idea to make an advantage of vertical and horizontal corporate connections is clearly imposed. The issue of networks is even marginalized in publications on changes of paradigms of the strategic management [Witek-Crabb 2006]. However, the elements of network approach can be found in the value chain, the portfolio analysis and the strategic potential. It is missed in a strategy, a mission and a vision.

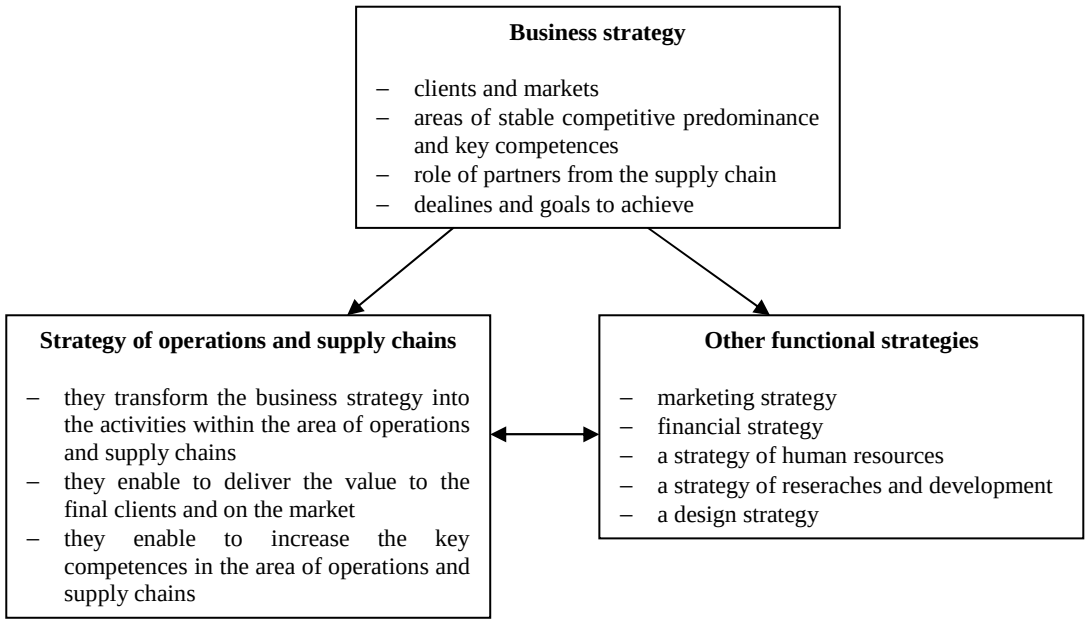
The network approach should be expected in the area of a subdiscipline related to international business relationships. However, the network is still not a permanent element of the internationalization theory in Polish publications. The networks are neither a part of paradigms of the theory of international exchange, nor the theory of direct foreign investments nor the theory of multinational company. The lack of a network approach is particularly strange to accept in the theory of internationalization. It is evidence that the network approach is described as a new concept even in the best Polish publications in this field [Gorynia, Jankowska 2007]. Of course, the networks are always connected with the concepts of globalization and internationalization. It can be concluded, that there is no network approach regarding their own paradigms in the discussed subdisciplines. Therefore, it is necessary to consider the benefits of the combined approach. The potential synergistic effects are enormous. It is enough to analyze the benefits of the connection of the knowledge from the paper "Theories of internationalization" with e.g. the knowledge in the field of supply chains.

Anyway, the logistics, as the newest subdisciplines among the discussed ones, should begin the process to connect stronger researches and theoretical considerations among those four subdisciplines.

STRATEGIES AND NETWORKS

The strategy is this area of the management, where the changes of a paradigm can be observed most strongly. As the world literature indicates, the network strategy can be in different relations concerning the strategy of a company: from the case where it is simply a developed logistic strategy of a company to the strategy of the highest level – the level of a network.

In the first case, the strategy of the supply chain/network (often together with an operational strategy) is treated as one of functional strategy of a company or a corporation. The relationships between a business strategy and a strategy of the supply chain as a multidimensional functional strategy are well described in the figure 2.

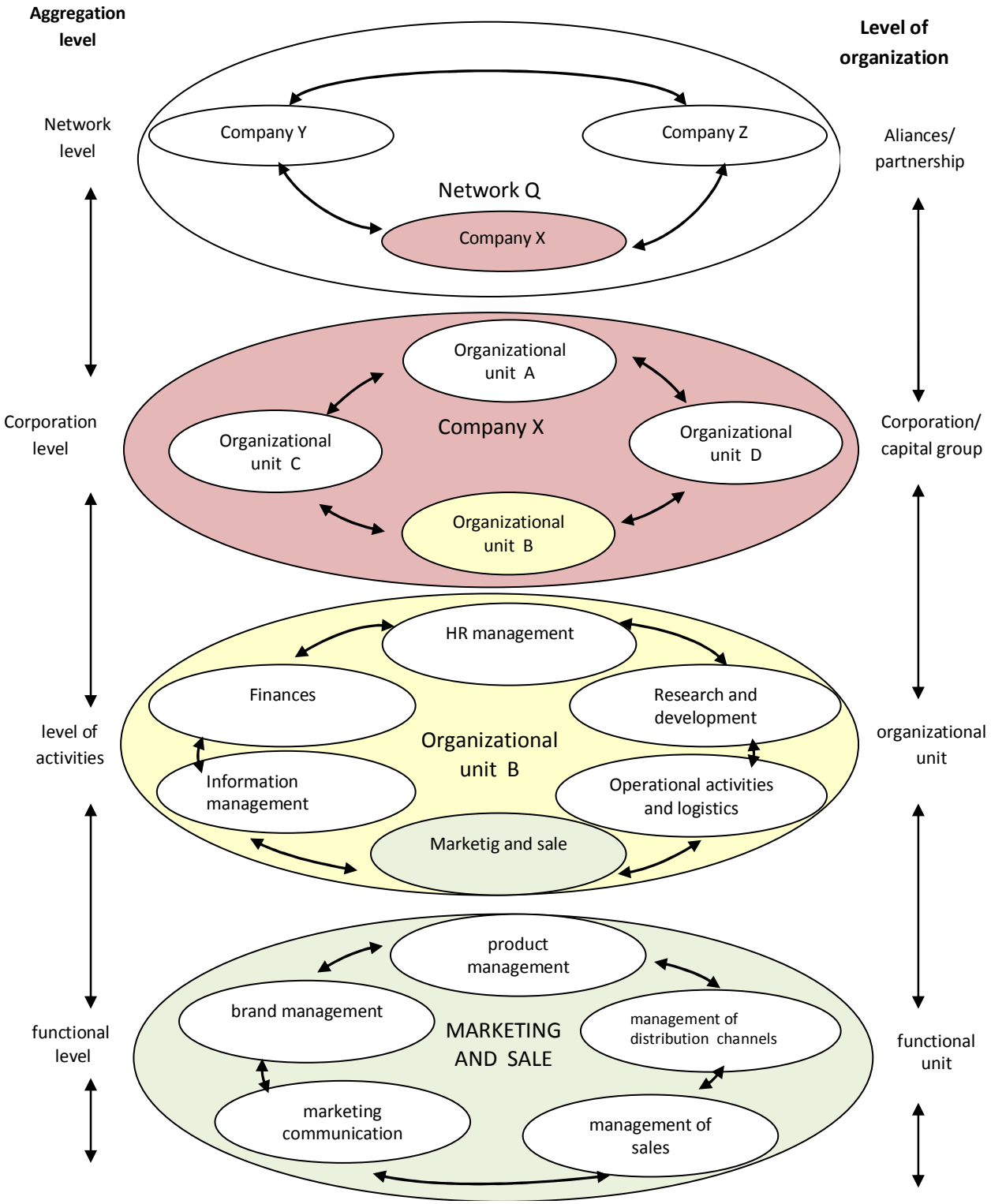


Source: Bozarth, Handfirld 2007

Fig. 2. The strategy of the supply chain within the strategy of a company or a corporation
Rys. 2. Strategia łańcucha dostaw w strategii przedsiębiorstwa lub korporacji

It is worth to mention, that the idea of the strategy of supply chains emerged already in the models related to the autonomous company. And so J.Kay [1996] suggested in his strategy model, that the competitive advantage can arise from the relationships with suppliers.

The strategy of the supply chain means how the activities related to flows are conducted and how these activities are managed [Hines 2004, Flynn, Huo, Zhao 2009]. It includes also the management of the relations within the supply chain as well as the integration in the areas of management, IT and technology. However, as a concept of a supply chain can be referred to not only a flow of goods and information or other activities like marketing, production or finances, so the concept of the strategy of a supply chain can be extended to these areas.



Source: Wit, Meyer 2007

Fig. 3. The levels of a strategy
Rys. 3. Poziomy strategii

There are three levels of a strategy according to a conventional approach: the level of a company, the level of a corporation and the level of a functional area within a company. However, the increase of the significance of business networks makes it necessary to distinguish the fourth level of the strategy – the strategy of a network. Bob de Wit and Ron Mayer [2007] write: "companies often merge into a group, consisting of two or more partners. This level is called the level of the network and the multi-organizational level. Such groups consist often of many members, like in case of strategical alliances, joint ventures or partnerships leading to create an additional value. They may be also networks, which consist of tens or even hundreds of organizations. Depending on the situation, the whole corporation or only a part of it can be joint to the cooperation with other companies. But the strategy developed for a group of companies is always called the strategy of networks, regardless of the nature or the extension of the cooperation". Therefore, the existence of the network is taken into account in a strategic approach. The companies decide, for such type of the cooperation, to get some advantages of vertical and horizontal integration, without covering the costs associated to them. The concept "strategies of activities within a network" is sometimes used. They are related to vertical and horizontal relationships. The latter ones concern networks and supply chains. The strategies of whole networks and of networks members are the strategies at the level of networks (strategies of network activities).

Unfortunately, the network level is still often disregarded in Poland in researches and publications in the field of the strategic management. The network strategies are discussed very rarely, as well as the network within other subdisciplines. It applies mainly the logistics. The words "network" and "strategy" are met quite rarely in the publications related to the logistics. Better situation is within the marketing, maybe because this subdiscipline covers the whole management in its researches, including the company's strategies. Obviously, both these words must be present firstly in international business relationships, but even in this area; Polish literature only now starts to connect the concepts and theories of networks with international strategies. The terminological mess and different places of the network in paradigms in above-mentioned subdisciplines can be regarded both as the reason and as the result of that disintegration, mentioned earlier.

CONCLUSIONS

The level of the integration between economic subdisciplines is low. It manifests in:

- significant differences among paradigms of various subdisciplines,
- the concept of network is treated in different way in different subdisciplines, and therefore, the concept of strategy is understood also differently. It is connected with the terminological mess.

It is easy to indicate the recommendations for the improvement. Firstly, the formation of interdisciplinary research teams should be intensified. Secondly, the methodological discussions on different levels (from the unification of concepts up to grouping and unification of paradigms) should be begun. It is important, that these discussions should be concluded by strict recommendations, accepted by the whole scientific community.

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ŁAŃCUCHY DOSTAW W KONTEKŚCIE WIEDZY O SIECIACH GOSPODARCZYCH

STRESZCZENIE. **Wstęp**: Łańcuchy dostaw są rodzajem sieci gospodarczych, aczkolwiek oba te pojęcia są ciągle różnie definiowane w Polsce. Wydaje się, że paradygmaty subdyscyplin ekonomicznych w różnych stopniu i w różny sposób zaabsorbowały wiedzę o sieciach gospodarczych. W Polsce w wielu obszarach nauk o zarządzaniu sieci są ciągle traktowane jako nowość.
Metody: Paradygmaty czterech subdyscyplin (logistyki, marketingu, zarządzania strategicznego i międzynarodowych stosunków gospodarczych) zostały poddane analizie i porównaniu.
Wyniki: Poziom integracji między subdyscyplinami nauk ekonomicznych jest niski. Występują znaczne różnice w paradygmatach subdyscyplin, pojęcie sieciowości, i co z tego wynika, pojęcie strategii, w poszczególnych dyscyplinach jest traktowane inaczej.
Wnioski: Należy zintensyfikować proces tworzenia interdyscyplinarnych zespołów badawczych jak również wywołać dyskusje metodologiczne na różnych poziomach (od ujednolicenia pojęć po zespolenie paradygmatów).

Słowa kluczowe: sieć, łańcuch dostaw, logistyka, paradygmat

LIEFERKETTEN IM KONTEXT DES WISSENS VON BUSINESS-NETZWERKEN

ZUSAMMENFASSUNG. Einleitung: Lieferketten sind eine Art von Business-Netzwerken. Die beiden Begriffe werden aber in Polen immer noch unterschiedlich definiert. Es scheint, dass die Paradigmen der wirtschaftlichen Teilgebieten das Wissen von Business-Netzwerken in verschiedenem Maß und auf verschieden Art und Weise absorbiert haben. In Polen werden Netzwerke in vielen Bereichen der Management-Wissenschaften immer noch als eine Neuigkeit betrachtet.
Methoden: Paradigmen von vier Teilgebieten (der Logistik, des Marketings, der Strategischen Verwaltung und der Internationalen Wirtschaftsbeziehungen) wurden analysiert und verglichen.

Ergebnisse: Das Niveau der Integration zwischen den Teilgebieten der Wirtschaftswissenschaften ist niedrig. Es sind bedeutende Unterschiede zwischen den Paradigmen der Teilgebieten zu verzeichnen. Der Begriff des Netzwerktums und was daraus folgt, der Begriff der Strategie werden in einzelnen Disziplinen anders betrachtet.
Fazit: Der Prozess der Bildung von interdisziplinären Teams soll intensiviert werden. Es sollen aber auch methodologische Diskussionen auf verschiedenen Niveau provoziert werden (von der Vereinheitlichung der Begriffe bis zur Vereinigung der Paradigmen).

Codewörter: das Netz, die Lieferkette, die Logistik, das Paradigma

Marek Ciesielski
Department of Logistics and Transport
Poznań University of Economics
Al.Niepodległości 10
61-875 Poznań
e-mail: marek.ciesielski@ue.poznan.pl

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RELIABILITY PROVISION FOR SUPPLIES PLAN IN LOGISTIC CHAINS

Vladimir Tkach

St. Petersburg State University of Economics and Finance, St. Petersburg, Russia

ABSTRACT. Background: The economics globalization leaded to the growth of the number of international and global supply chains, possessing potentially vulnerable places due to the reason of their high duration and existence of cultural and other barriers between the participants of supply chains. Intensification of international competition, in its turn, conditioned the increase of supply intensity, reduction of logistic chains links number and decrease in them of material reserves. Potential instability and unreliability of supply chains as well as their vulnerability also increased.
Methods: The basic aspects of supply reliability provision in logistic networks based on planning decisions were discussed.
Results and conclusions: There is grounded the necessity for accounting in supply plans of integral qualities of logistic systems, their functioning modes and life cycles of their elements relations. There is suggested the instrument for planning of maneuvers in supply networks in conditions of indeterminacy of future parameters of demand and resources deficit.

Key words: supplies reliability factor, logistic chains and networks, flexibility of logistic system, reliability of planning decisions, supply chains, supply plan.

World financial crisis, banns for flights due to Island volcano - all these events, that hourly destabilized the activity of many logistic chains. The row of such events only today marked the appearance of new priorities in supply chains management, such as safety and viability provision for supply chains, i.e. forming in them of quality for rapid recovery of normal activity after external and internal influences [Sheffi 2006]. Though the ground for recognition of these priorities was formed long ago before the coming of the above mentioned events. Namely, economics globalization leaded to the growth of the number of international and global supply chains, possessing potentially vulnerable places due to the reason of their high duration and existence of cultural and other barriers between the participants of supply chains [Kanchan 2011]. Intensification of international competition, in its turn, conditioned the increase of supply intensity, reduction of logistic chains links number and decrease in them of material reserves. Potential instability and unreliability of supply chains, and, correspondingly, their vulnerability in these conditions, also increased [Sakchutchawan et al. 2011].

The aim of this study was to discussed tthe basic aspects of supply reliability provision in logistcs networks and the infleunce of planning decisions on them.

Practical and scientific interest to the questions of safety and viability of supply chains shall be first of all estimated as a step to the fuller application of system approach to supply chains management. It is appropriate to remind, that in correspondence with the general theory of systems it is necessary to distinguish between integral qualities of systems, which determine its behavior: effectiveness, self-organization, security, stability, manageability, reliability, viability. We shall notice, that in theory of systems the concept of effectiveness differs from corresponding concept in economics. It is considered as a complex operational property ("quality") of the process of system functioning, which characterizes its fitness to operations aim achievement, i.e. to fulfillment of system task. Self-

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organization in systems theory is usually considered from position of availability of the following properties: ability for recognition of situations, adaptation, self-protection and others.

Account of integral properties of logistic systems shall be performed during planning of supplies in logistic chains (networks). The last notice, in our opinion, is the key notice, first of all from position of necessity for management with supply chains on the basis of normative models [Stock, Lambert 2005]. In the basis of these modules shall lay supply contracts, general totality of which provides coordinated actions of participants of logistic chains. Mission of logistic coordination in supply chains and, correspondingly, responsibility for supplies planning - is the prerogative of the focal company. Logistic "power" of focal company is predominantly determined by the fact, that it is the owner of goods movement channels in the sphere of finished product distribution. Such channels are the principal routes for transportation of products to consumer, and their personalization determines elementary content of supply chains. Exactly availability of rights for full control over products movement, though in some cases and limited (for example, in case of transfer by supplier of monopoly right for the selling of finished product to distributor in the certain territory), makes supply planning of focal company a prioritized type of logistic management.

Analysis of publications on logistics and management by supply chains allows to make at least one conclusion. Scientific discussion of question of supplies planning in logistic chains of-ten comes to the problem of material reserve management on the basis of economic order quantity (EOQ) and EPR-system modified model. Modification of EOQ model is performed by line of full record of all special supply cases for its general application as connecting agent, which means planning beginning also in supply chains [Roorda et. al 2010]. Such approach seems to be limited, at least due to three reasons. First of all, EOQ model a priory satisfies consumer's demands, i.e. does not consider possibilities and profit of supplier. This does not exclude exceed of minimal amount of goods shipment, calculated on the basis of EOQ model. Secondly, EOQ model correlates with condition of "perfect" order, which is often violated in practice. Parameters of such order are:

1. delivery in the day, specified by customer;
2. supply of everything that was ordered by the customer;
3. proper documentation for supply;
4. absence of damages in the process of transportation.

Thirdly, realization of EOQ model supposes allocation in planned order of corresponding cash assets, which is also not always possible. But the problem of this model usage as an approach for supplies planning is not in that. We share the opinion, that influence of reserves on reliability of supplies plan principally is possible only within certain limits [Inyutina 1983]. These limits are well seen in case of determinate demand. Absence of orientation for these limits or their ignorance leads to increase of reserve role in increase of supplies reliability level, and consequently, to formation of excess reserves. In relation to ERP-system we shall notice, that their application leads to growth of business-processes controllability. But they do not answer to supply chains management tasks. And they are not always effective by themselves.

The questions of supplies planning today are not passed over. For example, in [Wollas, Stal 2010] is supposed concept of volume planning of sales and operations. According to this concept is required periodical revision of sales plans (sales), manufacturing, forming of production and goods stocks of all supply chains participants. And it is necessary to refuse from excessive detalization of assortment politics. The main argument for benefit of such steps serves the following fact. Increase of „selling ability" of goods due to deep analysis of goods assortment and reflection of its results in procurement policy is not always possible. It is explained by the fact, that there exist special, time and other limitations of supply system reorganization. Also, unprepared changes in assortment policy often turn out to growth of goods reserve due to exit from circulation of part of finished product suggested for sale. Thus, the concept of volume planning foresees provision of balance between demand and supplies. Execution of this condition shall be performed by the way of regulation of sales speed, production rhythm, volumes of reserve and obligations by supplies [Schulz, Blecken 2001, Done 2011].

The concept of volume planning of sales and operations by itself is not new. And recommendations, given in [Wollas, Stal 2010] are quite general. But the work [Wollas, Stal 2010] is anyway very important, since it draws attention to the problem of logistic chains and networks management on the basis of sullies adaptive planning. We shall notice, that this problem is researched not for the first time. Namely, it was brought up in works [Inyutina 1983, Sokolov, Smirnov 1990 and others], in which was formulated the row of important statements, having direct attention to the theory of adaptive planning of supplies in logistic chains.

In work [Inyutina 1983] is proved, that exactly fluctuation of supply parameters determines the level of real, actual supply reliability. That's why during supplies planning it is necessary:

1. to consider confidence intervals for every plan condition of supply;
2. to foresee in supply contracts the system of indexes, allowing to consider both in detailed nomenclature and by types of material resources timeliness and degree of supplies plan fulfillment, i.e. supplies reliability;
3. to foresee in supply contracts possibility of making changes in supply plans.

In work [Kornai 1990] are comprehensively researched peculiarities of suppliers adaptation to deficit in economics, where predominate resource limitations. According to [Kornai 1990] there exist three types of such adaptation:

1. production volumes reduction (adaptation of production to "narrow places");
2. forced replacement of one material resources by others;
3. adaptation of manufactured production structure to the structure of available resources.

Demonstration of this regularity, as the world financial crisis showed, is possible even in the countries with developed market economics. In particular, deficit can appear also due to absence of production by the reason of incorrect or prepared late in time supply orders. That is why it shall be taken into consideration in the process of supplies planning. Apart from that in [Kornai 1990] draws attention statement, in which is grounded positive relation between intensity of production plan and frequency of resources limitations appearance. In other words, the higher is production plan intensity, the more possible, that shipment will be performed with deviations from planned supply conditions. It is necessary to notice, that in work [Inyutina 1983] analogous conclusion is made in relation to supply (procurement) plan.

One of significant statements of work, in our opinion, is grounding of reasonability of direct planning addition with reverse. Execution of this condition allows to move from planning of "logical" future to planning of desirable future. Application of such approach to adaptive supplies planning in logistic chains seems extremely necessary. This creates objective prerequisites for orientation of logistic chains on client, which means and for their successful functioning. Here it is appropriate to remind, that a start point in the question of supplies reliability provision is determination of logistic services norms, rendered by logistic chain to final consumers of material resources [Das, Sengupta 2010].

Practical and scientific interest for improvement of supplies planning in logistic chains presents work [Sokolov, Smirnov 1990], in which is considered a wide circle of questions, connected with plan decisions reliability. There is developed the idea, that reality of these decisions greatly depends on whether they possess manoeuvre properties or not. Applicably to supplies planning it can be interpreted in the following way. Maneuver properties of supplies plan reflect speed possibilities of reorganization (adaptation) of logistic chain (network) and its component objects. Evaluation of such properties shall be performed with consideration of at least two scenarios of disturbances development:

1. disturbances, inducted by suppliers (incomplete deliveries and other deviations of supply conditions from contract obligations);
2. "counter" disturbances, created by changes of supplies (sales) plans for final (end) participants of logistic chains.

Here it is appropriate to remember the effect of "stick", which appears during inappropriate interpretation by logistic chain participants of changes in supply orders for supply of material resources [Sheffi 2006]. It is obvious, that the basic reason of such effect appearance serves the absence of due supplies planning, not foreseeing coordinated actions of logistic chain participants during appearance in it of "counter" disturbances. It is logical to suppose, that prerequisites for "stick" effect appearance may be eliminated by the way of provision of information transparence of logistic chains. Logistic chains participants in this case should submit each other the following information:

1. forecast evaluations in relation to procurements, production and sales;
2. plans of procurements, production and sales;
3. actual data on supplies, shipments and stocks. Unfortunately practice shows, that many enterprises just are not ready for this step.

There are known attempts to establish information transparency in supply chains by means of state administration programs. For example, in its time in one of Russian state programs was foreseen elaboration and introduction of obligatory statistical report forms for observation under participants of trade markets through the whole chain of goods movement: "raw material producer → finish product manufacturer → trade organizations → consumers".

Supply chains information transparency has direct relation to provision of demand "transparency". In the basis of such a task decision lay certain points of demand "intrusion" up flow in logistic chain [Sheffi 2006]. This point is dislocated where actual demand corresponds to plan. Maximal movement of this point to the beginning of supplies chain is one of the actual and complicated problems of modern logistic management. One of the ways to achieve this goal is delay of order execution till revelation of actual demand. This variant shall be considered during supplies planning.

As the base for supplies plans elaboration in logistic chains serve results of design of such structures, steps of which are rather detailed described in [Bauercocks, Kloss 2001; Stock, Lambert 2005]. Anyway it is still seems necessary to draw attention to some economical peculiarities of their design. First of all, it is reasonable to foresee the appearance of double marginalization effect (mark-up). Such marup appears in case of consequence maximalization of profit by good manufacturer and its seller. And it conditions excess reduction of demand. Neutralization of this effect, as known, is possible with the help of vertical limitations:

1. establishment of non-linear price;
2. limitation of competition by means of establishment of exclusive territories for distributors.

Secondly, special attention during design of logistical chains shall be paid to transaction nature of adhesive powers in supply chains. Research object in this case shall be transaction expenses and specific investments of logistic chain participants.

Forecasting of transaction expenses allows more exactly establish interconnection between expenses in supply chains and effectiveness of their functioning. Apart from that it helps to objective establishment of term, required for elaboration of supply chains project. Receipt of such result is achieved due to understanding in particular of demand in conduct of negotiations with potential participants of supply chains and time expenses for these negotiations . Understanding of maximum transaction expenses allows to determine structural boundaries of logistic chains, in which is kept its controllability.

Specific investments are connected with forming of special types of assets, which include:

1. specificity of enterprise dislocation;
2. specificity of material assets;
3. specificity of human assets;
4. target assets, created on condition of availability of perspectives for their usage in the process of serving for certain consumer [Williamson 1996].

Capital, growth of which is increased by such investments, provides unstable position of enterprise in the market, since alternative usage of specific asset is accompanied by abrupt fall of its value. Specific investments may create significant growth of quasirent for that participant of supplies chain, that has less complication for the replacement of logistic partner. Such quasirent creates prerequisites for racket. Neutralization of such threat stimulates vertical integration in supply chains, i.e. amalgamation of business.

Conferring to supplies plans of maneuver qualities admits, that logistic chains participants content and relations between them may vary. That's way during grounding of these properties it is necessary to forecast depreciation of gains from maneuvering with supplies at the expense of inducted deformations of logistic chain of specific investments.

Economical basement of logistic chain project supposes evaluation of correlation between different levels of logistic service and corresponding expenses, which foresees the following stages:

1. determination of logistic chain configuration with the lowest general expenses;
2. evaluation of consumers service level and service possibilities of logistic chain, providing for minimal general expenses;
3. performance of sensitivity analysis to increase of service level and expenses, directly connected with creation of additional profit;
4. completion of logistic chain design. As indicators of logistic service level serve: accessibility (criteria: possibility of reserve lack; demand saturation norm, fullness of coverage with orders); functionality of logistic cycle (criteria: speed; regularity; flexibility; level of defects/elimination of deficiencies); reliability of supplies [Bauercocks, Kloss 2001].

Ways of supplies reliability provision may be classified in the following way:

1. forming of insurance reserve;
2. reserve (structural or with replacement);
3. usage of interchangeable material resources;
4. qualification control of supplier or logistic audit;
5. establishment with supplier of long-term economical relations or his enterprise acquisition.

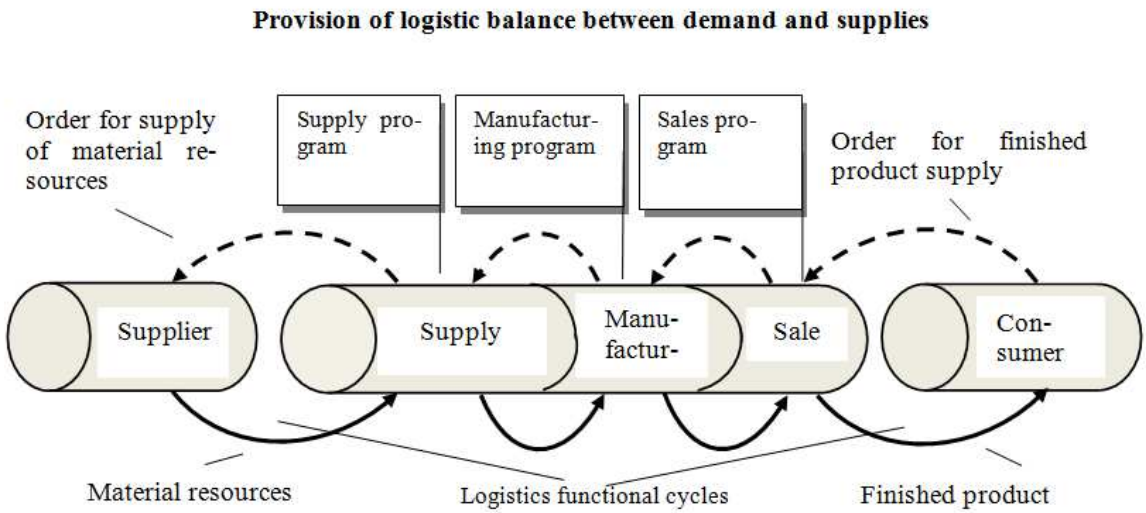

Fig. 1. Model of logistic chain as base for forming of integrated supplies plan
Rys. 1. Model łańcucha logistycznego jako podstawa do tworzenia zintegrowanego planu zaopatrzenia

Submission of logistic service at project (normative) level is a priority goal of logistic chain. And its fitness to achievement of such a goal characterizes effectiveness of such logistic system, which is

one of its integral properties. Important reserve for increase of this effectiveness is grounded choice of rational forms of supply and sales, and also development of progressive forms of logistic interactions in supply chains.

Results verification of logistic chain design shall be performed on the basis of integrated supplies plan reliability, considering local plans of supply, production and sales (figure 1). This plan shall provide logistic balance between demand and supplies, i.e. stability of supply chain under external and internal disturbances. And mission of such provision by its nature is greater than support of financial balance of enterprise [Shirenbek 2005].

Reliability of integrated supplies plan, as we have mentioned, depends on:

1. reliability of planning decisions for supplies realization;
2. availability at plan of maneuver qualities.

Fulfillment of the first condition supposes:

1. determination of possible deviations of design supply conditions from actual;
2. calculation of losses due to such deviations;
3. elaboration of suggestions on elimination of such deviations.

In other words, in this case is solved the question of increase of execution probability by suppliers of their contract obligations. Admittance of supply parameters deviations from contract conditions simplifies formalization of supplier reliability determination. It is appropriate to notice, that, for example, exact interval of supply for planned period is not always possible to determine. And instability of order execution time is frequent enough phenomenon [Stock, Lambert 2005].

Practical interest in this context is in the usage of integral reliability coefficient, which reflects supplies timeliness, parameters of repeated supply, fullness of volume, absence of assortment shifts in supplies structure (incompleteness) [Inyutina 1983]. Operational control of actual supply conditions deviations from contract in logistic chains creates possibility for rapid reaction for supply failures. Apart from that, it creates objective prerequisites for timely performance of logistic maneuvers in supply chains.

In order to give to supply plan maneuver qualities, first of all, it is necessary to present visually interactions in logistic chains. Matrix structure-flow model, present at figure 2 corresponds to this requirement [Tkacz 2010].

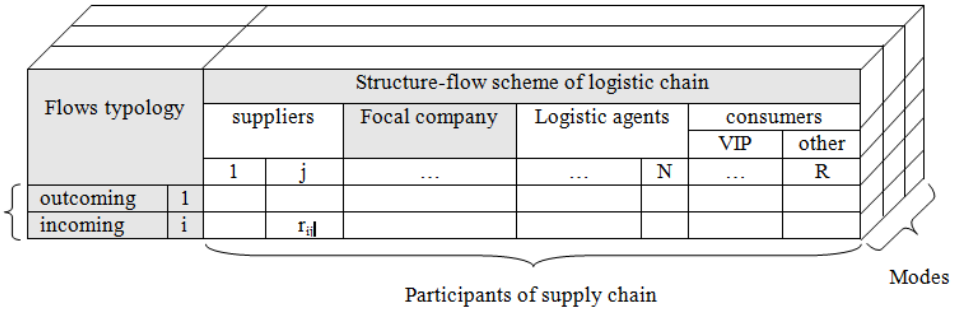

Fig. 2. Reflection of interconnections in logistic chain
Rys. 2. Model wzajemnych powiązań w obrębie łańcucha logistycznego

Structure-flow scheme of logistic chain foresees accounting of its functioning different modes, which form space for supplies maneuver (Fig. 2). Logistic chain configuration for different functioning modes may vary, since changing of requires to flows (supplies) often causes structural

reorganization. And multitude of such modes may lead to structural excessiveness of logistic chain, i.e. to structural reserves. These reserves are latent expenses, for example, during certain violations of supply plans. Optimization of structural reserves is related by us with consideration of "functional cut" principle, which consists in the following. In this scheme are included only that material formations and only in such relations, which have some significance in formation of considered effect [Kartashev 1995].

Assigning to supplies plan of maneuver properties makes necessary formalization:

1. of border conditions for transfer from one mode of logistic chain functioning to another (i.e. rules for achievement of new state of logistic chain or maneuver "corridor");
2. speed characteristics of such transfer [Sokolov, Smirnov 1990].

Problem of maneuver "corridors" establishment may be brought to establishment for every logistic chain participant of regulations for transfer to new supply plans. And such regulations may allow both full refuse from certain suppliers services (i.e. passive maneuver), and attraction of new logistic partners. Complexity of such regulations forming is conditioned by the number of factors, which include:

1. demand in standardization of limit deviations of supply plan from regular trajectory;
2. supplies nonstationarity in the period of transfer to the new mode of logistic chain functioning;
3. "irreversibility" of certain supplies during the transfers of such modes;
4. limitedness of allowable transfers to new functioning modes of logistic chains.

Design of supplies plan maneuver properties shall suppose provision of logistic chain security for all its functioning modes. Shall be distinguished two types of such security:

1. internal (ability of logistic chain to keep its normal functioning in conditions of external and internal influences);
2. external (ability of logistic chain to interact with the environment, preserving its integrity, i.e. excluding its "collapse") [Mogilevskiy 1999].

General task for security provision of logistic chain consists in exclusion of all its functioning modes, leading to collapse. One of the principles of its decision is consideration of consequential deterioration of logistic chain parameters, conditioned by its "ageing". To ageing are subject not only material resources. Flows, as structures also, which limit that, do not stay static in time, that is why logistic chains periodically need reorganization. Invariant principles of supply chains security provision are:

1. application of multi-level and balanced methods;
2. establishment of distinction between threatening situations and normal;
3. development of partnership and collaboration relationship;
4. forming of relation culture to security questions [Sheffi 2006].

Logistic chain security measure serves the guaranty of its stability. As opposed to classical balanced approach, the central element of modern economical views on considered problem is the concept of structural stability. Here the basic task is revelation of qualitative changes in logistic system behavior during its structure change. Also exists concept of related stability, in the basis of which lays supposition, that logistic relations are random variables, described by some known distribution functions [Casti 1982]. Evaluation of adhesive forces in logistic chain may be made on the basis of matrix, characterizing interrelations of this chain participants. Supplies chain shall be considered stable, if for all possible modes of its functioning is provided logistic balance (Fig .1). In Gyg [1981] the ability of system to stay in stability area is called system's "vitality". Close by interpretation to the term "vitality" is another term - "viability", i.e. ability for rapid recovery [Sheffi 2006]. For vitality analysis, in particular of technical systems, are used evaluations, which characterize the share or flow of functioning "refuses" with cascade development of initial disturbance. Close by nature to system stability quality are:

1. system ability for absorption of external disturbances without clearly expressed consequences for its behavior in established or transition conditions (adaptivity);
2. limit allowable ability of system for neutralization of disturbing influences without structural system changes (flexibility).

Flexibility of supplies integrated plans serves the main factor of logistic chains viability provision. Such flexibility is reached through:

1. interchangeability provision for material resources, logistic partners;
2. unification of account - contract units;
3. delays of supply order execution;
4. consideration of preliminary supply orders risk;
5. establishing contacts with consumers after failures in supplies of finished products;
6. elaboration of policy of selective logistic service for consumers;
7. usage of vulnerability maps for logistic chains [Sheffi 2006].

Independent direction for supplies plan reliability provision in logistic chains serves coordination of interaction in such structures. Such coordination strategy may be performed in different ways, which include:

1. interactions forecasting;
2. interactions evaluations;
3. "un-doing" of interactions, i.e. delegation of partial rights to chains participants for independent decision making;
4. vest responsibility to supply chains participants;
5. forming of coalitions in supply chains for simplifications of logistic decision taking.

SUMMARY

The necessity for accounting in supply plans of integral qualities of logistic systems, their functioning modes and life cycles of their elements relations were confirmed during the research. The instrument for planning of maneuvers in supply networks in conditions of indeterminacy of future parameters of demand and resources deficit were indicated. The identification of logistic systems integral properties creates objective prerequisites for assigning to integrated plan of maneuver qualities. Achievement of this goal, in its turn, provides reliability of such plan.

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ZAPEWNIENIE NIEZAWODNOŚCI PLANÓW ZAOPATRZENIA W OBRĘBIE ŁAŃCUCHÓW LOGISTYCZNYCH

STRESZCZENIE. **Wstęp**: W rezultacie postępującej globalizacji powstało wiele łańcuchów dostaw o zasięgu międzynarodowym i globalnym, charakteryzujące się wieloma wrażliwymi obszarami ze względu na istnienie różnych barier pomiędzy poszczególnymi uczestnikami łańcucha. Intensyfikacja konkurencji na skalę międzynarodową z kolei powoduje wzrost intensywności dostaw, redukcji ilości ogniw łańcucha oraz rezerw materiałowych. To z kolei zwiększa jeszcze niestabilność i wrażliwość łańcuchów dostaw.
Metody: Dyskusji poddano podstawowe aspekty zapewnienia zaopatrzenia w sieciach logistycznych w oparciu o decyzje planistyczne.
Wyniki i wnioski: W trakcie dyskusji zwrócono uwagę na konieczność uwzględniania w planach zaopatrzenia wartości całkowitych systemów logistycznych, ich funkcjonalnych części oraz cykli życiowych poszczególnych elementów. Zaproponowano narzędzie do planowania w obrębie sieci logistycznych w warunkach niepewności parametrów związanych z przyszłą podażą i popytem.

Słowa kluczowe: czynnik niezawodności zaopatrzenia, łańcuch i sieci logistyczne, elastyczność systemu logistycznego, niezawodność decyzji planistycznych, łańcuch dostaw, plan zaopatrzenia.

GEWÄHRLEISTUNG DER ZUVERLÄSSIGKEIT VON VERSORGUNGSPLÄNEN INNERHALB DER LOGISTIK-KETTEN

ZUSAMMENFASSUNG. Einleitung: Infolge der voranschreitenden Globalisierung sind viele Lieferketten von internationalem und globalem Charakter entstanden. Diese Lieferketten sind wegen des Vorhandenseins von unterschiedlichen Barrieren zwischen den einzelnen Teilnehmern einer Lieferkette durch empfindliche Zonen

gekennzeichnet. Die Zunahme des weltweiten Wettbewerbes hat ein ständiges Anwachsen der Intensität der Lieferungen und Reduktion der Anzahl von Kettengliedern und Materialvorräten zur Folge. Dies verursacht noch zusätzlich Unstabilität und Empfindlichkeit der einzelnen Lieferketten.
Methoden: Es wurden grundlegende Aspekte einer effektiven Gewährleistung der Versorgung innerhalb von Lieferketten wahrgenommen und mit Hilfe von planmäßigen Entscheidungen einer Diskussion unterzogen.
Ergebnisse und Fazit: In der Diskussion hat man bei Erstellung von Versorgungsplänen auf die Notwendigkeit einer Berücksichtigung des Gesamtwertes von Logistik-Systemen und deren Funktionsteilen, ferner der Berücksichtigung von Lebenszyklen der einzelnen Elemente hinzuweisen. Im Zusammenhang damit wurde ein Werkzeug für die Planung innerhalb der Logistik-Netzwerke für den Fall der Unsicherheit hinsichtlich der mit einem zukünftigem Angebot und zukünftiger Nachfrage verbundenen Parametern vorgeschlagen.

Codewörter: Parameter der Versorgungszuverlässigkeit, Logistik-Ketten und -netzwerke, Flexibilität des Logistik-Systems, Zuverlässigkeit von planmäßigen Entscheidungen, Lieferkette, Versorgungsplan.

Tkach Vladimir
St. Petersburg State University of Economics and Finance,
St. Petersburg, Russia
e-mail: vvt@finec.ru

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THE CONCEPT OF THE IMPLEMENTATION OF INVENTOMRY MANAGEMENT BY THE SUPPLIER WITH THE USE OF AGENT TECHNOLOGY

Waldemar Wieczerzycki, Piotr Januszewski

Poznan University of Economics, Poznan, Poland

ABSTRACT. Background: As it is well know, the implementation of instruments of logistics management is only possible with the use of the latest information technology. So-called agent technology is one of the most promising solutions in this area. Its essence consists in an entirely new way of software distribution on the computer network platform, in which computer exchange among themselves not only data, but also software modules, called just agents.
The first aim is to propose the alternative method of the implementation of the concept of the inventory management by the supplier with the use of intelligent software agents, which are able not only to transfer the information but also to make the autonomous decisions based on the privileges given to them. The second aim of this research was to propose a new model of a software agent, which will be both of a high mobility and a high intelligence.
Methods: After a brief discussion of the nature of agent technology, the most important benefits of using it to build platforms to support business are given. Then the original model of polymorphic software agent, called Multi-Dimensionally Versioned Software Agent (MDV) is presented, which is oriented on the specificity of IT applications in business. MDV agent is polymorphic, which allows the transmission through the network only the most relevant parts of its code, and only when necessary. Consequently, the network nodes exchange small amounts of software code, which ensures high mobility of software agents, and thus highly efficient operation of IT platforms built on the proposed model. Next, the adaptation of MDV software agents to implementation of well-known logistics management instrument - VMI (Vendor Managed Inventory) is illustrated.
Results: The key benefits of this approach are identified, among which one can distinguish: reduced costs, higher flexibility and efficiency, new functionality - especially addressed to business negotiation, full automation of work that in practice does not require the involvement of network users, the ability to use new communication channels, etc.
Conclusions: The proposed MDV model significantly enriched the advantages of software agents, which was then practically illustrated by the proposal of their use for the VMI implementation.

Key words: inventory management, VMI, software agents, MDV model.

INTRODUCTION

The Vendor Managed Inventory (VMI) is an instrument of the logistics management, where the responsibility of the management of clients' stock lies within supplier's competence [Manage..., Christopher 2005]. The scope of VMI covers all activities of monitoring and replenishment of client's stocks [Vendor..., Roussel 2005]. Traditionally, one of the following methods implements this process:

– "clean" VMI. The supplier generates orders based on information send by client mainly by EDI (Electronic Data Interchange) or Internet. The information is sent directly to the supplier's computer system, where they are processed and the relevant orders are created based on these data,

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- VMI based on merchandising activities. The sales representative visits regularly the points of sales of clients, controls the stocks levels and places orders on the previously agreed level,
- consignment stock VMI. The consignment stock is established based on the agreement between the supplier and the customer, i.e. the supplier is the owner of the goods, the recipient pays for them when they are taken for the production or sales purposes,
- designated representative of the supplier monitors the stocks levels at the recipient's warehouse and places orders in agreed lead-times.

The implementation of the new information technology, so called agent technology, is undoubtly a challenge for modern business with regard to the implementation of modern instruments of logistics management, especially in the area of the inventory management by the supplier.

In colloquial meaning, the word "agent" means somebody delegated to work in a certain place and there performing a specific task according to previously set agreements. In the information sense, the expression "software agent" is used. It is a computer program, working remotely or locally. It operates according to wishes of the user or other agent, which is able to start it. The software agent has some features, by which it can be distinguished from other traditional programs. They are [Rykowski 2008]:

- Environment – the agent works in a specific environment, which can be an operation system or an application dedicated specially for it,
- Target – the agent tries to achieve it in its activities. Its work is characterized by the high independence, and even isolation,
- Autonomy – the agent requires a certain operation time. It should work effectively and as long as it is needed, aiming to achieve the target set to it, even if the user (who delegates it) disconnects it from the system (which seems to be its biggest advantage),
- Adaptation – the agent has the ability to adjust itself to changes in its environment. Therefore, it manifests some features of the intelligence. It has an ability to learn and to make conclusions,
- Mobility – the agent can move within the environment and (what seems to be even more important) – between various areas, installed on various computers without changing the mission and the operation method.

There are two classes of agents: mobile and intelligent ones, the grouping made on the basis of the last from above-mentioned features of agents, which can occur even in very large disproportion to each other. In the context of the technology, the mobile agents are most often not intelligent and vice verse. It means that in practice, these features are usually in the opposition to each other. The reasons for such situation are that, the huge intelligence requires a big sophisticate computer code, which is not convenient to be sent in other locations within the network.

The following advantages of software agents for the implementation of instruments of the logistics management can be distinguished:

- Automation – the autonomous agent can find by himself the information it needs on the appropriate server. It communicates with the user after reaching the aim. It is able also to undertake the further steps, e.g. the negotiation of the cooperation conditions.
- Efficiency – the agent monitors new information 24 hours a day (if the server environment allows it).
- Communication – it is able to use mobile devices (mobile phones, palmtop, on-board computer) for the communication with the user. The communication e.g. in the form of SMS is possible.
- Negotiations. The agent is able to negotiate the conditions with the agent of the service provider. It is able to make the preliminary evaluation of the reliability of the customer as well as to finalize the agreement.

- Reduction of costs. The agent performs the task after sending it to the server and finishing the communication (modem connection). The results of the agent's search are collected in the next session.
- Versatility. The agent can move among various servers. While migrating to the new localisation, it moves together with information already acquired. It is able to compare a few different cooperation offers from different sources.

There are two aims of this study. The first one is to propose the alternative method of the implementation of the concept of the inventory management by the supplier with the use of intelligent software agents, which are able not only to transfer the information but also to make the autonomous decisions based on the privileges given to them. The second aim of this research was to propose a new model of a software agent, which will be both of a high mobility and a high intelligence. The proposed agent is an essential element, which constitutes the success of the implementation of VMI concept using the agent technology.

THE MODEL OF MDV AGENT

The software agent of MDV model consists of two largely autonomous parts. The first one is a kind of agent's head, so called bootstrap agent. It is relatively small and therefore has a high mobility. The main task of this bootstrap agent is to move within the networks and decide whether a newly visited environment is potentially interesting from the standpoint of the agent's mission, defined by the user, who delegated it. In case the environment is interesting, the bootstrap agent communicates with so called proxy agent, located on the parent computer (the computer, where the agent was created by the user) and demands the transfer of appropriate and necessary fragments of the code. These fragments are the additional modules, forming so called agent body [Wieczerzycki 2005]. The bootstrap agent communicates with the proxy agent via messages made in the agent-communication-language (ACL) [FIPA...].

In the situation when the agent's actions bring the assumed effect, the bootstrap agent re-establishes the communication with the proxy agent, demanding next fragments of the code, responsible for its further work. This situation will be described in details shortly.

When the agent's mission is ended in the visited environment (the goals are achieved or not), the agent's body is removed and the bootstrap migrates to another environment or returns to parent computer, where it is merged with the proxy agent.

Due to the versality of the proposed approach, it is assumed that the bootstrap agent is interpreted by the environment into which it goes and therefore it is able to visit any computer. It means, the agent is the source code and not a binary one.

There are four basic functions of the proxy agent:

- it serves as a communication medium between the user and the bootstrap agent. It has information about the current localisation of the bootstrap agent and is able to change both the directions of the agent's migration and the actions undertaken by it.
- it includes all variants of code, which forms the body of the agent and therefore provides the flexibility of its behaviour. Depending on the requests sent by the bootstrap agent, the proxy agent is able to send it the appropriate fragment of the code and therefore to increase its functionality and to enable the fulfilment of the mission given to it by the user.
- it collects and aggregates all data sent it directly by the bootstrap agent. It is very important feature, due to the fact, that redundant data reduce the mobility of the bootstrap agent and are not always useful for the completion of the agent's mission but they can be later useful for the user. The information is collected in so-called knowledge repository.

– it enables the user to monitor the progress of the agent's work. In case it decides that the information collected by the agent is sufficient, the proxy agent is able to finish its operation (together with dynamically broaden agent) and present the results to the user.

Summarizing the above considerations, the behaviour of the mobile component (code) can be described as follows. Only the bootstrap agent is sent during the migration to the following node of the network. All variants and additional modules, which constitute the agent, are removed from the preceding node. There is no need to send the whole code together with the agent, because the following environment, where the agent will be, will probably require a completely different code's variants. After finishing the migration, the agent checks the specific character of the new localisation and sends a request of the transfer of the most relevant fragments of the code to the proxy agent and then it continues its run.

During the analysis of individual network nodes, only information, which enriches the intelligence of a mobile agent, is integrated with the bootstrap agent (therefore the agent becomes slightly bigger over time). The information, which does not affect the agent's intelligence, is sent directly to its stationary part, where is stored in the knowledge repository. This property of rejecting the unnecessary data is called agent self-slimming.

The variability of an agent in the MDV model has two dimensions – horizontal and vertical one:

– agent segmentation,

– platform versioning.

Agent segmentation. The agent's mission can be usually achieved by performing a sequence of relatively autonomous activities (action steps). In order to increase the efficiency of the agent's activities, the whole its code is divided into so-called segments, each of them is responsible for a specific task. When the specific task is finished, the following segment of MDV agent's code is taken from the proxy agent and then it is of course executed. Depending on whether the agent's behaviour is of sequential or interactive nature, the previous code fragment is deleted (in first case) or kept during the following task (the second case).

For example, the first agent's segment can be responsible for checking offers on e-markets (e-marketplaces). If there is a potentially interesting offer for a client, the second segment (responsible for negotiations of cooperation conditions) is sent on the request of the bootstrap agent. If the negotiations are completed and the agreement is achieved, then the third segment is sent, which is responsible for signing the agreement, etc. In case one of steps of the procedure fails, there is no need to send the following segment of the code.

In this example, the recommended form of the agent's behaviour would be its sequentiality, which is able to reduce the number of transmitted segments of the code. It means, the first segment should analyze all available offers on e-market, flag the potentially interesting ones (worth to be negotiated) and then switch to the second segment. Similarly, negotiations should be conducted with all agents representing the flagged offers. If they are successfully finished, MDV agent should flag all these agents, to which the procedure of the third segment should be applied.

In the summary, the above-described dimension of variability of MDV agent (i.e. segmentation) is an attempt of modelling of multi-stage of the nature of software agents.

Platform versioning. Each segment of an agent is available in many variants, each responsible for specific configuration of any remote platform, where the agent will work (i.e. hardware configuration, operative system configuration, network communication protocols). Additionally, there is one special variant of each segment, stored in the form of a source code (and therefore platform-independed). It is sent to computers, which do not accept the binary code due to security reasons. It means, the agent can be interpreted by the environment instead of executing the fixed compiled code. Except this one particular variant, the proxy agent is able to store potentially unlimited number of binary variants.

If the target environment accepts the executable code, the proxy agent sents a variant of desired segment, corresponding to specific hardware requirements of the environment.

It is clear, that the executable (binary) variants of agent segments increase its productivity, while the stored source variant guarantees the fulfilment of all restrictive security requirements.

In summary, the above-described dimension of variability of MDV agent (i.e. platform versioning) is an attempt of modelling of platform independence of software agents, while maintaining their high efficiency of the work.

THE USE OF MDV AGENTS FOR VMI IMPLEMENTATION

The alternative method of the implementation of VMI concept (in relation to those presented in the first chapter) is the use of intelligent software agents as managers of stocks levels of customers. Due to the complexity of operations performed and the responsibility, the agents must have a high intelligence, which automatically reduces their mobility. Therefore, the ideal model of the software agent suitable for the implementation of VMI concept seems to be the MDV agent, described in the previous chapter.

The necessary condition, which has to be fulfilled for the proper work of the solution, is the preparation of reports by the customer. These reports include stocks levels, moves, forecasts and must be in the electronic form as a file or complex databases. The recipient must also provide the access to information to the supplier's agents. Based on this information, they are able to make right decisions on orders of goods and materials. The process of the implementation and the work of VMI concept by the use of MDV software agents is presented below.

The first step to begin the cooperation on VMI principles with use of agents must be the traditional negotiations between the supplier and recipient, during which the agreement on the admission of supplier's agents to data located on recipient's servers (especially in compiled binary form) is finalized. These arrangements are necessary from the security point of view, while the agent technologies have some potential risks (the access to business data by stranger agents can lead to data loss, leakage or modification, which in turn can threaten the future business activities, e.g. inaccurate forecasts due to the distortion of data). When the initial negotiations end in mutual agreement to use the agent technology, it is possible to start the procedure of monitoring of stocks and placing orders by software agents according to VMI rules.

The proper process of monitoring and replenishment of stocks is as follows. At the beginning the supplier sends its representative – an automatic bootstrap agent to each of his recipients (working on VMI principles) in order to obtain information on individual stocks levels. After reaching the contractor's server, the agent starts to look for the client's representative (also a software agent), with which it will be able to make electronic negotiations. This operation can be finished in two ways: the digital representative of the client is found or the client has no representative, which prevents the initiation of negotiations by the supplier's agent.

In the first case, the negotiations can be started. The bootstrap agent sends to the server, where its modules are stored (i.e. proxy agent) the request to send the fragment of the code, responsible for the negotiations. After joining this communication module, the agent is able to start the communication with the client's agent and receive information on actual stocks levels, current consumption and forecasts. The obtained information is compared to the client's data (required stocks levels, etc.), which are received in the form of the separate module downloaded from its server. If the stocks level is optimal, the agent finishes the procedure, removes downloaded modules and migrates to the computer of the next client. In other case, the agent sends next request for an additional module (exactly – the appropriate variant of the next segment), responsible for the analysis of the external factors (a module enables e.g. to get the information on the weather and after the analysis, it calculates its potential impact on the punctuality of deliveries). Knowing the impact of external factors on the complementary process, the agent is ready to start the proper negotiations with the representative of the recipient. The agent generates the proposal of the order, based on initial agreements with a client concerning the size and the punctuality of deliveries and taking into account the influence of the

external factors. If the client's representative accepts the proposal, the supplier's agent sends a ready order to the information system of the supplier. In other case, the negotiations continue until both sides reach an agreement. If the conditions imposed by agents are so divergent, that there is no possibility for an agreement, the negotiations end in failure and both the supplier and the recipient will be informed of the failure of negotiations and the need to solve the problem.

In the second analyzed cases, the agent does not find any client's agent and therefore there is no possibility of above described negotiations. It looks data on the client's server, to which it has an access. The data can occur in any digit format, e.g. XML files or entries in the database, to which the agent has an access by using the appropriate API (Application Programming Interface – the method of communication between the application and other programs, in this case it concerns the possibilities of the communication between the agent and ERP application of a client, which in turn has an access to databases. Due to security reasons, the agent has never an access directly to client's database). If the agent does not find any data, which could be analyzed, it sends a notification of a failed operation to both business partners and starts the migration procedure. If it can find data and is able to interpret them, it sends a request (to the proxy agent) to send it the appropriate module, which enables the interpretation of data. This module may allow to use interfaces, defined by a client or to facilitate the analysis of a file of a predefined structure. After downloading the desired fragment of a code, the found data are analyzed and the obtained results (present stocks levels) are compared to predefined norms. If the agent identifies the need of additional order of goods as a result of this analysis, it checks whether it has enough authorization to make a decision. If the agent's authorization is sufficient, it generates an order and sends it to information system of a supplier. In other case, it sends a requirement for the confirmation of the decision to the party, which is authorized to do it (supplier or recipient) and waits for a response. If it does not receive it in the specific time, it interrupts the procedure, removes redundant modules, sends a notification about the status of the operation to both business partners and migrates to the nest recipient.

When the order is generated or there is a failure of the operation, the agent always starts "self-slimming" (consisting in removing all additionally downloaded software modules and already redundant information) in order to return to the original level of the mobility. After removing all redundant components, the agent migrates to the next client, where the whole procedure is repeated.

SUMMARY

The aims assumed at the beginning of this work were achieved by the consistent presentation of proposed alternative implementation of stocks management by the supplier. The advantages of software agents, presented in the first chapter, are significantly enriched in case of the proposed MDV model, which was then practically illustrated by the proposal of their use for the VMI implementation.

Firstly, the MDV agent carries in the network not only necessary fragments of the code but simultaneously it conducts "self-slimming", sending back the already unnecessary parts of the code to the proxy agent. Therefore, it cancels the restriction, mentioned in first chapter, that a mobile agent is not mobile in practice. It can move effectively among the servers of the supplier's clients.

Secondly, the MDV agent is polymorphic – depending on the peculiarity of visited clients, the information platform used by them (type of ERP or WMS system), preferred scenarios of the cooperation, it requests from the proxy agent the necessary software modules, which fully respond to client's requirements.

Thirdly, in most of the case the MDV agent has a compiled form, matched to the information platform of a client, which efficiently increases the speed of its actions. The authors believe, it does not decrease the safety of the proposed approach, because the VMI implementation has to rely on mutual confidence of the supplier and clients, and thereby it should exclude the suspicion of the possibility of the transfer of a destructive code, in particular computer viruses.

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KONCEPCJA IMPLEMENTACJI ZARZĄDZANIA ZAPASAMI PRZEZ DOSTAWCĘ Z ZASTOSOWANIEM TECHNOLOGII AGENTOWEJ

STRESZCZENIE. **Wstęp**: Jak powszechnie wiadomo, wdrożenie instrumentów zarządzania logistycznego jest możliwe jedynie dzięki zastosowaniu najnowszych technologii informacyjnych. Jednym z najbardziej obiecujących rozwiązań w tym zakresie jest tzw. technologia agentowa. Jej istota polega na zupełnie nowym sposobie rozpraszania oprogramowania na platformie sieci komputerowej, w której komputery wymieniają między sobą nie tylko dane, ale również moduły programowe, zwane właśnie agentami.
Pierwszym celem pracy było zaproponowanie alternatywnej metody implementacji koncepcji zarządzania zapasami przez dostawcę, przez wykorzystanie inteligentnych agentów programowych spełniających rolę nie tylko medium przenoszenia informacji, ale także podejmujących autonomiczne decyzje w oparciu o nadane im przywileje. Drugim celem było zaproponowanie nowego modelu agenta programowego, który charakteryzowałby się zarówno mobilnością jak i wysoką inteligencją.
Metody: Po krótkim przybliżeniu istoty technologii agentowej przedstawiono najważniejsze korzyści wynikające z jej wykorzystania do budowy platform informatycznych do wspomagania biznesu. Następnie zaproponowano oryginalny model polimorficznego agenta programowego o nazwie MDV (ang. Multi-Dimensionally Versioned software agent), zorientowanego na specyfikę zastosowań IT w biznesie. Agent MDV jest wielopłaszczyznowo wersjonowany, co umożliwia przekazywanie przez sieć komputerową jedynie najbardziej odpowiednich fragmentów jego kodu i tylko wtedy, gdy jest to niezbędne. W konsekwencji, między komputerami transmitowane są niewielkie ilości kodu programowego, co gwarantuje dużą mobilność agentów, a tym samym wysoką efektywność funkcjonowania platform informatycznych zbudowanych w oparciu o proponowany model. Dalej przedstawiono propozycję adaptacji agentów programowych, funkcjonujących zgodnie za modelem MDV, do implementacji znanego instrumentu zarządzania logistycznego - VMI (zarządzanie zapasami przez dostawcę, ang. Vendor Managed Inventory).
Wyniki: Najważniejsze korzyści takiego podejścia to: obniżone koszty, większa uniwersalność i efektywność działania, nowe możliwości funkcjonalne, zwłaszcza w odniesieniu do prowadzenia negocjacji biznesowych, pełna automatyzacja pracy, niewymagająca w praktyce zaangażowania użytkowników sieci, możliwość wykorzystania nowych kanałów komunikacyjnych.
Wnioski: Zaproponowano alternatywną implementację zarządzania zapasami przez dostawcę. Przedstawione zalety zastosowania agentów programowych są istotnie wzbogacone w przypadku proponowanego modelu MDV, co zilustrowano praktycznie proponując zastosowanie takich agentów do wdrożenia instrumentu VMI.

Słowa kluczowe: zarządzanie zapasami, VMI, agenty programowe, model MDV.

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EIN KONZEPT FÜR DIE IMPLEMENTIERUNG DES BESTANDSMANAGEMENTS VON LIEFERANTEN UNTER NUTZUNG EINES AGENTEN-VERFAHRENS

ZUSAMMENFASSUNG. Einleitung: Die Nutzung der Instrumente für das Logistik-Management ist heutzutage nur mit Anwendung der modernsten Informationstechnologien möglich. Eine der erfolgversprechenden Lösungen in diesem Bereich stellt ein sog. Agenten-Verfahren dar. Das Wesen der Lösung beruht auf einer ganz neuen Methode mittels Streuung von Software auf der Plattform des Werknetzes, auf welcher die einzelnen Rechner nicht nur gegenseitig Daten austauschen, sondern auch Programm-Module, die eben als Agenten bezeichnet werden.
Das vorrangige Ziel der Arbeit war es, eine alternative Methode für die Implementierung des durch den Lieferanten betätigten Bestandsmanagements-Konzeptes unter Anwendung intelligenter Programm-Agenten vorzuschlagen, welche nicht nur als Medium für den Datentransfer ihre Funktion ausüben, sondern auch anhand der ihnen eingeräumten Privilegien autonomische Entscheidungen treffen können. Die andere Zielsetzung stellte die Ausarbeitung eines neuen Modells für den Programm-Agenten, welcher sich sowohl durch große Mobilität, als auch durch hohe Intelligenz auszeichnen würde, dar.
Methoden: Nach einer einleitenden Projizierung des Agenten-Verfahrens wurden die wichtigsten Vorteile für den Aufbau von informationstechnischen, Business unterstützenden Plattformen vorgestellt. Des weiteren wurde das originelle Modell eines polymorphischen, auf die Eigenart der IT-Anwendung im Businness orientierten Software-Agenten namens MDV (eng. Multi-Dimensionally Versioned software agent) vorgeschlagen. Der MDV-Agent ist in Mehrflächen-Versionen konfiguriert, was ihn für die Übertragung innerhalb des Werknetzes nur der am meisten brauchbaren Fragmente seines Codes und dies nur dann, wenn das unentbehrlich ist, prädestiniert. Im Endeffekt werden zwischen den einzelnen Rechnern fragmentarische Teile des Programm-Codes transferiert, was eine große Mobilität der Agenten und dadurch eine hohe Effektivität der Funktionstüchtigkeit des vorgeschlagenen Modells gewährleistet. Ferner wurde ein Vorschlag für die Anpassung der gemäß dem MDV-Modells funktionierenden Programm-Agenten an die Implementierung des VMI-Modells (eng. Vendor Managed Inventory - Bestandsmanagement durch den Lieferanten) als bekanntes Instrument für das Logistik-Management dargestellt.
Ergebnisse: Die wichtigsten Vorteile eines solchen Herangehens sind wie folgt: gesenkte Kosten, größere Universalität und Effektivität des Handelns, neue funktionale Möglichkeiten, insbesondere in Hinsicht auf die Durchführung von Handelsnegotiationen, volle Automatisierung der Arbeit, die in der Praxis gegebenenfalls kaum Engagement seitens der Netzwerk-Nutzer mehr bedarf, sowie die Möglichkeit einer Inanspruchnahme von neuen Kommunikationskanälen.
Fazit: Es wurde eine alternative Implementierung des durch den Lieferanten betätigten Bestandsmanagements vorgeschlagen. Die aufgezeigten Vorteile der Anwendung von Programm-Agenten beim vorgeschlagenen MDV-Modell sind ausschlaggebend, was mit dem Vorschlag zur Anwendung solcher Agenten für die Einführung des VMI-Instruments praktisch projiziert wurde.

Codewörter: Bestandsmanagement, VMI-Modell, Programm-Agenten, MDV-Modell.

Waldemar Wieczerzycki
Poznan University of Economics, Poznan, Poland
Poznan School of Logistics, Poznan, Poland
e-mail: w.wieczerzycki@ue.poznan.pl
Piotr Januszewski
Poznan University of Economics, Poznan, Poland

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CRITICAL CHAIN PROJECT MANAGEMENT AND DRUM-BUFFER-ROPE TOOLS INTEGRATION IN CONSTRUCTION INDUSTRY - CASE STUDY

Piotr Cyplik, Michał Adamczak, Łukasz Hadas

Poznan School of Logistics, Poznań, Poland

ABSTRACT. Background: The concept of integrating the theory of constraints tools in reorganizing management system in a mechanical engineering company was presented in this article.
The main aim of the concept is to enable the enterprise to satisfy the customers' expectations at reasonable costs, which allows for making a profit and creating an agile enterprise in the long run.
Methods: Due to the individual character of the production process and service process in analyzed company, the described concept using theory of constraints project management (CCPM) and manufacturing (DBR) tools. The authors use performance levels conception to build an integration tool focused on the interaction and collaboration between different departments. The integration tool has been developed and verified in Polish manufacturing company.
Results: In described model a tool compatible with CCPM operates on the level of the customer service process. Shop floor is controlled based on the DBR method. The authors hold that the integration of between TOC tools is of key importance. The integration of TOC tools dedicated to managing customer service and shop floor scheduling and controlling requires developing a mechanism for repeated transmitting the information between them. This mechanism has been developed.
Conclusions: The conducted research showed that the developed tool integrating CCPM and DBR had a positive impact on the enterprise performance. It enables improving the company performance in meeting target group requirements by focusing on enhancing the efficiency of processes running in the company and tasks processed at particular work stations. The described model has been successfully implemented in one of the Polish mechanical engineering companies.

Key words: Critical Chain Project Management, Drum-Buffer-Rope, process integration, company effectiveness.

INTRODUCTION

Globalization processes and increased market competition force organizations to reorganize production processes to reduce lead time and manufacturing costs. These objectives are in logical conflict. How to conduct manufacturing operations oriented on unit orders and remain competitive with standard solutions produced with the application of the scale effect?

The authors of this paper conducted research and development works at a mechanical engineering enterprise, which used the theory of constraints tools to streamline the current management of basic operations (customer service and manufacturing processes). It was observed that deployment of the Critical Chain Project Management and Drum-Buffer-Rope did not yield the expected results. The problems encountered prior to the implementation were only partly solved. The authors hold that it was because the tools had a local impact. The flow of information between them was inadequate, which obliterated any positive effect in the entire company. The aim of this paper is to present the tool designed by the authors for the purpose of integrating the theory of constraints tools.

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THEORETICAL BACKGROUND

Theory of Constraints tools

Theory of Constraints (TOC) has been proposed by Eliyahu Goldratt. TOC has been developed as a theory of continuous improvement of the enterprise business operations. Five steps for enhancing an organization performance, developed by the author of the theory [Goldratt 2004]:

1. Identify the constraint.
2. Decide how to exploit the constraint.
3. Subordinate and synchronize everything else to the above decisions.
4. Elevate the performance of the constraint.
5. If, in any of the above steps the constraint has shifted, go back to Step 1.

To proceed with the subject, continuous improvement consistent with TOC may occur on three planes. The highest level involves processes taking place across the entire organization and the interrelations between them [Gupta, Boyd 2008]. Streamlining the system at the highest level is possible thanks to continuous improvement described in 5 steps. At the operational (2nd level), TOC suggests applying the Logical Product Structure (LPS) method and V-A-T analysis. LPS method results in the information on the flow of materials and components of the product analysed by the enterprise, including all the operations, starting from raw materials up to a finished product [Gupta, Boyd 2008]. V-A-T analysis allows for determining the location of buffers in a manufacturing system [Hadas, Cyplik, Fertsch 2009]. At the detail-oriented (3rd level), TOC proposes applying the concept of Drum - Buffer - Rope (DBR) manufacturing system management. Streamlining the production system according to TOC is connected with [Wu, Yeh 2006]:

1. increasing the system throughput (amount or value of products per time unit);
2. reducing work in process;
3. shortening production cycles and improving on-time order delivery.

All the advantages listed above are geared towards greater customer satisfaction and lower operational costs.

There are 3 components in the DBR concept, which allow for increasing a manufacturing system throughput. The first component is Drum - the system constraint that sets the production pace. An overriding importance of the constraint follows from TOC assumptions, in particular from the 2nd step in the system improving - 'exploiting' the bottleneck. Buffer - a kind of protection (time or materials) from disruptions occurring at the preceding processing step. Rope - a mechanism ensuring that all the system components work at a pace set by the bottleneck, which will reduce work in progress level [Koh, Bulfin 2004].

An ever-growing importance of projects in the company management has been noticed by the authors writing on TOC. It gave rise to a new method of project management evolved, based on the so called Critical Chain - Critical Chain Project Management (CCPM). Critical Chain is a set of interrelated tasks with the longest completion time, taking into account the system resource constraints. The constraints are, among others: the availability of funds, time, multitasking etc. In scheduling the use of resources, individual tasks in the critical chain have no time buffers and are scheduled backward (postponing until the last moment) [Robinson, Richards, 2009]. Introducing the latest start times possible and shortening their duration by removing time reserve requires estimating and scheduling measures compensating for any natural deviations and the events of multitasking [Rahman, 2004]. There are two basic time buffers:

1. Project buffer - inserted at the end of the project, ensures its timely completion. Buffer size is often described as half the size of the critical chain [Stratton, Knight 2010].
2. Feeding buffer - inserted at the end of tasks not included in the critical chain, protecting the critical chain [Herroele, Leus, Demeulemeester 2002].

Improving performance

Gaining competitive advantage can be gained in the conditions described in the introduction can take place through continuous performance improvement. Performance is defined as: 'the degree to which an employee or a group applies skill and effort to an operation or task as measured against an established standard' [Blackstone, Jonah]. Improving performance ought to take place at three levels: organization, process and work stations. Managers willing to improve performance at the organization level should focus on setting goals that reflect the organization's values and the customers' requirements. At the next level the key are efficient basic processes in business operations. It combines the last two levels, thus opening up greater performance improvement opportunities. The last but not least level of enterprise performance is the performer level, referred to every single work station. Performance management at the lowest level may only produce a result that is marginal in terms of what could be achieved [Rummler, Brache 1990].

TOC highlights the need for surrendering local optimums in favour of global optimums. Decisions made based on local performance measures could adversely affect the entire system [Mabin 2003]. Benefits from seeking global optimums can be enjoyed thanks to an internal integration defined as "the quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment' [Lawrence, Lorsch 1967]. Nowadays, in the era of SCM, internal inter-functional integration is focused on the interaction and collaboration between different departments [Ellinger, Daugherty Keller 2000] and it will be understood as such in the course of this paper.

CURRENT STATE ANALYSIS

The enterprise described in this paper specializes in manufacture of equipment for pumping water and wastewater. The nature of customer needs and requirements calls for providing highly customized solutions. In the enterprise under analysis customer service is unit in nature, which makes the process akin to project implementation.

The Production System Virus Analysis (PSVA) [Cyplik, Hadas 2011] was applied to identify the problems responsible for the company's failure to complete unit orders at an acceptable cost.

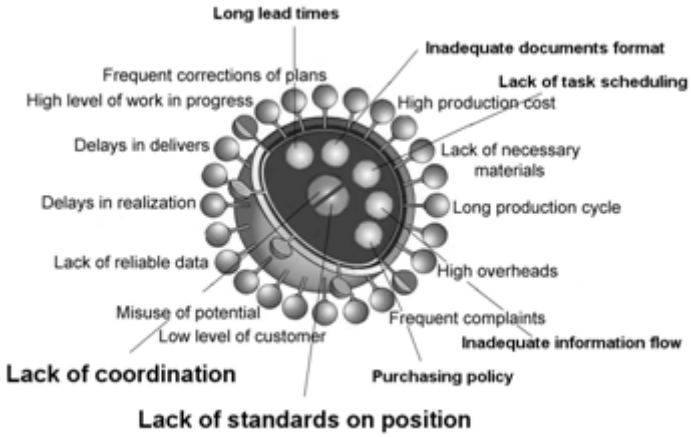

Fig. 1. Production System Virus in analyzed company
Rys. 1. Wirus systemu produkcyjnego analizowanego przedsiębiorstwa

Fig. 1 presents root problem occurring in the company. TOC tools have been deployed to solve them. The CCPM tool was selected to streamline customer service management. By implementing the methodology and support IT tools the managers obtained the information on the progress of each project and the level of time buffer exploitation. The DBR tool was applied to improve the shop floor operations. It was supposed to reduce work in process inventories and the manufacturing process time.

THE INTEGRATION OF TOC TOOLS

The implementation of TOC tools in the analysed company resulted in sorting out the activities performed as part of customer services. The measures illustrating individual processes showed improvement, yet the overall effectiveness across the company failed to achieve the assumed level. In reference to the diagnosed problem, the authors emphasized the need for perceiving the company as a total of work stations and processes performed there. While striving to improve the performance of conducted business it is necessary to seek potential reserves at each work station. An enhancement of the effectiveness of operations at work stations is followed by an improvement in the processes. In line with the process approach, an organization consists of the processes it performs. Hence a simple conclusion that if process efficiency is improved, the entire enterprise benefits.

Assuming the above, the authors attempted to systematize the levels of efficiency in the analyzed company. From the organization point of view, customer service is of prime importance. It is directly related to new order winning, their completion and timely delivery of products to the customer. From the customer service point of view it is manufacturing that is crucial. This is due to not only to the processing of raw materials, materials and components into the finished product, but also owing to high cost-consumption and numerous difficulties leading to late deliveries to customers.

The decision to implement the project management tool was inspired by the nature of customer service processes, making it akin to project implementation, the possibility to implement the tool in the existing ERP system and the benefits in the form of enhanced process efficiency and reduced completion time. It had been assumed that this tool will enable the improvement of performance at the process level.

At the level of work stations it was decided to implement the DBR tool, because it allowed for easy shop floor control. Shortening production cycles and reducing work in process inventories was supposed to enhance shop floor performance.

Research conducted following the implementation of the solutions suggested by TOC did not support the assumptions. According to the authors, the reason behind it was a lack of coordination between individual components of the customer service process, with considerable emphasis on the production process. Streamlining activities were local in nature and their impact on the entire organization was negligible. Based on these observations the authors observed the need for integrating the existing TOC tools. The integration scheme is presented in Fig. 2.

Fig. 2 illustrates the application of TOC tools in the context of building up the organization efficiency. A tool compatible with CCPM operates on the level of the customer service process. Shop floor is controlled based on the DBR method. The authors hold that the integration of between TOC tools is of key importance. Input information on the requested production process due dates, the extent of buffer exploitation, the order of devices to be produced are critical for proper shop floor control. As the shop floor organization is consistent with the DBR principle, this information is used as input data to queue work at the bottleneck, which controls the process of pulling materials according to the 'pull' logic. The materials pulled in the manufacturing system are pushed between individual work stations in line with the 'push' logic. On the assumption that all work stations on the shop floor are more efficient than the bottleneck, such measure is expected to minimize work in process. The production system pulls as many resources as the system constraint allows. Other work stations do not reach their maximum throughput, because it would result in accumulating work in process and, on top of that, would not shorten the duration of the shop floor process. Therefore, by cutting the manufacturing costs its effectiveness is raised, assuming throughput is the same. This assumption is valid on account of the fact that bottleneck manufacturing capacity remains unchanged. The information from the project management tool to the shop floor management is as important as important as the information sent the other way round. In the proposed model the shop floor objective is to produce finished goods and take care of the quality of the information sent to the project management tool. If manufacturing is to be treated as one of the stages of the customer service process, it is necessary to report on the work progress and expected completion dates. Any problems likely to affect the scheduled date of product

delivery should be reported and such knowledge should be used for making decisions in providing service to a given customer.

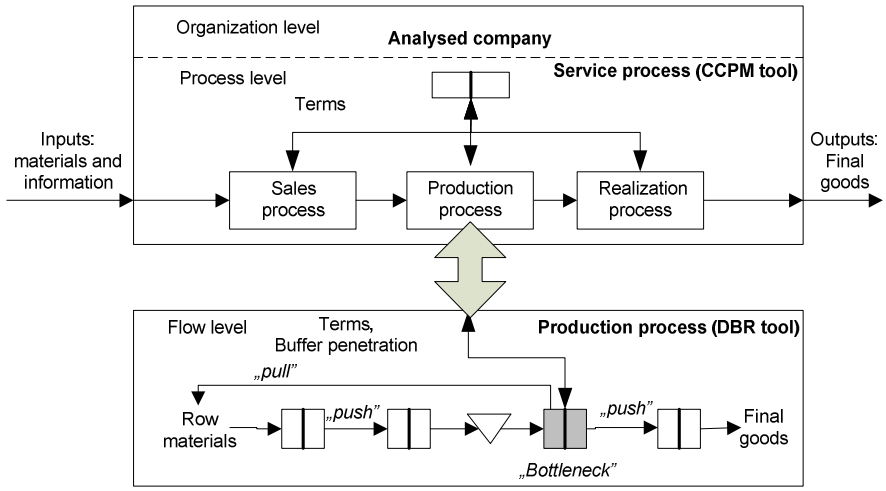

Fig. 2. TOC tools integration
Rys. 2. Integracja narzędzi teorii ograniczeń

In the course of optimization, many a time the shortening one of subprocesses does not reduce the time of the entire process. It is caused by losses sustained while waiting for the execution of the subsequent subprocess resulting from multitasking. Then all the effort taken for the purpose of achieving local optimization is frustrated. In reference to the situation under analysis, even though the enterprise implemented TOC tools, generating the information on the progress of each process, such information was not put to any use at subsequent links. The persons in charge of scheduling and controlling shop floor did not know the actual priorities of pending production tasks. The only shop control information provided was the scheduled date of shipment to the customer. Task queuing with a view to the presented criterion led to numerous problems in executing tasks with a lower priority. As part of tool integration it was necessary to develop a tool determining the actual priorities in implementing production tasks. The solution to this problem is presented in subsequent chapters of this paper.

PARAMETERIZATION OF THE INTEGRATION TOOL

The integration of TOC tools dedicated to managing customer service and shop floor scheduling and controlling requires developing a mechanism for repeated transmitting the information between them. Its basic objective is the prioritization of tasks in terms of the assumed criterion. The goal of the enterprise is to maximize shareholder value [Pitman 2003, Sundaram, Inkpen, 2004]. For this purpose profitable activity must be conducted. Hence, in the context of system constraints, the need for taking measures aimed at yielding the greatest profits from the point of view of the maximum bottleneck exploitation.

Starting deliberations from the customer service level, one should focus on the profitability of each project, either in process or potential. An indicator reflecting the real profitability of a project is profit per man hour generated by the system constraint.

$$pb_x = \frac{pr_x}{\tau_x} \left[\frac{\$}{h}\right]$$

pb_x - profitability of bottleneck in project x

pr_x - project x profitability [$]

τ_x - use of bottleneck [h]

If we know the bottleneck profitability values of each project, they can be sorted in descending order of the indicator value. Thus the company can be confident that with certain resources at its disposal, it will select the most profitable projects out of a set of projects. This can be applied in the sales department responsible for seeking new orders. Accepting new orders would depend on the profitability index compared with other potential orders. Orders accepted via the project management support tool are divided into tasks and assigned to individual departments. The project manager is obliged to set deadlines for completing each project stage by the departments in terms of available resources and the scheduled product delivery date.

The integration of project management and shop floor control tools requires determining priorities for filling manufacturing orders in the context of the information obtained from customer service. To avoid decisions that could be chaotic or not urgency-driven, the authors developed a two-stage prioritization scheme. A priority index matrix was used for this purpose. The first stage of creating a matrix is calculating the priority index for each production order in the work queue. Production order contains a tool constituting a component of the project developed for the customer.

$$pi_{xy} = \frac{c_x}{e_{xy}}$$

pi_{xy} - priority index of the X device towards the Y device

c_x - importance of the customer ordering the X project

e_{xy} - bottleneck changeover time - from processing the Y device to the X device

The customer importance parameter must be known to calculate the priority index. It is important for making decisions on the order in which production orders will be filled. If on-time delivery of orders is jeopardized, the orders placed by profitable and prospective clients take priority. The next parameter used for determining priority index is changeover time at the production system bottleneck. It should be minimised to be exploited to the full. Hence, orders with shorter changeover time are given higher priority. As it is required to display changeover times must be presented in a matrix system (changeovers between particular devices), priority index also creates a matrix. The priority index matrix system is presented in Table 1.

Priority index is determined for each changeover variant between any two devices awaiting completion in a production system. For reliable information on the urgency of each order, shop floor controller should take into account the extent of time buffer use for each project and, respectively, devices.

Table 1. Priority index matrix
Tabela 1. Macierz wskaźników priorytetowości

	Device $_x$	**Device $_y$**	**…**	**Device $_z$**
Device $_x$				
Device $_y$				
…				
Device $_z$				

The next stage of developing the CCPM and DBR integration tool would be to make it possible to apply priority index colours on the presented matrix, which would be reflective of the buffer use status, provided for each project. According to the traffic light analogy logic, low buffer penetration (buffer consumption of less than 1/3) is marked with green; medium buffer penetration (buffer consumption between 1/3 and 2/3) is yellow, whereas deep buffer penetration (over 2/3) - red [4]. The information on the buffer penetration status is sent from a customer service management support tool. The data on the actual buffer use is sent every time the queue of devices awaiting processing is refreshed. It can be either automatic upon moving the order to the processing stage, every given time interval, or manual - at the request of shop floor controller. Thus the worker deciding on the order of works on the shop floor can choose in the first place the devices with the highest (red) priority - the most urgent ones, intended for the most important customer and with the lowest changeover time, which allows for reducing waste at the bottleneck.

The major advantage of the described integration tool is providing the information on the actual priority of each production task. Thus, the managers will be confident that the most urgent tasks from a given set are processed in the first place. It allows for reducing their completion times and improving product delivery timeliness. The enterprise resources and, first of all, the resources constituting the bottleneck, are the tasks most profitable for the organization. This, in turn, translates into an enhanced performance of the enterprise.

CONCLUSION

The tool presented in this paper has been tested as part of research and development works. It was decided to apply 4 logistic measures. The research was conducted in two 6-month periods: prior to and following the implementation. The analysed periods involved estimated demand distribution and the characteristics of placed orders. In the context of the tool implementation the first measure under analysis was Dock to Dock Time (DDT). Following the implementation its average value fell by 12 per cent, which is reflective of an increase in the material flow across the enterprise and its greater flexibility. Reducing lead times should go hand in hand with their timeliness. Order timeliness is measured by the On Time In Full (OTIF) performance indicator. The number of orders delivered on time and in full rose by 4 per cent. Production scheduling and shop floor control were analysed using the production flow control efficiency indicator, showing the number of production orders processed on schedule compared with the total number of orders. As production scheduling did not function properly before the implementation, the indicator went up by as much as 56 per cent. What is vitally important, the suggested solution reduced not only the time of material flow, but also costs. The Stock Coverage (SC) was examined in terms of value for overall stock (raw materials, work in process, finished goods). After the implementation the indicator went down by 17 per cent, resulting in cash release and improved financial situation of the enterprise.

The conducted research showed that the developed tool integrating CCPM and DBR had a positive impact on the enterprise performance. It enables improving the company performance in meeting target group requirements by focusing on enhancing the efficiency of processes running in the company and tasks processed at particular work stations.

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INTEGRACJA NARZĘDZI ŁAŃCUCHA KRYTYCZNEGO ORAZ WERBEL-BUFOR-LINA W BRANŻY BUDOWY MASZYN - CASE STUDY

STRESZCZENIE. **Wstęp**: Artykuł prezentuje koncepcję integracji narzędzi teorii ograniczeń wykorzystaną do reorganizacji funkcjonowania przedsiębiorstwa z branży budowy maszyn.

Głównym celem prezentowanej koncepcji jest umożliwienie przedsiębiorstwu zaspakajania potrzeb klientów po racjonalnych kosztach, co ma w konsekwencji doprowadzić do zwiększenia zysków a w perspektywie długofalowej do zbudowania zwinnej organizacji.
Metody: Ze względu na jednostkowy charakter procesów produkcji oraz obsługi klienta opisana koncepcja wykorzystuje znane z teorii ograniczeń narzędzia: łańcuch krytyczny oraz werbel-bufor-lina. Autorzy wykorzystali również poziomy efektywności organizacji do zbudowania narzędzia w celu integracji poszczególnych działów przedsiębiorstwa. Zaprezentowany model został opracowany i z sukcesem wdrożony w jednej z polskich firm z branży budowy maszyn.
Wyniki: W opracowanym modelu narzędzie CCPM funkcjonuje w obszarze obsługi klienta natomiast narzędzie DBR odpowiada za kontrolę sterowania produkcją. Integracja obu narzędzi wymagała również stworzenia mechanizmu przepływu informacji pomiędzy nimi.
Wnioski: Przeprowadzone badania pokazały, że stworzone narzędzie integrujące CCPM oraz DBR miało pozytywny wpływ na efektywność jednego z polskich przedsiębiorstw z branży budowy maszyn. Pozwoliło na poprawę spełniania wymagań klienta poprzez wzrost efektywności procesów funkcjonujących w przedsiębiorstwie oraz zadań realizowanych na pojedynczym stanowisku roboczym.

Słowa kluczowe: łańcuch krytyczny, werbel-bufor-lina, integracja procesów, efektywność przedsiębiorstwa.

PROJEKTMANAGEMENT DER KRITISCHEN LOGISTIKKETTE UND DIE INTEGRATION DES WERKZEUGES AM BEISPIEL DES TROMMEL-PUFFER-SEILES IM MASCHINENBAU - EINE CASE STUDY

ZUSAMMENFASSUNG. Einleitung: Der Artikel präsentiert ein Konzept für die Integration der Werkzeuge der Theorie von Begrenzungen, die bei der Reorganisation der Funktionsausübung eines Unternehmens aus der Branche des Maschinenbaus in Anspruch genommen werden. Das Ziel des dargestellten Konzeptes ist es, dem Unternehmen die Erfüllung von Bedürfnissen seiner Kunden zu rationellen Kosten zu ermöglichen. Das sichert auch die Erhöhung der Gewinne und in der Langzeit-Perspektive den Aufbau einer agilen Wirtschaftsorganisation.
Methoden: In Hinsicht auf den komplizierten Charakter von Produktionsprozessen und der Kundenorientierung nimmt das beschriebene Konzept die von der Theorie von Begrenzungen her bekannten Werkzeuge: der kritischen Logistikkette und des "Trommel-Puffer-Seiles" in Anspruch. Die Autoren haben zum Aufbau eines Instruments zum Zwecke der Integration der einzelnen Abteilungen eines Unternehmens auch das Niveau der Effektivität der jeweiligen Organisation einbezogen. Das präsentierte Modell ist in einer polnischen Firma des Maschinenbaus ausgearbeitet und erfolgreich eingeführt worden.
Ergebnisse: Das CCPM-Werkzeug funktioniert innerhalb des konzipierten Modell im Bereich der Kundenbedienung und das DBR-Werkzeug ist für die Kontrolle der Produktionssteuerung verantwortlich. Die Integration der beiden Tools bedurfte auch des Aufbaus eines Algorithmus zur Integration des Informationsflusses zwischen ihnen.
Fazit: Die durchgeführten Untersuchungen haben gezeigt, dass das geschaffene Werkzeug, die CCPM und DBR integrierende Werkzeugvariante die Effizienz eines polnischen Maschinenbau-Unternehmens positiv beeinflusst hat. Es erlaubte eine verbesserte Erfüllung der Kundenbedürfnisse und -anforderungen infolge der erreichten Erhöhung der Prozess-Effektivität im Unternehmen und auf dem einzelnen Arbeitsplatz bei der Ausführung von konkreten Produktionsaufträgen.

Codewörter: kritische Kette, Trommel-Puffer-Seil, Prozess-Integration, Effizienz eines Unternehmens.

Piotr Cyplik
Poznan School of Logistics
ul. Estkowskiego 6, 61-755 Poznan, Poland
e-mail: piotr.cyplik@wsl.com.pl
Michał Adamczak
Poznan School of Logistics
ul. Estkowskiego 6, 61-755 Poznan, Poland
e-mail: michal.adamczak@wsl.com.pl
Łukasz Hadaś
Poznan School of Logistics
ul. Estkowskiego 6, 61-755 Poznan, Poland
e-mail: lukasz.hadas@wsl.com.pl

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DEVELOPMENT OF AN AUTOMATED SYSTEM FOR THE DECENTRAL FRACTIONING OF MUNICIPAL WASTES

Heiko Vesper, Tobias Erxleben, Jens Schulze, Michał Kurpisz

Projektlogistik GmbH, Wildau, Germany

ABSTRACT. Background: There is a growing problem of the increasing amount of unsorted municipal wastes with the resulting consequences for the environment.
The aim of this study was to present a new solutions of the system for the decentral fractioning of municipal wastes, which enable simplification and improvement of the process together with the reduction of total costs.
Methods: The description of the problem of the increasing amount of unsorted municipal wastes with the resulting consequences for the environment as well as an alternative solution for the decentral fractioning of such wastes was presented. The influence onto the environment as well as the efficiency of the costly mechanical sorting of wastes was queried. The nowadays used principles of sorted and unsorted waste disposal were elucidated and their advantages and disadvantages evaluated.
Results and conclusions: Based on this evaluation an innovative and future oriented development of an automated system for the decentral fractioning of municipal wastes was presented. The new developed systems aim at the achievement of an easier, less costly and environment-friendlier process for the disposal of municipal wastes from apartment buildings.

Key words: Municipal waste, decentral fractioning, waste disposal, disposal methodologies, automation, waste sorting.

INTRODUCTION

Before the problems of waste disposal are presented, the main term of municipal waste shall be defined and the different fractions of waste that are differentiated today shall be declared. Municipal waste means all the wastes that accrue in a normal household. These are differentiated into the following fractions: biological- and remaining waste, papers, glasses, plastics and wastes that are summarized in Germany as the "Grüner Punkt" which contain plastics, metal and all other kinds of packaging without papers. Regarding to this, when in the article unsorted municipal waste is mentioned it means the mixing of these fractions. Other wastes like bulk rubbish, commercial wastes, construction waste, waste wood or greencut are not defined as municipal wastes. Picture 1 shows the classification of waste fractions while focusing onto municipal wastes in a graphical manner [Bilitewski, Härdtle, Marek, 2000, Mansoor, Cotton, Westlake 1999, United Nations ... 2010].

Regarding the economics of waste disposal there is a fundamental and crucial difference between unsorted and presorted wastes. Presorted wastes can be recycled a lot more economically since they do not need to be mechanical fractioned and sorted, which leads to a lesser environmental pollution. Unfortunately, most of the inhabitants of apartment buildings are not aware of the economic and environmental burden that unsorted waste produces. To reach a future oriented waste disposal all people must understand that avoidance instead of disposal is the only way to reduce the devastation of the environment through landfills and waste combustion. Only with a reduction of the created wastes, the environment can be spared effectively.

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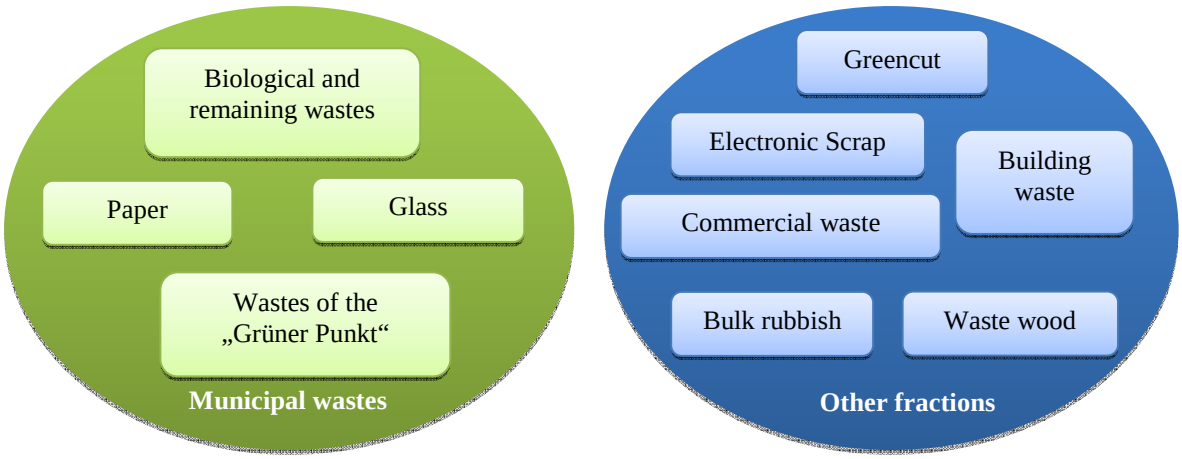

Fig. 1. Classification of usual fractions of waste
Rys. 1. Klasyfikacja frakcji odpadów

The second important approach is the still not much common idea of "conscious disposal". This term means the proper sorting, but also the disposal of the right amount of municipal wastes. With a compulsory waste fractioning directly at the causer, each person can support an environment-friendly disposal of the produced wastes. By this, the attitude of the waste producing people can be changed to a complete presorted disposal of municipal wastes.

The raising amounts of municipal waste are now and will be in the future one of the mayor problems for mankind. The demanded space for landfills rises because the waste sorting plants are utilized to the capacity cap and through this our planet is more and more polluted by wastes that are difficult to sort and process. To reach the goal of a more environment-friendly waste disposal there has to be made an adjustment to the waste processing concept, so that only presorted wastes will be processed. As a prelude to this change of concept, it is necessary to presort the wastes direct by the causers. For this, a system is needed to improve and simplify the process of waste collecting and to do not even allow a false disposal of different kinds of waste. With such a system, it would be possible to establish a "conscious disposal" without the need for laws and rules to enforce it [United Nations ... 2010, Mulvaney 2011, Cord-Lanwehr 2000].

EXISTING APPROACHES TO A SOLUTION

The main cause for the need to process unsorted wastes lies in the missing obligation for the causers to presort the waste. Regarding to this, the municipal waste is often not sorted due to the ease of disposing them together in just one container. For most people the sorting of the waste, deposing it in different bags and transport these into the different containers are additional efforts they want to avoid. Often people still think that unsorted wastes will be sorted afterwards mechanically or burned altogether and so the presorting is not necessary.

Furthermore recycling is still not as much common as it should be and a lot of people still do not live by the idea of "avoidance instead of disposal". While recycling creates the possibility to reuse wastes in the same or a different manner it is not a magical solution to the disposal of all the wastes produced today. The main disadvantage of recycling is that the main process is very complex and

expensive and produces pollutions due to the release of the exhaust gasses that arise in the process. Anyhow recycling as a method of waste processing is, especially due to the continuous research of new processing technologies, a future oriented solution and does a lot less damage to the environment then thermal processing since the reduction of the waste extent is reached by a much lesser pollution of the air [Cord-Lanwehr 2000, Caldecott, Coggins, McIlveen 2009].

To enable the recycling process the presorting of the waste fractions is of crucial importance. Two different approaches to the presorting process are used today:

– Subsequent sorting of mixed disposed wastes by complex sorting plants,

– Manuel sorting of the fractions by the causer and disposing into different containers.

To compare the two approaches of presorting their advantages and disadvantages are presented in the chart below.

Chart 1. Advantages and Disadvantages of presorted and subsequent sorted waste fractions
Schemat 1. Zalety i wady frakcji odpadów z sortowania wstępnego i zasadniczego

	Advantages	**Disadvantages**
Presorted waste fractions	– No additional sorting by costly sorting plants necessary – Recycling directly possible – Resource saving and environment-friendly disposal process – Conscious Disposal – Future oriented process	– Labour-intensive presorting process for the users – More complex transportation system needed for the disposal companies
Subsequent sorted waste fractions	– Easy disposal from the users point of view – Easier transportation system for the disposal companies – High accuracy of the subsequent sorting process	– Intensive subsequent sorting effort – Higher demand for thermal treatment of the unsortable remaining wastes – Inefficient disposal process compared to the disposal of presorted wastes – Higher demand for landfills – Pollution due to the exhausts of the sorting plants

The unsorted waste disposal has advantages for the users due to the lack of need for the presorting but also for the waste disposal companies since they do not need as many trucks to collect the wastes. But because of the overwhelming disadvantages of an unsorted waste disposal this approach will have to be reduced or even completely eliminated in the near future. The part of unrecyclable wastes that can only be treated thermal in unsorted wastes is a lot higher than in presorted wastes. Because of the dense conglomeration between the different kinds of waste, the danger occurs that they cannot be sorted completely and recyclable material is lost and can only be treated thermal anymore.

The presorting of waste by the causer is enabling a direct recycling without the need for expensive and polluting waste treatment plants. Due to this, the recycling process can be less costly and more resources can be regained. Because of this environment-friendly background, the presorting of wastes by the causer has to be viewed as a future oriented treatment process. But this solution has one major disadvantage. If the presorting is not done correctly by the users the recycling process cannot be done or a second inefficient sorting of the waste has to be done. Due to this, the main task at the development of new waste collection systems is to prohibit the false fractioning of wastes by the user.

One more disadvantage is shared by both approaches presorting and subsequent sorting as it is done today. Mostly the wastes are collected in containers outside the buildings so that the trucks of the waste collection companies can reach them more easily. While this is an advantage for the companies,

it inhabits disadvantages for the users, which even lead to a less good presorting behavior. Firstly, the users have to leave the building to dump their waste, which causes inconveniences while it is raining or snowing. Also in the area of the containers, it comes to annoyances due to the smell of the wastes or even vermin. To encounter these problems it would be of a major advantage for a waste collection system to store the wastes inside the houses when the cleanliness can be guaranteed.

ALTERNATIVE APPROACH TO THE PROBLEM - DECENTRALIZED FRACTIONING OF THE MUNICIPAL WASTES

Regarding the above mentioned major problems of today's waste disposal systems a new approach was developed to collect and fraction the wastes decentralized at their production place. With said system, it should be possible to create an easier waste disposal system for the users and by this spread the idea of conscious disposal to the people.

A lot of resources can be saved when the number of processes of mechanical sorting plants can be reduced. The innovative disposal system is based on this idea. The system was developed for the adoption of presorted municipal wastes. The responsibility for the sorting process lies by the causer while the system secures that only correctly sorted waste is disposed. The system works by identifying, weighting and transporting the waste that is placed into special interjection units. The transportation process works without any propulsion, just by gravity the waste is transported from the interjection units, in the several floors of the building, to the cellar where the containers are placed. From here the containers with a pure filling of just one fraction are disposed by the recycling companies. In the following picture, the waste disposal process of the system is described from the user, the technology and the recycling company's point of view.

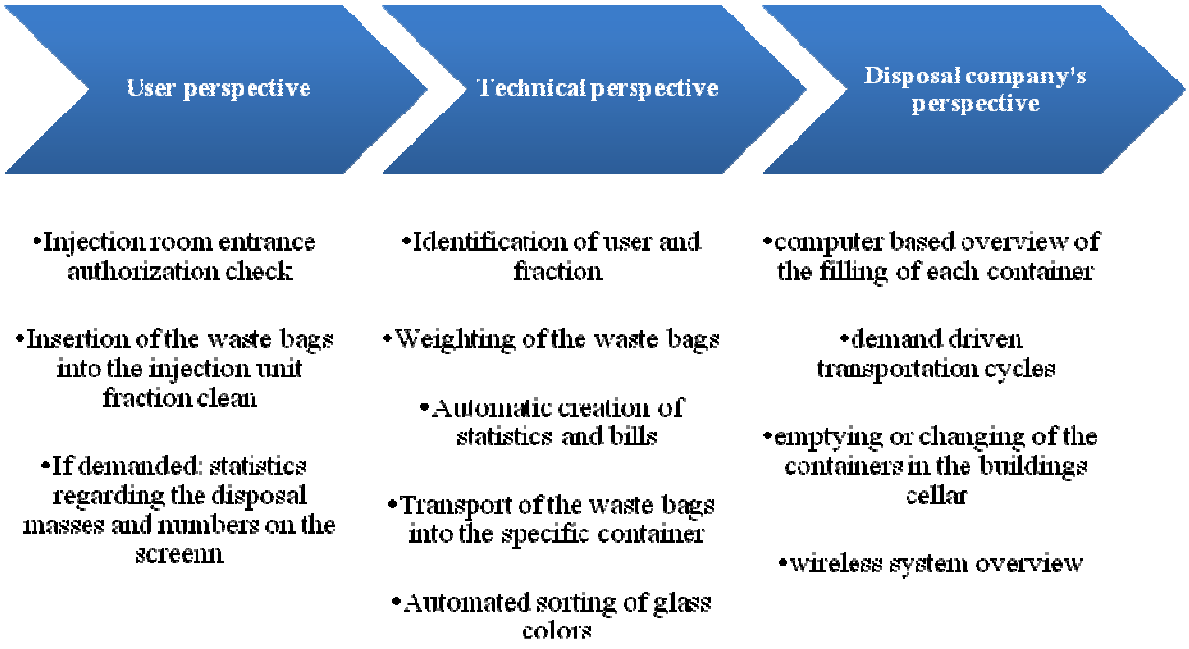

Fig. 2. Presentation of the disposal process from the user, technical and disposal company's perspective
Rys. 2. Proces wywozu z punktu widzenia użytkownika, technicznego i firmy wywożącej odpady

The interjection units are placed on every floor in separated disposal rooms. Entrance to the disposal rooms is given once a person is identified by the chip card that each user is handed for the system. By this, the security of the system and the users is guaranteed and wittingly done damage to the system is prevented. The system is designed to only allow correctly presorted wastes locked within plastic bags to prevent smell, soiling of the area and contamination by vermin. Before the waste can be

introduced into the injection unit, the user again has to identify himself by his chip card. By this the system can refer the dropped waste to the user for later billing. After the identification of the user the waste can be placed into the injection unit. Once the waste is placed into the unit, it is weighted and scanned for accurate presorting. Beside the injection unit is a screen installed on which the user can view the statistics of the waste he just disposed into the system. It is possible to view the weight, kind of fraction, date and time of disposal and mostly important the cost, as well as the cost for the last week or month. By this, the system shall not only provide information but also raise the awareness of the users for the amounts of waste they produce, so that they will come to a more conscious disposal.

After the waste was associated to the user, identified and weighted, it will be transported to the collection containers. The transportation is done by a pipe that leads from the injection units to the containers. Since the containers are placed inside the cellar, there is no need for propulsion but the transport works by gravity. Due to this the waste bags reach a high speed when they are transported downwards. Since the bags can be damaged by the high speed, especially when they reach their destination, the system has a complex device to reduce the kinetic energy of the waste bags. This device is one major part of the system since any damage to the plastic bags would lead to contamination and smell which has to be avoided since the containers are placed inside the houses cellars.

Another waste fraction that is mainly influenced by this problem is glass waste. Without the kinetic reducer unit, the glass would be destroyed at the end of the transportation process and a fractioning of the different glass colors would be impossible. Behind the kinetic reducing unit, a sorting system is placed that transports the waste into the container of its fraction. Here also the glass waste is sorted by the glass color into different containers. Every container contains a sensor that measures how much it is filled already. These sensors are directly connected to the computer system of the disposal companies. By this, it is possible for the disposal companies to plan their truck transports exactly by the filling of the containers and so reduce the transportation costs and the pollution by the trucks.

All the above mentioned necessary identification and sensory processes are calculated in milliseconds so that there are no waiting times for the user in the process of waste disposal. Also the system is directly communicating with the operator so maintenance and repair processes can be done fast and only when needed. By sensors placed inside the system it is capable of identifying the reason of any malfunction and guide the maintenance team directly to the damaged section. So it is not only possible to reduce the reaction time but also to lower the maintenance costs in comparison to a today used system.

BOTTOM LINE

With the use of the newly developed system for a completely automatic decentral fractioning of municipal wastes, it is possible to reduce all the inconveniences involved in today's waste disposal and to ease the process of disposal for the users. Due to the use of an computer controlled system and the implemented sensor technic it is not only possible to guarantee a correct, fraction clean disposal but also a billing system that is fair for the users and enables a complete listing of all disposed wastes of each user. By the use of the presented system, it is possible to automate the waste disposal process and to minimize the costs for the disposition.

But also with such an innovative intelligent system, a healthy environment can only be guaranteed if the users adopt the idea of avoidance instead of disposal on any kind of waste.

SUMMARY

The article is describing the problem of unfractioned and unsorted waste disposal in urban settlements. It describes a research subject with the target to develop a possibility for future sorting of

municipal waste. At first, several examples of today used systems for the fractioning and their advantages and disadvantages are presented. It will be shown, that the most prominent disadvantage of these systems can be found in the lack of an obligation for the users to sort the waste before disposing it and that often the waste will not be sorted because of the laziness of the users. Because of this today used systems have several downsides like: high efforts for the additional waste sorting at high cost sorting facilities, contamination of the environment because of the necessary thermic treatment of no longer separable wastes and the constant overload on the landfills. Accordingly, the article presents alternative solutions, in which, by the usage of automated processes the peripheral waste disposal in urban settlements can be done in the future.

The main principle of this new disposal concept is that the user will have the obligation to presort the waste in the today used fractions like: paper, wastes of the "Grüner Punkt" system, glass and household waste. These wastes will be transported in units using the already established plastic bag system. These bags will be disposed by the users through special insertion modules, which are connected with a pipe system that transports the bags to a central collection station. During the disposal process each bag will be weighted, the fraction of waste will be recorded by a sensor system and the bag will be associated with the appropriate user. By this, the system will be capable to directly collect each waste fraction in a different container and to create an exactly done billing-paper for every user. By this, the system can determine the exact measurement of the filling of the container and will be able to send this information to the service provider for the dispose of the waste containers. Also the system will be connected directly with the service provider for the maintenance of the system to allow a fast reaction if the system is damaged. In the bottom line of the article it will be pointed out that even with the use of such new, intelligent systems for the waste disposal it will be necessary to change our view onto waste management from disposal to avoidance to reach a green and healthy nature for our future.

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OPRACOWANIE ZAUTOMATYZOWANEGO SYSTEMU DO ZDECENTRALIZOWANEGO SORTOWANIA ODPADÓW W OSIEDLACH MIESZKANIOWYCH

STRESZCZENIE. **Wstęp**: Istnieje ciągle zwiększający się problem ilości niesegregowanych odpadów w osiedlach mieszkaniowych wraz z jego konsekwencjami dla środowiska.
Celem tej pracy było przedstawienie propozycji nowego rozwiązania systemu zdecentralizowanego sortowania odpadów komunalnych, które umożliwiają uproszczenie i usprawnienie procesu wraz z obniżką kosztów całkowitych.
Metody: W artykule przedstawiono problematykę zwiększania się ilości niesegregowanych odpadów w osiedlach mieszkaniowych wraz z konsekwencjami dla środowiska jak również przedstawiono alternatywne rozwiązania

zdecentralizowanego usuwania odpadów. Został także poddane dyskusji wpływ na środowisko oraz efektywność kosztownego mechanicznego sortowania odpadów. Zaprezentowano obecnie stosowane zasady wywozu sortowanych i niesortowanych odpadów wraz z oceną ich zalet i wad.
Wyniki i wnioski: W oparciu o tą ocenę zaprezentowano innowacyjne zorientowane na przyszłość rozwiązanie automatycznego systemu zdecentralizowanego segregowania odpadów w osiedlach mieszkaniowych. Nowotworzone systemy są zorientowane na prostszy, tańszy i przyjaźniejszy dla środowiska proces wywozu odpadów komunalnych w osiedlach mieszkaniowych.

Słowa kluczowe: odpady komunalne, zdecentralizowane sortowanie, usuwanie odpadów, metodyka utylizacji, automatyzacja, sortowanie odpadów.

ENTWICKLUNG EINES VOLLAUTOMATISIERTEN SYSTEMS FÜR DEZENTRALE SORTIERUNG VON KOMMUNALEN ABFÄLLEN IN STÄDTISCHEN WOHNSIEDLUNGEN

ZUSAMMENFASSUNG. Einleitung: Es besteht ein immer größer werdendes Problem der wachsenden Mengen von Abfällen in städtischen Wohnsiedlungen sowie dessen Konsequenzen für die Umwelt. Das Ziel der Arbeit war es, den Vorschlag eines Systemkonzeptes für dezentrale Sortierung von kommunalen Abfällen, welches Vereinfachung und Vervollkommnung des Sortierungsprozesses sowie Senkung dessen Gesamtkosten ermöglicht, zu unterbreiten.
Methoden: Im vorliegenden Artikel wurden die Problematik der immer wachsenden Mengen nicht segregierten Mülls in städtischen Wohngebieten, dessen Konsequenzen für die Umwelt sowie alternative Lösungen für dezentrale Müllentsorgung dargestellt. Dabei wurden der negative Einfluss auf die Umwelt und die Effektivität der mechanischen Sortierung der kommunalen Abfälle angesprochen, wobei man die heutzutage geltenden Regeln und Prinzipien für die Abfuhr des sortierten und nicht sortierten Mülls samt der Abschätzung der betreffenden Vor -und Nachteile projiziert hat.
Ergebnisse und Fazit: In Anlehnung an diese Beurteilung wurden die auf die Zukunft orientierte Lösung des vollautomatisierten Systems für die dezentrale Sortierung der kommunalen Abfälle in städtischen Wohnsiedlungen präsentiert. Die neuentwickelten Systeme sind auf einfachere, billigere, umweltfreundlichere Abfuhr von kommunalen Abfällen in städtischen Wohngebieten ausgerichtet.

Codewörter: kommunale Abfälle, dezentrale Sortierung, Müllentsorgung, Entsorgungsmethodik, Automatisierung, Sortierung von kommunalen Abfällen.

mgr inż. / Dipl.-Wirtsch.-Ing. (FH) Heiko Vesper
e-mail: h.vesper@projektlogistik-gmbh.de
mgr inż. / Dipl.-Wirtsch.-Ing. (FH) Tobias Erxleben
e-mail: t.erxleben@projektlogistik-gmbh.de
Dipl.-Wirtsch.-Ing. (FH) Jens Schulze
e-mail: j.schulze@projektlogsitik-gmbh.de
Dipl.-Wirtsch.-Ing. (FH) Michał Kurpisz
e-mail: m.kurpisz@projektlogistik-gmbh.de
Projektlogistik GmbH
Planung, Entwicklung und Realisierung von Logistik-Systemen
Bahnhofstraße 1 / Halle VII
15745 Wildau, Niemcy

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SIMULATION ANALYSIS OF A PRODUCTION PROCESS WITH SELECTED SIX SIGMA RATIOS

Michał Dobrzyński, Piotr Waszczur

Gdansk University of Technology, Gdansk, Poland

ABSTRACT. Background: Computer technologies allow more and more to model as well as to perform simulation experiments of various processes. The simulation analysis provides a better understanding of the interdependencies between various stages of production processes.
Methods: The results of simulation studies were presented, the aim of them was to show the opportunities of the analysis of the process according to the scenarios and variants developed in connection with the qualitative assessment process. The study was based on simulation models developed and programmed for the processing of parts in an automated production line. The results of the conducted simulation experiments were referred to the primary ratios of the system work like the use of machines and other means of production, capacity, number of defects, etc. The analysis of the process was expanded by the qualitative assessment, based on selected ratios used in Six Sigma methodology.
Results: The significant influence of the identification of so-called "hidden factories" in the production process on the value of sigma level was observed.
Conclusions: The application of Six Sigma methodology and its statistical methods has a significant importance in the estimation and improvement of processes. The identification and the choice of number of inspection points are important for the monitoring and evaluation of the whole process. The obtained results confirmed the earlier assumptions of great importance of "hidden factories". Not revealing them influences significantly the quality of a process.

Key words: production line, manufacturing, modeling, simulation, Six Sigma

INTRODUCTION

The Six Sigma concept is used to improve the product quality and to reduce the amount of defected products, mainly by the changes in the organization of the production process as well as by the continuous monitoring of processes and their parameters. The application of statistical methods for the improvement of processes, where there is a big impact of human factor, proved to be useful also in such areas of activities like researches, development and innovations. The efforts of Six Sigma are directed to strategical improvement of business activities by the use of tools for analytical and design management [Barney, McCarty 2005]. It should be noted, that the improvement of financial results by the improvement of the quality is the main purpose of its application. The increasing interest in the implementation of Six Sigma methodology is shown by most of big companies, as well as small an medium ones. It is a results of the continuos aspirations to improve the quality in time of strong competition and the tendency of reducing costs [Wessel, Burcher 2004, Bratić 2011].

The Six Sigma strategy is based mainly on the measurement of actions' effectiveness, which should be measured at each step of the primary and secondary processes. The sigma level determines the fractions of incompatibilities in processes, which could occur during its implementation. The process of counting of incompatibilities allows comparing processes, which seem to be incomparable and it is the main advantage of this concept.

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To estimate the effectiveness (called sigma level), the following ratios are used: DPU (defects per unit), DPO (defects per opportunity) and DPMO (defects per million opportunities). The above-mentioned sigma level can be determined based on calculated number of defects. In qualitative terms, the higher the sigma level, the lower the probability of the defect. It should be noticed, that an average company operates usually at the sigma level equal to 3-4. In case the sigma level is under 3, the companies are not able to survive on the competitive market and the cost associated with the securing of the quality is equal to 25-40% of incomes from the sale [Wodecka-Hyjek, Walczak 2006; Harry, Schroeder 2001].

Analyzing the process in terms of sigma level, the value of this level can be calculated for any stage of the process as well as for the whole process. The choice of the place of measurement, the measurement methods and methods of processing and handling of data are of great significance in Six Sigma concept. The choice of measurement points should be determined by the steps critical for the quality of a process and its costs. The operations related to measurement and data collection should be conducted fairly and reflect the real process. Only information gathered in such a way can be used in the process of the analysis and the improvement [Hamrol 2005, Shetwan, Vitanov, Tjahjone 2011].

It should be considered that the sigma level at the output of the process could be different, and even lower, than at its various stages. Depending on the characteristics of the process, there can be such cases, that the incompatibility disqualifies a production unit (defect/lack) and/or the incompatibility can be removed and restored in the process (incompatible unit/fixable). Therefore, there is a possibility of a situation that the calculated sigma level do not reflect the actual level of the process quality. It does not take into account the impact of additional activities, so called "hidden factories". The evaluation of such state can be conducted by the determination of the probabilities of the incompatibility in various stages of the process. The ratio TY (Throughput Yield) is used to determine the probability of no incompatibility in a single production unit in a given operation of the process. The indication RTY (Rolled-Throughput Yield) is used to estimate the whole process. It gives the probability that the individual finished part, leaving the production is without any incompatibility [Pyzdek 2003]. In case, when the ratio RTY is higher than the product of ratios TY of analyzed stages of the process, it should be assumed, that the additional operations (in order to remove incompatibilities) are taken at some stages of the process and they should be taken into account during the evaluation of the quality of a process.

The process of modelling of complex processes and simulations of dynamic analysis of processes play the increasing role in many modern business areas like industry, logistics, telecommunications, services and public sector. The simulations are defined as numerical techniques, used to carry out the experiments on certain types of mathematical models, which describe the behaviour of a complex system in long period by the use of a digital machine. The processes, which already exist as well as these at the design stage, can be modeled and simulated. The computer simulation of the process enables the analysis and the optimization of processes without the need for costly and time-consuming experiments on real objects.

Summary, the aim of the use of simulation models presented in this paper, is to find optimal solutions for the processes analyzed in terms of the performance, finding the critical points or the prediction of the behavior of the production system under certain conditions. In this context, the attention of the research was focused on the simulation of the real industrial case. The aim of both this analysis and this study was to compare the results obtained from computer simulations of the various variants of the production line, whose effectiveness was evaluated by the use of selected ratios used in Six Sigma methodology.

SAMPLE ANALYSIS OF A PROCESS

The model of a system was based on the production line of an automobile company. The line consists of series of workstations, connected by the common transport system. The scheme of this line is presented on the Figure 1. *Workstation 1* and both stands *Inspection 1* and *Inspection 2* consist of

homogeneous machines of equal process capabilities (processing, measuring and control ones). The stands *Workstation 2* and *Workstation 3 as* well as *Packager* are a single machine.

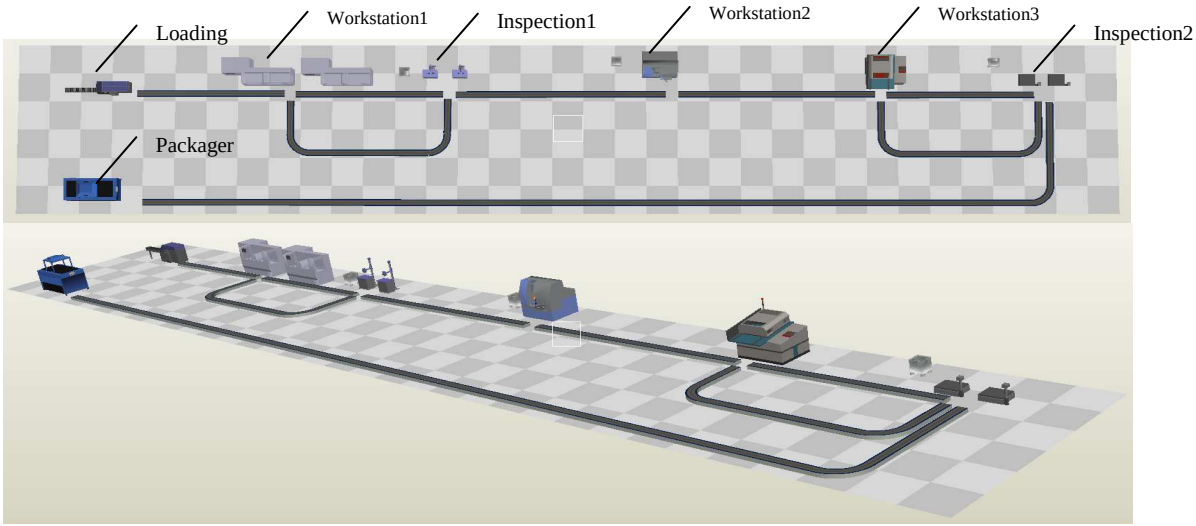

Fig. 1. The layout of workstations of a production line
Rys. 1. Rozmieszczenie stanowisk (layout) linii produkcyjnej

The different workstations work according to parameters related to number of parts processed simultaneously at this workstation, the processing time (specified deterministically or stochastically) and setups, characterized by their duration and number of operations, after which they appear (Table 1).

Table 1. Parameters of workstations in the analyzed production line
Tabela 1. Parametry pracy stanowisk w analizowanej linii produkcyjnej

	Workstation	processing block [pieces]	Processing time [min]	change-over time [min]	number of operations before the change-over [pieces]
1	Workstation 1	6	TRIANGLE (5.5,6.0,7.2,6)	1	10
2	Workstation 2	10	TRIANGLE (2.7,3.0,5.1,7)	0,5	5
3	Workstation 3	5	TRIANGLE (1.8,2.0,2.2,8)	0,3	10
4	Inspection 1	1	1	0,2	1
5	Inspection 2	2	1	0,25	1
6	Packager	60	5	3	1

It can be observed based on the above data, that there is no synchronicity of processing operations in the presented process and therefore the continuity of the production process is disrupted. The tact of the conveyor is 0,1 min, and the maximum number of parts on individual sections are successively 30, 30, 20, 30 15 and 80 pieces in main transport route and 20 pieces in both secondary transport routes of "hidden factories" (Fig. 2).

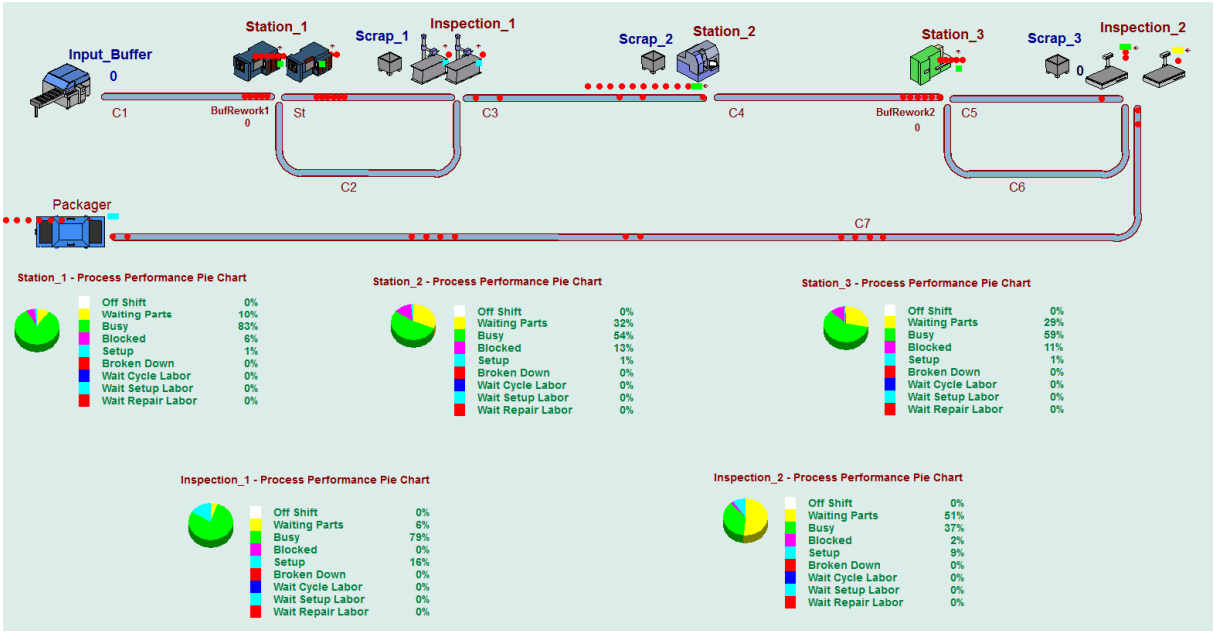

Fig. 2. The analyzed model of the process according to the simulation scenario 1
Rys. 2. Analizowany model procesu po symulacji według scenariusza 1

It was assumed that the defects are generated at the *Workstation 1* and *Workstation 3*. The probability of their appearance was calculated based on historical data obtained in previous implementation of the process using machines now used in these positions. The computer simulations were carried out for these values and they were defined as a scenario 1. The additional operations were assumed to be taken in the scenario 2. Their aim was to reduce the number of defects. The improvement of all stages was assumed to be done by eliminating inconsistencies and focusing on the right organization of the process, using methods and techniques of quality improvement tools, so called TQM. The right organization of processes, training of the technical personnel, investments and implementation of methods to prevent defects (Poka-yoke) are to aim to the total elimination of defects at the workstations *Workstation 1* and *Workstation 2*, and a number of defects are to be reduced significantly. The average percentage values of a good production are presented in the table 2.

Table 2. The average level of a good production for the analyzed scenarios
Tabela 2. Średni poziom dobrej produkcji dla analizowanych scenariuszy

	Workstation 1	Workstation 3
Scenario 1	93%	98%
Scenario 2	98%	99,9%

The experiments were conducted for both scenarios, performing five consecutive replications, each of 2880 min, for each scenario. The time of the initial instability of the process (warm-up period) was set at 960 min. On basis of obtained data, the number of parts made in given period of time increases from 4320 to 4380 pieces. It should be noted that, the increase of the productivity was obtained without any changes in parameters of various workstations of the production line and it was only the result of improvement of the process at the workstations.

The number of irreparable defects decreased by 33.3% in scenario 2 in analyzed period and the number of parts, which had to be reprocessed, decreased significantly. The data are presented in the table 3.

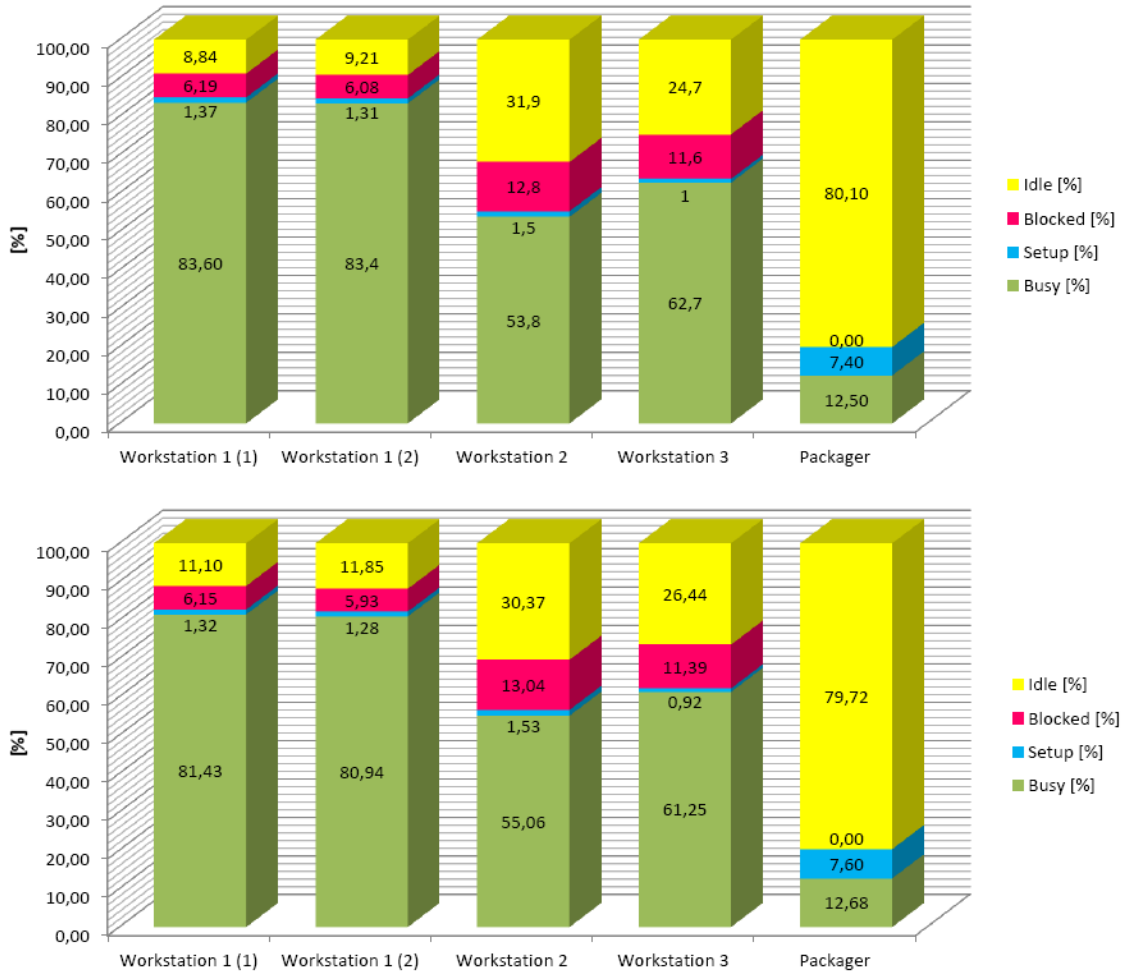

Fig. 3. The average percentage usage of workstations in scenarios 1 (a) and 2 (b)
Rys. 3. Średnie procentowe wartości wykorzystania stanowisk w scenariuszach 1 (a) i 2 (b)

It can be concluded on the basis of the date presented in the figure 3, that the parameters of the use of each particular means of production did not change significantly and the differences were up to 2,5%. The improvement of the organization of a process should be the next step, which will result in the increase of the productivity and better utilization of the system.

Table 3. The average number of defects for the four variants of analyzed scenarios
Tabela 3. Średnie liczby jednostek niezgodnych dla analizowanych scenariuszy z uwzględnieniem czterech wariantów

	Variant 1	Variant 2	Variant 3	Variant 4
Scenario 1	0	413	264	677
Scenario 2	0	125	14	139

In order to show the influence of “hidden factories” on the value of sigma level, a few variants of calculations were conducted. The Variant 1 represents a situation where the steps of restoring the reparable defects at any stage of the process are not taken into account at the determination of sigma level. Therefore, it is assumed in this variant, that no “hidden factories” were identified. The sigma level of 4,11 to 4,45, obtained in this case, does not correspond with the real quality of the process.

After revealing “hidden factories” (respectively workstations 1 and 3 in variants 2 and 3), the value of sigma level was from 2,78 to 4,10 (Fig. 4).

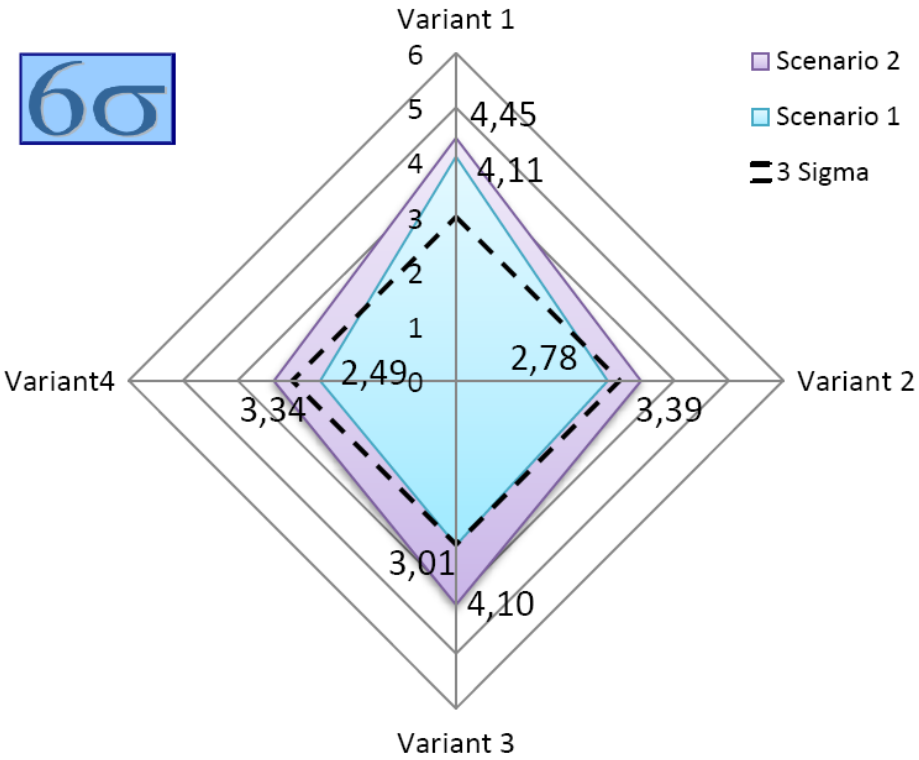

Fig. 4. The average values of sigma level for four variants of analyzed scenarios
Rys. 4. Średnie wartości poziomu sigma dla analizowanych scenariuszy z uwzględnieniem czterech wariantów

The value of sigma level decreased rapidly after revealing „hidden factories” in the production process (Variant 4). It is particularly evident in the scenario 1, where the value was reduced by almost 40%. However, in the scenario, where the activities for the improvement of a process were undertaken, the value was reduced from 4,45 to 3,34 (by 25%). The simulation of a process, which takes into account parameters of the whole process, shows the scale of actions, which should be undertaken to improve the production process or one of its parts in order to obtain the better value of sigma level.

SUMMARY

The application of Six Sigma methodology and its statistical methods has a significant importance in the estimation and the improvement of processes. It allows determining the sigma level for various processes and enables to compare them. The identification and the choice of number of inspection points are important for the monitoring and evaluation of the whole process. The results of the simulation process were presented, which, enriched by the qualitative analysis of the process (based on the calculation of the sigma level), give a comprehensive picture of the conducted system, which does not focus only on its efficiency and its utilization. In the case of the analyzed production line, it was proved to be important to disclose "hidden factories" at different stages of production. The comparison of the values of sigma levels achieved for the developed scenarios and variants allows a complete analysis of the process. The obtained results confirmed the previous assertions of great importance of "hidden factories" as well as the fact that if they are not disclosed, it significantly affects the quality of the process. Summary, the combination of simulation analysis of the system with the simultaneous

evaluation of numeric model gives the potential to prepare assumptions and conclusions of the behavior of real systems. It gives, therefore, the possibility of the estimation of scenarios, impossible of difficult to be conducted in real conditions. Therefore, the managers become the option to analyze existing processes in order to improve them.

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ANALIZA SYMULACYJNA PROCESU PRODUKCYJNEGO Z UWZGLĘDNIENIEM WYBRANYCH MIERNIKÓW SIX SIGMA

STRESZCZENIE. **Wstęp**: Obecnie narzędzia komputerowe pozwalają w coraz większym zakresie modelować i przeprowadzać eksperymenty symulacyjne procesów i zjawisk. Analiza symulacyjna umożliwia lepsze zrozumienie współzależności pomiędzy etapami realizacji poszczególnych procesów produkcyjnych.
Metody: Przedstawiono wyniki badań symulacyjnych, których celem było pokazanie możliwości analizy przebiegu procesu wg opracowanych scenariuszy i wariantów w powiązaniu z oceną jakościową procesu. Badania oparto o modele symulacyjne opracowane i oprogramowane dla przetwarzania części w zautomatyzowanej linii produkcyjnej. Wyniki dla przeprowadzonych eksperymentów symulacyjnych odniesiono do podstawowych wskaźników pracy systemu jak wykorzystanie maszyn i innych środków produkcji, wydajności, liczby jednostek niezgodnych itp. Analizę procesu poszerzono o ocenę jakościową, opartą o wybrane mierniki stosowane w metodologii Six Sigma.
Wyniki: Zaobserwowano znaczący wpływ identyfikacji tak zwanych "ukrytych fabryk" w systemie produkcyjnym na wartość poziomu sigma.
Wnioski: Zastosowanie metodologii Six Sigma, wykorzystującej statystyczne metody analizy, ma duże znaczenie w ocenie i usprawnianiu procesów. Identyfikacja, dobór liczby i miejsc inspekcji ma duże znaczenie dla kontroli i oceny całego procesu. Zestawienie uzyskanych poziomów sigma dla opracowanych scenariuszy i wariantów pozwala na pełną analizę przebiegu procesu. Uzyskane wyniki potwierdziły wcześniejsze twierdzenia o dużym znaczeniu "ukrytych fabryk", a fakt ich nieujawnienia znacząco wpływa na jakość procesu.

Słowa kluczowe: linia produkcyjna, wytwarzanie, modelowanie, symulacja, Six Sigma

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SIMULATIONSANALYSE DES PRODUKTIONSPROZESSES MIT BERÜCKSICHTIGUNG AUSGEWÄHLTER SIX SIGMA-MESSWERTE

ZUSAMMENFASSUNG. Einleitung: Rechnerunterstützte Werkzeuge ermöglichen heutzutage bei Erkundung von Prozessen und technischen Erscheinungen in einem immer größer werdenden Ausmaße, Simulationsexperimente zu modellieren und durchzuführen. Demzufolge erlaubt die Simulationsanalyse, die Zusammenhänge, welche zwischen den Ausführungsetappen innerhalb von einzelnen Produktionsprozessen vorkommen, besser zu verstehen.
Methoden: Im Rahmen der dargestellten Simulationsversuche wurden Möglichkeiten ausgearbeiteter Szenarien und Varianten, verbunden mit Qualitätsbewertung des jeweiligen Prozesses durchgeführt und dessen Verlauf aufgezeigt. Die Versuche waren auf die Simulationsmodelle gestützt, die für die Zwecke der Verarbeitung von Teilen innerhalb einer vollautomatisierten Fertigungslinie konzipiert und programmiert wurden. Die Ergebnisse der durchgeführten Simulationsexperimente wurden auf die grundlegenden Kennziffern der Arbeit des Systems, wie Auslastung der Maschinen und anderer Produktionsmittel, Produktionsleistung, Anzahl von Ausschuss-Einheiten u. ä. bezogen. Die Prozess-Analyse wurde mit der Six Sigma-Technologie und den angewendeten Messwerten ergänzt.
Ergebnisse: Es wurde ein weitgehender Einfluss der Identifikation der sog. "versteckten Fabriken" im Produktionssystem auf das Niveau des Sigma-Wertes wahrgenommen.
Fazit: Die Anwendung der Six Sigma-Technologie hat eine große Bedeutung bei der Bewertung und Vervollkommnung der Prozesse. Identifikation, Auswahl der Anzahl und Orte der durchzuführenden Inspektionen spielen eine große Rolle bei der Kontrolle und Bewertung des Gesamtprozesses. Die Zusammenstellung des ermittelten Sigma-Niveaus für die ausgearbeiteten Szenarien und Varianten erlaubt eine vollständige Analyse des Verlaufs eines Prozesses. Die gewonnenen Ergebnisse haben frühere Feststellungen bezügl. der großen Bedeutung der "versteckten Fabriken" bestätigt, wobei die Tatsache deren Nichtaufzeigens wesentlich die Qualität des Prozesses beeinflusst.

Codewörter: Produktionslinie, Fertigung, Modellierung, Simulation, Six Sigma.

Dr inż. Michał Dobrzyński
Faculty of Mechanical Engineering
Gdansk University of Technology
Narutowicza 11/12, 80-233 Gdańsk
e-mail: mdobrzyn@pg.gda.pl
Dr inż. Piotr Waszczur
Faculty of Mechanical Engineering
Gdansk University of Technology
Narutowicza 11/12, 80-233 Gdańsk
e-mail: waszczur@pg.gda.pl

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MANAGEMENT OF STRATEGIC COOPETITION AMONG PARTNERS WITHIN INTERNATIONAL AIRLINE ALLIANCES

Frank Himpel

Hochschule Anhalt, Bernburg, Germany

ABSTRACT. Background: International network-carriers span the globe by linking airports on all five continents. At the core of those networks are hub-airports that serve as the centers for (inter-)national in- and outbound traffic flows. From a business model point of view, the major international carriers are so-called network-carriers, for their core concept is based on transfer-oriented hub-and-spoke-systems. In order to maximize revenue streams of network-carriers, changes in strategic slot allocation and strategic net planning are becoming increasingly relevant.
The aim of this work was to analyze the impact of various elements of the management of strategic coopetition among partners within international airline alliances on the revenues obtained by individual partners.
Methods: the problems related to the optimization of strategic slot allocation and strategic net planning from the point of view of the individual profit shared and added net contribution margins were discussed.
Results and conclusions: Two extreme scenarios may be projected. The first one is that partners within a given alliance system may start to increase merger and acquisition activities. Thereby scale effects may be utilized. The other one is, when rivalry becomes too dominant over time, some partners may (have to) exit alliance systems. Thereby "atomic" subsystems may be on the rebound. Strategic coopetition management is aimed to keep leading international network carriers "on track" in the field of alliance management of that nature.

Key words: network-carriers, airport, slot allocation, coopetition, airline alliances.

INTRODUCTION

International network-carriers mainly link three major intercontinental markets: North America, Europe, and Asia. European carriers are particularly interested in transporting passengers to and from North America and Asia, while European airports serve as their hubs. Large-scale business-oriented customers are the prime business segment that those carriers typically target. For those passenger segments, it is particularly important to be offered time-windows for departure and arrival that suit their overall and overriding business needs. In order to offer their business passengers that kind of timing, European network-carriers need relevant slots in markets they serve. A slot itself is being interpreted as a right to use a certain infrastructure (e.g. runway) at a certain airport at a certain time and/or during a defined time frame.

The aim of this work was to analyze the impact of various elements of the management of strategic coopetition among partners within international airline alliances on the revenues obtained by individual partners.

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MARKET-ORIENTED OPERATIONS

A "market" is defined as a combination of time and place. In other words, a relation from Frankfurt to New York-John F. Kennedy at 7 o`clock in the morning is perceived a completely different market as a relation from Frankfurt to New York-John F. Kennedy at 4 o`clock in the afternoon. While in both cases the destination remains the same, arrival time makes all the difference for business travellers. This market definition implies that the passenger demography for the early morning arrival in New York may be completely different from the passenger demography for the afternoon arrival in New York.

Demand for those service offerings is typically correlated with the overall economic well-being in a certain region. For example, the indicator "Revenue Passenger Miles" (as an indicator for demand) is correlated to the overall "Gross Domestic Product" (as an indicator for wealth) of a region. While those two-dimensional explanatory models are only functional, and not causal in nature, they still do inherit a specific usability and plausibility to explain current and to predict future demand patterns for (potential) markets.

SLOT ALLOCATION

By establishing a "portfolio" of slots in international relevant "markets", network-carriers aim to sustain their own corporate growth. In other words, by linking international economic growth centers, network-carriers are trying to become less dependent on their respective home markets, and to establish a link from their own business to global growth engines. In doing so, European carriers are aiming to become more and more independent from the development and allocation of wealth in their own European markets. In this "investment" logic, only those slots and markets are preferred that brings about a major traffic volume. Critical in all of this, however, is not the overall volume in terms of quantity. Moreover, volume refers to the financial image of that volume, as may be expressed in terms of marginal contributions per market, for example.

Each carrier possesses a unique set of slots. This set enables the carrier to realize net contribution margins throughout the entire destination portfolio. Strategic slot management aims to maximize the returns and contribution margins from establishing such portfolios. Over the past 20 years, however, net contribution margins for European network carriers have decreased for about 20 % in intercontinental markets due to a fall in relevant yields. As cost savings are relatively hard to accomplish, for that network carriers carry a heavy proportion of fixed costs, yield decline may often only balanced by an increase in overall turnover. In order to achieve substantial added earnings, slots at selected destinations need to be modified as they induce different economic effects for the carrier. For example, contribution margins are correlated to time-based slot allocation (see picture 1).

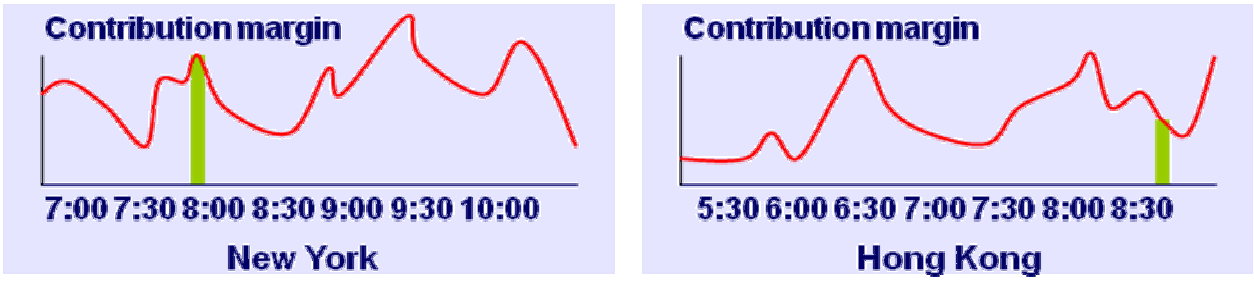

Fig. 1. Contribution margins depend on time-based slot allocation
Rys. 1. Marże zależne od alokacji w czasie

Optimization of revenue streams based on adequate slot allocation is hard to accomplish on an individual basis, however. It shows that carriers do need partners in order to optimize their respective time-stamps in their slot portfolios among their markets. In other words, maximization of the added revenue that can potentially be drawn from a slot or market portfolio is subject for interorganizational cooperation. Dissolution of wing-to-wing-operations is just one example of how to maximize profit contributions. All in all, this aspect may serve as one key cause for the emergence of airline alliances.

COOPETITION

It becomes evident that partnering in an airline alliance is aimed at increasing individual profit shares and added net contribution margins. Therefore, partnering in an airline alliance does serve as a means to an end. This is largely an instrumental way of looking at alliances. It is intuitive that cooperation and partnering go along. However, it may well be contraintuitive that competition among partners is arising along the same train of thought: Not all the partners in airline alliances are alike. As a matter of fact, they group into several segments within an alliance system. As a result, some partners do profit more from their cooperation in an alliance system that do others (see picture 2).

Fig. 2. Economic rivalries among partners within airline alliances are based on uneven allocation on aggregated contribution margins
Rys. 2. Ekonomiczna konkurencja pomiędzy partnerami w obrębie sojuszy linii lotniczych spowodowana nierówna alokacją zagregowanych marży

To increase the volume of aggregated contribution margins, carriers aim to dissolve wing-to-wing-operations, aim to intensify bilateral cooperation among partners by means of increased code shares, and aim to deepen bi- or trilateral partnerships among members of alliance systems by establishing cost-, risk-, and/or revenue sharing models. All of this is basically meant to improve the individual position of any carrier engaging in such activities. In other words, the individual goal system remains to be dominant.

For that some partners gain more from partnering in an alliance than others, rivalry emerges. This rivalry focuses on competition for (business) travellers and for a more evenly balanced cost-, risk-, and/or revenue sharing mechanism. Cooperation and competition emerge almost simultaneously, which is depicted in the term "coopetition". Both patterns do not represent alternatives. Moreover, one does not go without the other - as two sides of a coin. While the economic motivation for coopetition is based on allocation mechanisms, legal constraints remain unweighted in this article. However, with respect to legal aspects, coopetition might be even fierce.

Leading international network-carriers try to measure the level of coopetition. For example, a "coopetition index" might help to determine each partner's position in a portfolio of appreciated cooperation and accepted competition. The coopetition index itself may consist of a cooperation index on the one hand and of a competition index on the other. Several indicators may be employed to measure cooperation, while several other indicators (or even the same) may be utilized to measure competitive artefacts.

Each partner is monitoring their partners and is tracking cooperation and competition indices for each of them. For cooperation indicators, there are minimum requirements and standards of partnership that have to be met. For competition indicators, there are maximum allowances that must not be topped. If measured regularly, partners will receive an idea about what kind of level of coopetition to expect from their partners over time (see picture 3). In its simplest way, this mode is being measured in a two-dimensional scaling system. However, multi-dimensional scaling models to measure coopetition are feasible and applicable.

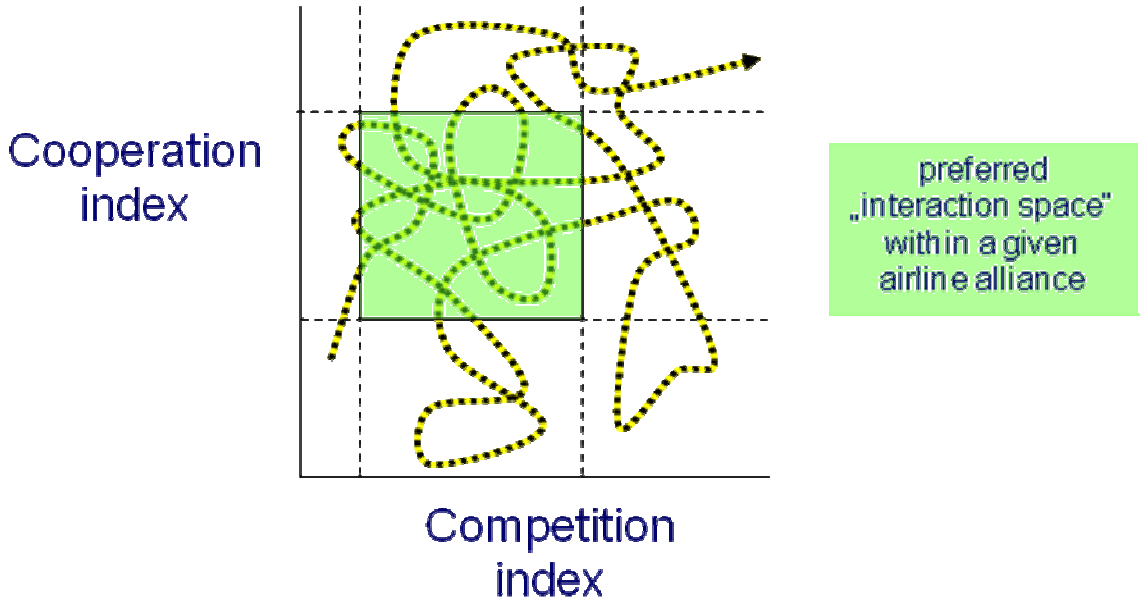

Fig. 3. Management of strategic coopetition within a frame of cooperation and coopetition by setting minimum requirements for cooperation and maximum allowances for competition within airlines alliances
Rys. 3. Zarządzanie strategią konkuperacji w ramach kooperacji oraz konkuperacji poprzez wyznaczanie minimalnych wymagań dla kooperacji oraz maksymalnych możliwości konkurencji w obrębie sojuszy linii lotniczych

SUMMARY AND OUTLOOK

Network-carriers aim to serve markets across all five continents. In order to maximize their revenue streams, changes in strategic slot allocation and strategic net planning are becoming increasingly relevant. For that, this kind of optimization is hard to execute on an individual basis, however, carriers need to team up. Within alliance systems, cooperation is a pure instrumental play. It does not surprise that some profit more from it than others.

Rivalry still exists, for that, there are no specifically dedicated fleets per cooperation. In other words, for that carriers do not allocate specific portions of the aircraft fleets to any given cooperation, sharing models of almost any kind fall short of completely eliminating uneven allocation of additional revenue derived from common optimization.

Two extreme scenarios may be projected: On the one hand, partners within a given alliance system may start to increase merger and acquisition activities. Thereby scale effects may be utilized. On the other hand, if rivalry becomes too dominant over time, some partners may (have to) exit alliance systems. Thereby "atomic" subsystems may be on the rebound. Strategic coopetition management is aimed to keep leading international network carriers "on track" in the field of alliance management of that nature.

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ZARZĄDZANIE STRATEGICZNĄ KONKUPERACJĄ POMIĘDZY PARTNERAMI MIĘDZYNARODOWYCH SOJUSZY LOTNICZYCH

STRESZCZENIE. **Wstęp**: Międzynarodowa sieć połączeń lotniczych obejmuje swym zasięgiem cały świat, łącząc lotniska znajdujące się na wszystkich pięciu kontynentach. Bazą tych sieci są wielkie porty lotnicze, służące jako centra (między-) narodowych przepływów. Z punktu widzenia modelu biznesowego, większość międzynarodowych przewoźników jest tak zwanymi przewoźnikami sojuszy linii lotniczych, zaś koncepcja ich działalności opiera się na systemach typu hub-and-spoke. W celu maksymalizacji przychodów przewoźników należących do sieci, konieczność zmian w strategicznej alokacji slotów oraz strategicznego planowania sieciowego wydaje się nieodzowna.
Celem pracy była analiza wpływu różnych elementów zarządzania strategicznego konkuperacji między partnerami w międzynarodowych sojuszy linii lotniczych na przychody uzyskiwane przez poszczególnych partnerów.
Metody: problemy związane z optymalizacją strategicznej alokacji slotów jak również strategicznego planowania sieciowego z punktu widzenia zysków uzyskiwanych poprzez poszczególnych partnerów zostały poddane dyskusji.
Wyniki i wnioski: Dwa skrajne scenariusze mogą zostać przyjęte. Pierwszy z nich zakłada, że partnerzy w ramach danego systemu sojuszu wzmogą działania na rzecz fuzji i przejęć. W ten sposób efekt skali działania może zostać wykorzystany. Drugi scenariusz dotyczy sytuacji, kiedy rywalizacja staje się zbyt dominująca i niektórzy partnerzy mogą (muszą) zrezygnować z uczestnictwa w sojuszu. Tym samym mogą zacząć przeważać tzw. systemy "atomowe".
Celem strategicznego zarządzanie konkuperacją jest utrzymanie wiodących międzynarodowych przewoźników w sojuszach linii lotniczych, do których należą.

Słowa kluczowe: przewoźnikcy lotniczy, port lotniczy, slot, alokacja czasu, konkuperacja, sojusz linii lotniczych.

MANAGEMENT VON STRATEGISCHER KOOPKURRENZ IN INTERNATIONALEN LUFTVERKEHRSALLIANZEN

ZUSAMMENFASSUNG. Einleitung: Im internationalen Passangerlinien-Luftverkehr verbinden global agierende Netzwerk-Carriers international dezentralisierte Hauptverkehrsregionen aller fünf Kontinente über zentralisierte Hub-and-Spoke-Systeme. Jeder Netzwerk-Carrier versucht entsprechend als Leistungsanbieter, kritische Slots in jedem dieser Märkte einzunehmen. Die dabei zugrundliegende Marktdefinition weicht von typischen Marktbegriffsfassungen ab: im internationalen Passangerlinien-Luftverkehr versteht sich ein Markt als ein Zielort (d.h. Destination) zu einer gegebenen, bestimmten Zeitenlage (d.h. Slot). In dieser Sicht ist es nicht immer problemlos, sofern ein Netzwerk-Carrier einen spezifischen Slot für eine in seinem strategischen Fokus stehende Destination aufbauen möchte. Aus diesem Grund kooperieren Netzwerk-Carrier in internationalen Luftverkehrsallianzen, um diese strategischen Ressourcen einander verbessert zugänglich zu machen.
Das Ziel der Arbeit war es, den Einfluss der unterschiedlichen Elemente des strategischen Managements im Rahmen einer Koopkurrenz zwischen den Partnern der internationalen Luftverkehrsallianzen auf die von den einzelnen Teilnehmern notierten Einnahmen einer Analyse zu unterziehen.
Methoden: Es wurden die Probleme mit der Optimierung des strategischen Slot-Managements sowie der strategischen Netzwerk-Planung unter dem Gesichtspunkt der von den einzelnen Partnern erzielten Gewinne projiziert und durchdiskutiert.
Ergebnisse und Fazit: Es können zwei Randszenarien betrachtet werden. Das erste nimmt an, dass die im Rahmen eines Verbunds wirkenden Partner ihre Aktivitäten auf die Fusionen und Übernahmen ausrichten. Auf diese Art und Weise kann der Effekt der Wirkungsskala erzielt und ausgenutzt werden. Das andere Szenario bezieht sich auf die Situation, in welcher der Wettbewerb allzu sehr dominierend wird und deswegen manche Partner auf die Teilnahme an der Allianz verzichten können (müssen). Somit können die sog. "Atom"-Subsysteme an Übergewicht gewinnen.
Als Ziel des strategischen Managements der Koopkurrenz erscheint also die Aufrechterhaltung der führenden, kooperierenden Netzwerk-Carriers in internationalen Luftverkehrsallianzen, denen sie angehören.

Codewörter: Netzwerk-Carrier, Flughafen, Slot, Allokation der Zeitenlagen, Koopkurrenz, Luftverkehrsallianz.

Prof. Dr. habil. Frank Himpel
Betriebswirtschaftslehre, insbesondere Logistik und Produktionswirtschaft
Hochschule Anhalt
Strenzfelder Allee 28
D-06406 Bernburg (Saale)
e-mail: f.himpel@wi.hs-anhalt.de

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SUPPLY CHAIN RELIABILITY MODELLING

Eugen Zaitsev

St.Petersburg State University of Engineering and Economics, St.Petersburg , Russia

ABSTRACT. Background: Today it is virtually impossible to operate alone on the international level in the logistics business. This promotes the establishment and development of new integrated business entities - logistic operators. However, such cooperation within a supply chain creates also many problems related to the supply chain reliability as well as the optimization of the supplies planning.
The aim of this paper was to develop and formulate the mathematical model and algorithms to find the optimum plan of supplies by using economic criterion and the model for the probability evaluating of non-failure operation of supply chain.
Methods: The mathematical model and algorithms to find the optimum plan of supplies were developed and formulated by using economic criterion and the model for the probability evaluating of non-failure operation of supply chain.
Results and conclusions: The problem of ensuring failure-free performance of goods supply channel analyzed in the paper is characteristic of distributed network systems that make active use of business process outsourcing technologies. The complex planning problem occurring in such systems that requires taking into account the consumer's requirements for failure-free performance in terms of supply volumes and correctness can be reduced to a relatively simple linear programming problem through logical analysis of the structures. The sequence of the operations, which should be taken into account during the process of the supply planning with the supplier's functional reliability, was presented.

Key words: supply chain, optimization of planning, functional failure, structural reliability.

INTRODUCTION

Today it is virtually impossible to operate single-handedly on the international level in the logistics business. This promotes establishment and development of new integrated business entities - logistic operators who actively use business process outsourcing in supply management - in the global market for logistic services. The advantages of such outsourcing in supply chain (SC) management are obvious, and demand for this technology in the mature US and European markets is steadily growing. At the same time, efficiency of this technology largely depends on confidence and coordination in relations and operations of all supply chain partner companies. Economic vulnerability of such entities lies in the risk of SC disruptions at the boundaries of functional areas. Such disruptions cause breaches of contractual obligations related to supply timeliness (JIT - Just in Time), sequence (JIS - Just in Sequence) and completeness (capacity, JIC - Just in Capacity), and can be viewed as SC failures. The economic impact of such failures is usually substantial both for the focus company and for the partner companies. This is what makes transition from qualitative analysis of SC risks in the context of classic risk management to quantitative analysis based on the general systems reliability theory models and methods so relevant. The need for quantitative evaluation of SC risks has already been recognized by major logistic companies, manifesting itself in wider standardization of requirements for supply quality and reliability both for the purposes of attracting new customers and establishing specifications to be met by suppliers of goods and services (Tables 1, 2). Ensuring supply reliability is becoming one of the highest priorities in modern day logistics.

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The aim of this paper was to develop and formulate the mathematical model and algorithms to find the optimum plan of supplies by using economic criterion and the model for the probability evaluating of non-failure operation of supply chain.

Table 1. Service quality indicators
Tabela 1. Wskaźniki poziomu obsługi klienta

Indicator	**Value**	**Company**
Delivery timeliness	98 %	3M
Ideal order: Timeliness & Completeness & Payment	90 %	Procter&Gamble
Requirements for suppliers: just-in-time delivery	99.5 %	Philips Sem.
	98 %	Sequent Comp.
Perfect order: Correctness & Completeness & Accuracy	98 %	Hewlett-Packard
Guaranteed delivery time (UK)	days	RS Components
Total cost of supply process ownership (TCO): supplier ranking score	points	Sun Microsystems

Table 2. Supply quality and reliability requirements standardization practice
Tabela 2. Metody standaryzacji jakości dostaw i wiarygodności zapotrzebowań

Company	Risk factor	Factor value (permissible, planned, required)	Process reliability (failure-free performance)
Tesco (UK)	Permissible delay in delivery	0.5 h	0.985
	Order configuration correctness	0.5 %	0.995
Vision Express (UK)	Time taken to deliver the goods to the customer	1 h	0,95
Nissan (UK)	Number of defective (faulty) articles in the delivery	0.005 %	0.99995
Royal Mail (UK)	Probability of delivery within one day	-	0.9
Saturn	Permissible delay in delivery	0.25 h	-
Siemens EMS	Percentage of the supply plan accomplished by the established deadline	98 %	0.98

SUPPLY CHAIN FAILURE CONCEPT AND GENERAL APPROACH TO SUPPLY PLANNING

Failure is the key concept in the systems reliability theory. Let us assume that a SC failure means an event consisting in non-fulfilment of goods delivery obligations under any contract clause constituting a risk factor (time, volume etc.) due to a disruption in the SC. For our purposes, it is practical to view the SC from the process and operational standpoint rather than in the traditional object/function context (supplier, manufacturer, intermediary etc.). I.e. the supply chain should be analysed as a sequence of interconnected processes through which the focus company fulfils its contractual obligations related to delivery of goods from the supplier to the end consumer using the well-known 5-process SCOR model [15]. This approach to SC representation and analysis is fully consistent with the process control methodology and ABC (Active Base Costing) process-by-process costing technology. Besides, it allows clearly formalizing the task of providing supply channel redundancy based on the reliability requirements using the systems structural reliability theory models.

Let us consider a situation that can occur when the JIT (Just in Time) technology is implemented. Let us assume that deliveries are consolidated into one shipment. A functional failure is defined as an event where planned time t0 for the delivery of an order with the volume of Q_0 is exceeded. Let $F(t > t_0)$ be the probability of exceeding the planned time needed to process the entire order, and $P_0(t_0)$ - the specified probability of failure-free operation. To ensure this level of failure-free performance, we need to create a network of n channels by analysing the supplier market and evaluating their potential functional capabilities. The functional condition of failure-free operation of the *i*-th supply channel will be defined by the following expression:

$$t_i = \frac{Q_0}{\lambda_i} \le t_0,$$

where λ_i - potential supply rate through the i-th channel.

The above formula shows that two channel types can exist in the network: primary channels with the possible supply volume of $q_i = \lambda_i t_0 \ge Q_0$ and auxiliary channels that cannot handle the necessary supply volume within the planned time by themselves. Auxiliary channels can be combined into chains subject to the following condition:

$$t_j = \frac{Q_0}{\sum_j^k \lambda_j} \le t_0, \quad k < n.$$

A supply network with a serial-parallel structural reliability scheme is created from the primary channels and auxiliary channel chains. Optimal supply plan $\{Z_i\}^n$ is found by solving the following mathematical programming problem:

$$S = \sum_{i=1}^{n} C_i Z_i \to \min$$

subject to the following limitations:

$$\sum_{i=1}^{n} Z_i = Q_0, \quad 0 \le Z_i \le q_i \quad (i = \overline{1,n}), \quad P(t \le t_0) \ge P_0(t_0),$$

where:

C_i, q_i - cost price and possible volume (capacity) of supply through the *i*-th chain, respectively ($q_i = \lambda_i t_0$);

$P(t \le t_0)$ - failure-free performance of supply determined using the structural reliability model.

SUPPLY CHAIN PROCESS MODEL

The classic process model of SC management (Figure 1) based on the minimum cost criteria with independent processes and the specified failure-free performance requirement looks like the following:

$$S_\Sigma = \sum_{i=1}^{n} \sum_{j=1}^{m} S_{ij} X_{ij} \to \min \qquad (1)$$

subject to the following limitations:

$$\sum_{j=1}^{m} X_{ij} = 1, \qquad i = \overline{1,n};$$

$$\prod_{i=1}^{n} \sum_{j=1}^{m} P_{ij} X_{ij} \ge \beta;$$

where:

n – number of processes,

$m = \max \{k_i\}_n$,

k_i - number of possible alternatives (strategies) for implementation of the ***i***-ith process,

S_{ij} – costs of the i-th process in the SC during implementation of the j-th strategy,

$\{S_{ij}\}_n^m$ - process cost matrix,

β – specified (required) SC failure-free performance (probability of failure-free SC operation),

P_{ij} – probability of failure-free implementation of the j-th strategy in the i-th process,

$\{P_{ij}\}_n^m$ - failure-free operation probability matrix,

X_{ij} – binary variable (selection variable) that takes the value of 0 or 1.

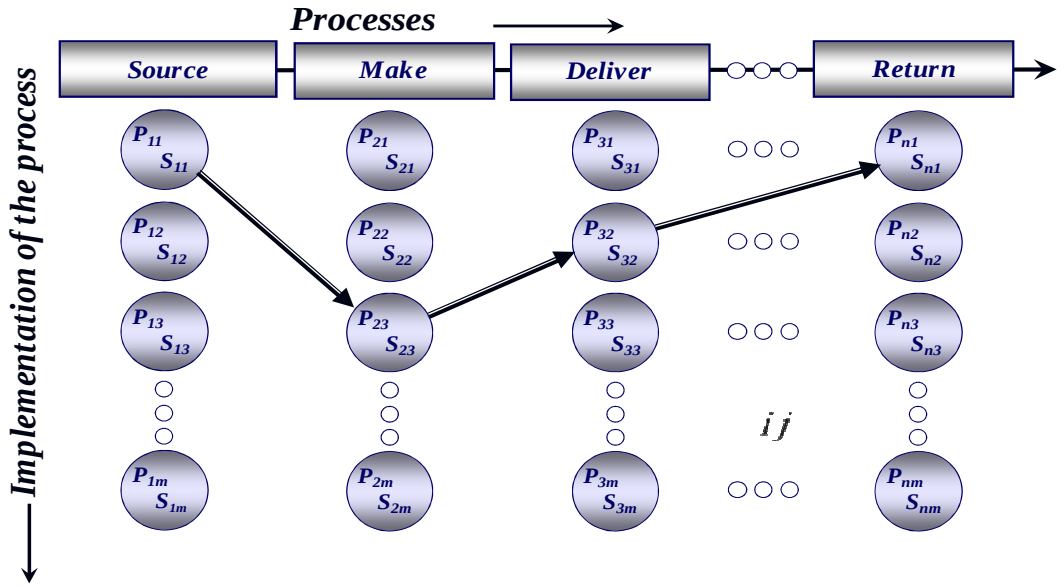

Fig. 1. Business process selection diagram
Rys. 1. Schemat procesu dokonywania wyboru

An additional limitation of individual process reliability in the SC can be introduced into the model:

$$\sum_{j=1}^{m} P_{ij} X_{ij} \geq \alpha_i, \qquad i = \overline{1,n};$$

where: $\{\alpha_i\}_1^n$ - process failure-free operation limitation vector ($i = \overline{1,n}$).

The solution is found as a non-vanishing vector from matrix $\{X_{ij}\}_n^m$.

Model (1) requires an excess of offers in the business process market, which is not always the case in practice. If it is impossible to select a set of processes that would ensure the required SC reliability, a model that allows maximizing the SC reliability within the given cost limitations can be used:

$$\prod_{i=1}^{n} \sum_{j=1}^{m} P_{ij} X_{ij} \rightarrow \max,$$

$$S_{\Sigma} = \sum_{i=1}^{n}\sum_{j=1}^{m} S_{ij} X_{ij} \le S_0, \sum_{j=1}^{m} X_{ij} = 1, \quad i = \overline{1,n};$$

where: S_0 - budget limitation.

STANDARDIZATION OF RELIABILITY REQUIREMENTS

The use of model (1) poses certain difficulties since statistical studies are necessary to obtain objective evaluations of matrix $\{P_{ij}\}_n^m$. At the same time, when designing the SC, one needs to solve the problems of selecting service (i.e. process) providers based on the end consumer's supply reliability requirements β. In other words, the problem of standardizing failure-free process performance requirements emerges. Let us consider the algorithm of solving this problem, assuming that the processes are independent, and the failure flows are simple.

Based on the primary reliability equation, we obtain:

$$P(t_\beta) = \exp(-\lambda_0 t_\beta) = \beta, \tag{2}$$

therefore:

$$\lambda_0 = -\frac{\ln(\beta)}{t_\beta}, \tag{3}$$

where:
$\boldsymbol{\lambda_0}$ – SC failure flow rate;
$\boldsymbol{t_\beta}$ – risk factor value (time, volume etc.) at failure-free performance level β.

If there are no processes with dominant failure rates in the SC, we can assume that:

$$\lambda_{ij} = \lambda_0 \omega_{ij}, \tag{4}$$

where:

$\boldsymbol{\lambda_{ij}}$ – ***i***-th process failure rate under the ***j***-th implementation strategy,
$\boldsymbol{\omega_{ij}}$ – weight factor of the contribution of the ***j***-th strategy of the ***i***-th process to the total SC failure rate.

Taking into account (2), we obtain:

$$P_{ij} = \exp(-\lambda_0 \omega_{ij} t_\beta) = \exp[\omega_{ij} \ln(\beta)]. \tag{5}$$

The only thing left is to define weight factor matrix $\{\omega_{ij}\}_n^m$. Obviously, the more damage a failure of a particular process can cause, the higher the reliability requirements for that process should be. Damage can be measured in process recovery costs, losses in sale of goods etc. For example, costs can be assessed through turnover and tariff losses using the following formula:

$$R = Qd[1 - (1 - \frac{\delta}{100})(1 - \frac{\varepsilon}{100})],$$

where:
Q – turnover,
d – sale price,
δ, ε – turnover and price losses in %, respectively.

In this case, weight factors are inversely related to costs and are calculated according to the following formula:

$$\omega_{ij} = \frac{1}{R_{ij}\sum_{i=1}^{n}\frac{1}{R_{ij}}}, \tag{6}$$

where R_{ij} – costs related to failure in implementation of the ***j***-th strategy of the ***i***-th process.

GENERALIZED OUTSOURCING SUPPLY PLANNING MODEL

Ensuring the required failure-free performance in SCOR-type supply chain process models involves the need to provide supply chain redundancy. Let us consider a situation that can occur when the JIT technology is implemented. Let us assume that deliveries are consolidated into one shipment. A functional failure is defined as an event where planned time t_0 for the delivery of an order with the volume of Q_0 is exceeded. Let $F(t>t_0)$ be the probability of exceeding the planned time needed to process the entire order, and $P_0(t_0)$ - the specified probability of failure-free operation. To ensure this level of failure-free performance, we need to create a network of *n* channels by analysing the supplier market and evaluating their potential functional capabilities. Let us assume that reliability requirement $P_0(t_0) = \varphi(p_1, p_2,...., p_n) \geq P_2^*$ (where $\varphi(p_1, p_2,...., p_n)$ - function determined by the structural reliability scheme (redundancy scheme); P_2^* - end consumer's supply reliability requirements) had been determined as a result of solving the standardization problem and has been agreed upon with the responsible supplier or supply operator (level 1 supplier). If the responsible supplier is unable to meet the contractual terms by itself, it creates a network of level 2 suppliers based on outsourcing principles. Those suppliers can, in turn, build level 3, 4 etc. networks based on the same principles. In this supply network failures mean independent events consisting in non-fulfilment of contractual obligations by one or several functional parameters - such as time, sequence, completeness or volume of supply.

Since a supply network can be made up of channels with different characteristics, the network structural reliability model will, in general, include both channels consisting of individual suppliers and supply chains or even entire sub-networks with a relatively complex (fractal) structure (Figure 2).

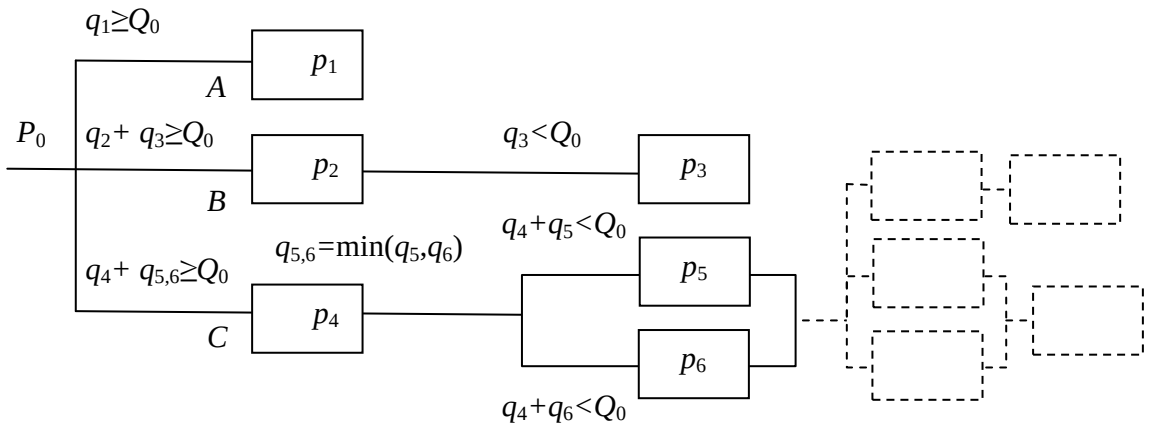

Fig. 2. Multi-level supply network structural reliability model
Rys. 2. Wielopoziomowy model wiarygodności łańcucha dostaw

For the customer, the problem of building a supply network turns into the problem of selecting the most economically sound channels that meet the requirements for functional parameters (such as

volume) and failure-free performance determined using the formula for the simple serial-parallel scheme:

$$P_0 = 1 - \prod_{i=1}^{m} (1 - \prod_{j=1}^{n} p_j)_i,\ m \le n,\ if\ x_{i,j}\ not\ 0,$$

where:

n – number of suppliers,

m – number of supply chains (channels),

$x_{i,j}$ – binary variable (selection variable) that takes the value of 1 if the capacity of *j* suppliers included in the *i*-th supply channel allows meeting demand $\sum_{j=1}^{n} q_j x_{i,j} \ge Q_0$ or the value of 0 – if not, i.e. $\sum_{j=1}^{n} q_j x_{i,j} < Q_0$. The binary variable is used to create *m* chains from *n* channels.

In a particular case where n = m the supply network structural reliability model consists of *n* channels with the capacity of $q_i \ge Q_0$ connected in parallel.

Therefore, it is suggested to use the logical-and-probabilistic analysis method to create multi-level supply network models with a complex structure.

CONCLUSIONS

The problem of ensuring failure-free performance of goods supply channel analysed above is characteristic of distributed network systems that make active use of business process outsourcing technologies. An essential condition is the availability of a mature logistic service market and intense competition in the market for business processes. The multi-level outsourcing model structure can be similar to that of a finite fractal. The complex planning problem occurring in such systems that requires taking into account the consumer's requirements for failure-free performance in terms of supply volumes and correctness can be reduced to a relatively simple linear programming problem through logical analysis of the structures. In general, to summarize the approach described in this article, supply planning with the supplier's functional reliability taken into account can be represented as a sequence of the following operations:

- Building a functional diagram of the network, with specification of all level 2 suppliers and their characteristics.
- Defining the failure concept and establishing the suppliers' functional capabilities criteria values based on the customer's requirements.
- Creating a serial-parallel scheme and a structural reliability calculation model based on the failure-free performance requirements and the supplier's functional capabilities.
- Determining the optimum supply plan that keeps the costs to the minimum while meeting the failure-free performance requirements.

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MODELOWANIE WIARYGODNOŚCI ŁAŃCUCHA DOSTAW

STRESZCZENIE. **Wstęp**: Obecnie nie jest możliwym prowadzenie działalności logistycznej o zasięgu międzynarodowym bez współpracy z innymi partnerami. Fakt ten doprowadził do powstawania i rozwoju nowych struktur organizacyjnych - operatorów logistycznych. Jednak taki typ współpracy w obrębie łańcucha dostaw stwarza możliwość występowania wielu problemów związanych z wiarygodnością tego łańcucha oraz optymalizacją planowania dostaw.
Celem pracy było opracowania matematycznego modelu dla znalezienia optymalnego planu dostaw przy zastosowaniu kryteriów ekonomicznych oraz modelu prawdopodobieństwa niezawodności łańcucha dostaw.
Metody: Model matematyczny oraz algorytmy wyznaczające optymalny plan dostaw został opracowany i sformułowany poprzez zastosowanie kryteriów ekonomicznych oraz modelu prawdopodobieństwa niezawodności łańcucha dostaw.
Wyniki i wnioski: Problem niezawodności łańcucha dostaw, który został poddany analizie w pracy, występuje często w sieciowych systemach dystrybucyjnych, stosujących metodę outsourcingu. Problem planowania występujący w takich systemach, które muszą uwzględniać wymagania klientów dotyczące niezawodności dostaw, może być zredukowany do relatywnie prostego zagadnienia programowania liniowego poprzez logiczną analizę struktur. Przedstawiono sekwencję operacji, które należy wziąć pod uwagę w procesie planowania dostaw przy uwzględnianiu funkcjonalnej wiarygodności.

Słowa kluczowe: łańcuch dostaw, optymalizacja planowania, porażka funkcjonalna, wiarygodność strukturalna.

MODELLIERUNG VON ZUVERLÄSSIGKEIT EINER LIEFERKETTE

ZUSAMMENFASSUNG. Einleitung: Es besteht heutzutage keine Möglichkeit mehr, eine logistische Aktivität von internationaler Reichweite ohne Zusammenarbeit mit anderen Partnern zu betätigen. Diese Tatsache führte zur Entstehung und Entwicklung von neuen Organisationsstrukturen - d. h. Logistik-Operateuren. Ein solcher Typ der Zusammenarbeit innerhalb einer Lieferkette generiert jedoch bestimmte Gefahren hinsichtlich der Glaubwürdigkeit und Zuverlässigkeit jeweiliger Lieferketten sowie hinsichtlich der Optimierung der Planung von Anlieferungen.
Das Ziel der Arbeit war es, ein mathematisches Modell für die Erstellung eines optimalen Zeitplans für Anlieferungen unter Benutzung von wirtschaftlichen Kriterien und des Modells der Wahrscheinlichkeit der Zuverlässigkeit einer Lieferkette auszuarbeiten.

Methoden: Das mathematische Modell und die den optimalen Anlieferungsplan bestimmenden Algorithmen wurden unter Benutzung von wirtschaftlichen Kriterien und des Modells der Wahrscheinlichkeit der Zuverlässigkeit der betrachteten Lieferkette konzipiert und effektiv formuliert.

Ergebnisse und Fazit: Die Frage der Zuverlässigkeit der in der Studie analysierten Lieferkette tritt oft innerhalb der Netzwerk-Distributionssysteme, welche die Outsourcing-Methode anwenden, auf. Das dabei in solchen, die Kundenanforderungen hinsichtlich der Lieferzuverlässigkeit zu berücksichtigenden Systemen auftretende Problem der Zeitplanung kann zur einer relativ einfachen Frage der linienmäßigen Planung bei Inanspruchnahme einer logischen Analyse von Strukturen reduziert werden. Es wurde eine Operationssequenz dargestellt, welche man im Prozess der Lieferplanung bei Berücksichtigung der funktionstüchtigen Zuverlässigkeit der Lieferkette in Betracht ziehen muss..

Codewörter: Lieferkette, Optimierung der Planung, funktionsmäßiger Ausfall, strukturelle Zuverlässigkeit.

Eugen Zaitsev
Doctor of Economics
Professor of Faculty of Logistics and Transportations
St.Petersburg State University of Engineering and Economics
St.Petersburg, Russia
e-mail: eiz@engec.ru

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THE DETERMINANTS OF FOREIGN INVESTMENT IN PAKISTAN: A GRAVITY MODEL ANALYSIS

Syed Waqar Azeem[1], Haroon Hussain[2], Rana Yasir Hussain[3]

[1)]Independent Researcher, [2)]Department of Commerce, University of Sargodha, Pakistan, [3)] University of Education, Lahore

ABSTRACT. Background: During the last two decades Pakistan was one of the most attractive countries that received Foreign Direct Investment (FDI) among developing economies, and especially in first half of the last decade the growth was so rapid and sustainable in different industries as well as in agriculture. In Pakistani economy the role of Foreign Direct Investment is very important. Policies are clear about the foreign investment even then adjustments are made according to the time, objective, needs and economic circumstances in the country.
Methods: The present study aims to investigate the determinants of foreign investment in Pakistan by using Gravity model. By using panel data of FDI which is used as dependent variable and Gross domestic product, Gross domestic product per capita, Gross domestic product growth rate, Inflation rate, Trade, Total government expenditure, Population growth and Distance used as independent variable from 1999 to 2009 for empirical consequences, the study encompasses the examination of Foreign Direct Investment inflows from different countries and their geographical distance from Pakistan.
Results: Two type of test is used (1) fixed and (2) random effect to check the relationship among foreign direct investment and independent variables. In our both models distance shows a negative impact on the decision to make an investment by investing partner while GDP and GDP growth have a positive and significant impact. Gravity in this regards does not effect that much for foreign direct investment attraction because results are negatively significant in this case that shows higher distance is a hurdle for the inflow of foreign investment but rest of the variables are significantly positive and related to the inflow of foreign investment except population growth which is negatively correlated.
Conclusion: This research concludes that there is a strong evidence of existence of gravity between Pakistan and its investing partners. It is also conclude that those countries have less distance from Pakistan, having more investment in Pakistan, therefore, attracting these countries for investment in Pakistan would cause a greater chance of economic growth in Pakistan.

Key words: gravity model, foreign investments, Pakistan.

INTRODUCTION

World is transformed into global village and the developing countries and developing countries also try to be part of this transformation. To overcome the scarcity of technology and capital therefore they always try to attract foreign investment inflow in their economy. Both the investor and the investee are having mutual benefit of foreign investment. The local market provides the facility of withdrawing the skill resources within the host country. This provides the employment opportunities to the local ones and this act of foreign direct investment (FDI) helped its contribution in the economic growth as compared to the local investment in the country. It is also said that external financing is one of the major sources of the foreign direct investment that contributes along with the savings of the host country. As foreign direct investment accompanies the technical know how, so this also help the host country to be more innovative in research and development (R&D) sector which also leads towards self dependency, higher GDP and at the end contribute in the expansion of exports, more employment and higher tax revenue for government [Mirza 2004]. In 1990s the global foreign direct investment grows significantly which shows rise of about 54000 transnational corporations. These corporation as

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recorded were responsible of global inflows to developing countries of almost average of 13% of total inflows from 1990-1997 [Carson C. S. 2003]. Over inflow of 70% and outflow of 94% is accounted by the developed countries of the world [International Monetary Fund 2003]. In the last couple of decades the trend of Regional Trading Agreements (RTAs) and Bilateral Trade Agreements (BTAs) have grown remarkably. A large number of World Trade Organization (WTO) Countries are the members of Regional Trading Agreements. World Trade Organization notified total 312 Regional Trading Agreements out of 170 are in position in 2005, whereas remaining are in operation [Rahman, Shadat & Das 2006].

Pakistan started to facilitate foreign investor and for this market based economic reorganizational policies are introduced in early 1980 and in late 1980s. At the same time government has also taken the start towards the liberalization of trade and investment attraction, like offering the generous fiscal and trade incentives to the upcoming investors like provision of credit facility, tax and tariff concessions as well as relaxing the control over foreign exchange [Khan & Kim 1999]. In start political stability, peaceful law and order situation, level of technical labor force and mineral resources and liberal policies of the government became main forces to attract foreign investors in Pakistan [Aqeel & Nishat 2005]. But later political instability rumors and inconsistent policies, electricity shortage and then law and order situation affect the inflow of foreign investment in Pakistan. These are the main contributors of very low foreign investment in last couple of years. The economic policies of Pakistan shows heavy reliance on foreign investment, this decade brought significant amount of 22881 million dollars of FDI in Pakistan. The specific objectives of this research include; evaluation of the foreign investment in Pakistan, to evaluate the determinants of foreign investment inflows into Pakistan using Gravity Model and to the improvement of investment climate in Pakistan for the attraction of FDI, policy recommendation are provided to the makers of policy.

As this is one of the main concerns of government to increase foreign direct investment inflow in country. Panel estimation with the help of gravity model is done to see the inflow of foreign direct investment from different countries and see the impact of different determinants on the policies to make investment in Pakistan. This study targets GDP growth, GDP p/c, Inflation and the distance as main factor which may influence the decision of investing partner to invest and see what should be done to increase the trend of FDI inflow in Pakistan, as Pakistan was an emerging market for foreign investment, therefore an empirical solution is needed to find out the rational of liberalization and deregulation and its impact on FDI, this study tries to provide the answer to all these problems.

LITERATURE REVIEW

Foreign investment plays an important role in the development of the any country, foreign investment not only provide the capital necessary for the growth but also helps out by providing job opportunities to the people of host countries. Foreign direct invest and foreign portfolio investment are the two kinds of foreign investment, where direct investment relates investment of a country or MNEs multinational enterprises in a particular field while portfolio investment focuses to invest in different fields. From home to host country attraction of foreign investment heavily rely on some incentives and factors that could include tax exemptions, market size, demand of investment in particular investing area, expectation of return, political environment etc. According to Razin and Loungani [2001] foreign direct investment faces a threat of being reversed to home country through financial transaction and benefits are limited by leverage. They also point out that FDI excess in total country's capital reflects weakness rather strength. Habib and Zurawick [2002] study examine the impact of corruption on foreign direct investment (FDI), panel data of 89 countries including developed and developing countries is used. Two models are used OLS regression and PROBIT. The result provides support for the negative impacts of corruption and foreign direct investment (FDI). The findings leads that the foreign investors usually stay away from corruption because it is taken as a wrong and it guide towards the operational inefficiencies. FDI helps out the countries that are very much behind in innovation and technology because of FDI the investing countries shift somehow the technology for the operation purposes in host countries. The shifting of that technology gives the opportunities to the

host countries to excel in the innovation and technology field. Hejazi and Pauly [2003] study keep focus on the changing pattern of foreign direct investment (FDI) and its impact on the domestic gross fixed capital formation (GFCF), they regress the data of 15 available Canadian industries over the period from 1984 to 1995. They find that the increase in inflow of foreign direct investment (FDI) contributes to domestic capital formation, on the other case increased outward flow of FDI reduces it, and this generalization is inappropriate. They find that rapid growth in outward FDI, relative to inward growth, should not be considered as a negative development, and may reflect success. Empirical identification of determinants of growth in foreign direct investment in Pakistan from 1961 to 2003 by using different variables like GDP, Wages, Tariff and Exchange rate and also indicators that reflects trade, fiscal and liberalization in financial sector that helps in the attraction of FDI in Pakistan [Aqeel and Nishat 2005]. They use co-integration and error correction techniques, results indicates that the share price index and wage rate are insignificants for the attraction of FDI while others are, besides the policy of attraction of FDI on both long and short run in Pakistan. The base of gravity model is linkage and interaction of different countries across border. This model has indirect relationship between the destination and base. Ratnayake and Townsend [1999] applied the Gravity Model to analyzing the geographical pattern of international trade. The researcher had worn the concept of the Gravity Model from Anderson [1979] and Bergstrand [1985] to convey the function of variables representing the supply and demand conditions of exporters and importers and trade resisting and promoting factors. The findings of the researchers showed that distance and exporter and importer incomes are highly significant in all year's estimated (1987-1992). The coefficient for the exporter population is also highly significant. However, the coefficient for the importer population is major in only three out of six years. The dummy variable is positive in all years as expected, but it is considerably different from the relationship among group members. The Gravity Model can estimate the cause of international trade on international debt [Rose and Spiegel, 2004]. Rose and Spiegel estimated a wealth of potential variables. Their study showed a significantly positive effect of bilateral trade on bilateral lending patterns, debtors tended to borrow more from creditors with whom they shared more international trade ties. Africano and Magalhães [2005] study the relationship between FDI stock and geographical prototype of flow of trade in Portuguese economy. The gravity model applied to trade between Portugal and organization of economic cooperation and development countries including Brazil of two year from 1998-2000. The attraction of inflow of FDI is positively associated with the trade and closely linked between two countries. Due to increase inflow of FDI reflects its strength in the shape of increasing the export as compared import and this helps the country to maintain a good trade balance. Outflow of FDI has no significant impact on exports and imports of Portugal. They also find out that FDI helps to maintain above normal exports to other countries and EU while below normal imports from the candidates countries.

THEORETICAL FRAMEWORK

Foreign investment flows from home to host country which have several reason of flowing like low labor cost, low material, tax exemptions, market size and possibility of growth etc. one of the basic aim of every investor is to maximize the profit so that's why keeping in view of highest return the foreign investment travels from home to host country. The investing firms and countries keep a close look on the abundance of the resources the host one have and lack of competition because of lower quality of production. Electric paradigm is theory of economics that analytically views all the researches and studies of foreign direct investment and international production. Internationalization theory is the base of Electric paradigm which includes specific factors by location of different countries from the determination of foreign investment. Internationalization theory itself base on transaction cost theory and according to that theory internationalization is when transaction cost in free market is higher than within institution [Dunning 1980]. Resource-Based Theory, Grant [1980] states that competitive advantage can be gained by the business according to their market share by keeping in view of two things where and how to compete. The competitive advantage can be defined as the advantage that a firm have in particular field over its competitors. Internal and external forces help

a lot for the attainment of Competitive advantage [Barney 2001]. According to the Resource-Based Theory, firms can beat their competitors even if they have short, rare and unique resources by improving their performance of using those resources that is how the competitive advantage can be attained. For the better use of resources, resources are the base like financial, human resource and organizational resources. Definition of network as described by Porras, Clegg, & Crawfor, [2004] is "a long-term relationship between organizations as actors that share resources to achieve negotiated actions for joint objectives". The idea behind of networks is to bring FDI and explore those resources which are still waiting to exploit. Networks are one of the biggest ways to attract FDI and will help towards sustainable development and attaining the competitive advantage. These advantages are attaining expertise in the business field, market intelligence etc. [Chen and Chen 1998, Gulati, Nohria, & Zaheer 2006]. Newton's law of Gravitation is the base of resemblance of gravity model which is used for the prediction of commodities and movement information between different countries and distances among them [Rosenberg 2004]. The base of gravity model is linkage and interaction of different countries across border. This model has indirect relationship between the destination and base.

William J. Reilly set up the Reilly's Law of Retail Gravitation in 1931.

Written as

$$F_{ij} = \frac{A\, M_i\, M_j}{D_{ij}}$$

where:

F_{ij} is the gravity forces

M_i and M_j are the national incomes in country *i* and *j*, respectively,

D_{ij} is the distance between country *i*,

A is a constant of proportionality.

METHODOLOGICAL NOTES AND DATA SOURCES

Previously, many studies target to see and evaluate the determinants of foreign investment and effect of gravity on the inflow of foreign investment. This study also tries to see the influence of different factors on FDI inflow in Pakistan. Gravity model has been used by many researchers to analyze the role of different factors to attract FDI inflow in different economies but in Pakistan yet no research made for the determinants of foreign investment using Gravity model. Therefore this study may a driving force to start research on this issue in Pakistan.

DATA SOURCES

This study evaluates determinants of FDI by using gravity approach. FDI is dependent variable and GDP, GDP Per Capita (PCGDP), GDP Growth Rate, Inflation Rate, Trade, total government expenditure (TOTGOVEXP), population growth (POPGR) and Distance are independent variables. The data source for the foreign direct investment which is dependent variable and of trade which is independent variable is board of investment of Pakistan (BOI) while data for the independent variables GDP, GDP Per Capita (PCGDP), GDP Growth Rate, Inflation Rate, total government expenditure (TOTGOVEXP), population growth (POPGR) are taken from world development indicators [WDI 2007].

THE FIXED AND RANDOM EFFECT MODELS

This research tries to investigate of causal impact of foreign investment determinants with Gravity model by using panel data and for this purpose it uses fixed and random effect models to analyze its research problem. As discussed earlier, that a lot of researches also successfully tried to show a significant impact of foreign investment determinants on the economic growth e.g. Anderson [1979], Bergstrand, [1985] and Africano and Magalhães [2005] analyzed the impact of determinants with the help of gravity model by using panel data, at the same time many other researchers also showed the impact of foreign investment determinants on the economic growth in cross section framework that involves the estimation of single cross country regression. Thanyakhan, [2008] study used the fixed effect and random effect model, the importance of determinants of foreign investment cannot be ignored. However the primary use of the applying random effect model is its thriftiness and it added only a single to the model. On the other hand some researchers prefer to use fixed-effect models only when inferences are being made about the sample under consideration but prefer Random effect models when making inferences about larger population and if there is possibility to have some nuisance parameters, this decision rule is not relevant and this study focus on both random as well as fixed effect methods.

This present study focuses on fixed and random effect models both, purpose is to analyze the determinants of foreign investment: a gravity model approach. After the investigation of fixed and random effect, this study will also focus to see the causal relationship of foreign investment and gravity. This research focuses on to scrutinize the determinants of foreign investment in Pakistan. For this purpose it uses both theoretical base evidence and data base approach. The theoretical findings reveals that the FDI in Pakistan is function of GDP, GDP Per Capita, Wage Rate, GDP Growth Rate, Inflation Rate, Trade, total government expenditure (TOTGOVEXP), population growth (POPGR) and Distance plays an important role in defining gravity for FDI in Pakistan. On the other hand, Gravity model for panel data helps to analyze the theoretical findings with the help of available data. This gravity model is very famous among researcher to evaluate FDI in many countries and they estimate the cause of international trade on international debt with the help of this model. As Rose and Spiegel [2004] applied gravity model and estimate a wealth of potential variables with the help of trade, exchange rate, inflation, geographical distance and market size (GDP, GDP Per Capita, and GDP Growth Rate) with same pattern. This study also focuses on the factor which initiate foreign investment in Pakistan, therefore takes Pakistan as a host country and 9 major investing countries which invest in different sectors of Pakistan. The gravity model called for its analogy with Newton's law of universal Thanyakhan [2008] used the gravity equation for the determination of FDI and FPI The study use Thanykhan's model to check the gravity and intensity of impact of different variables on foreign investment in Pakistan.

$$FDI = f\ (GDP, CAP, GDPGR, D, T, X, INFL)$$

For estimation purposes, the extended gravity equation for FDI inflows into Pakistan applied in log-linear form expressed as follows:

$$\ln FDI_{it} = \alpha + \beta_1\ (GDP_{it}\ X\ GDP) + \beta_2\ (PCGDP_{it}\ X\ PCGDP_t) + \beta_3\ (GDPGR_{it}) + \beta_4\ DIS_{it} + \beta_5\ TRADE_{it} + \beta_6\ INFL_{it} + \beta_7\ TOTGOVEXP_{it} + \beta_8\ POPGR_{it} + \varepsilon_{it}$$

Whereas FDIit represents the bilateral flow of FDI inflow from investing partner *i* to Pakistan in year *t* that is dependent variable in this study, *GDPit* is the gross domestic product of investing partner *i* in year *t*, *GDPt* is the gross domestic product of Pakistan in year *t*, *PCGDPit* is the gross domestic product per capita of investing partner *i* in year *t*, PCGDPt is the gross domestic product per capita of Pakistan in year *t*, GDPGRit is the gross domestic product growth rate of investing partner *i* in year *t*, DISit is the geographic distance between investing partner *i* and Pakistan, *TRADEit* is the total amount of imports and exports between investing partner *i* and Pakistan in year *t*, *TOTGOVEXPit* represents

the total government expenditure in year *t*), *INFLit* is inflation rate of investing partner *i* in year *t*, *POPGRit* represents the population growth both in host and investing partner it is error term.

FOREIGN INVESTMENT IN PAKISTAN

Historically, economy of Pakistan is heavily dependent on the foreign direct investment inflows from United States, Switzerland, Germany, Japan and Saudi Arabia. That is accounted for about 50% of all foreign direct investment inflows. This geographic pattern of foreign direct investment remains almost constant except the inclusion of more countries U.A.E and China from 1998 and there portion increased especially from 2000. And a new geographical diversified pattern of foreign direct investment inflows countries evolves that includes United States, Switzerland, Germany, Japan, U.A.E, China and Saudi Arabia. Pakistan is opened itself for international community for investment especially in early new millennium.

Table 1 shows the last decade distribution of foreign direct investment flows to Pakistan since 2001. Foreign direct investment inflow just started with 484.7 $ million in 2001towards Pakistan and started exceed and became 786 $ million and pace continues till 2007-08 when foreign direct investment of 5409 $ million came in Pakistan. This was highest of the decade and then sudden decline in FDI inflow in 2008-09 when Pakistan able to attract foreign direct investment of 3719.9 $ millions which was about 31 percent less of last year and same trend shows on 2009-10 [BOI 2010]. Pakistan be able to attract of 310.5 $ millions FPI in 2009-10 which is of 6 months. The reason of decline in FDI and FPI is of financial crisis in world and the power scarcity in Pakistan as well as terrorism, with continues improvement in worlds economies will leads toward improvement of foreign direct investment and foreign portfolio investment in Pakistan as well [economic survey 2010]. Due to weak economic condition and import oriented culture exist in Pakistan that is one of the major causes of deprecation of rupee against dollar that depreciated up to 41 percent against dollar since 2005-06 [SBP, 2010].

Table 1. Growth Indicators
Tabela 1. Wskaźniki wzrostu

Indicators	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**
Population (millions)	139.9	144.7	148.1	153.55	159.3	162.91	166.41	169.94	173.51
GDP growth rate	3.1	4.7	7.5	9.0	5.8	6.8	3.7	1.2	4.1
Inflation Rate (%) CPI	3.54	3.10	4.57	9.28	7.92	7.77	12	22.35	11.49
Exchange rate (Rupee per 1 US $)	-	-	-	-	60	62	72.5	80	84.5
Inflow FDI (in US $ million)	484.7	798.0	949.4	1523.9	3521.0	5139.6	5409.8	3719.9	1012.3 July-Dec
Portfolio inflow (in US$ million)	-	-	-	-	-	-	-	-163.8	310.5
Interest rate %	-	-	-	-	9.5	10	15	14	12.5

Source: Economic Survey of Pakistan 2009-10

AN ECONOMIC OVERVIEW OF PAKISTAN

Pakistan's real GDP rose by 7.5% in 2003-04 and increased to 9% in 2004-05 that is highest in whole decade [Economic survey, 2009-10]. Growth in 2005-06 was 5.8% and inflation was 7.92% in 2005-06 while in previous year 2004-05 it was 9.28%, comparing to 2005-06 a decrease is shown of 0.15% and becomes 7.77% in 2006-07 (see Table 1). In order to control inflation interest rates hikes up to 15% this is the highest level of the decade in 2007-08. The purpose was to control the money supply inflation was 12% but in the following year it became 22.5% when the interest rate was 14% in 2008-09. Since 2001-02, economic performance of Pakistan started towards recovery and growth rate GDP was started to claim and in 2004-05 it was at 9% and till 2007 it was quit handsome. In 2008, with the start of financial crisis Pakistan's growth rate also squeeze down and in 2008-09 it was just 1.2% the contributor in this very low growth rate was energy crises too that is still running out. In 2009 -10, the sector wise contribution towards growth is as: services contributed 59% total growth of the year while industry 30% and agriculture 11%. Manufacturing sector contributed 23% of total growth for the year followed by Wholesale & Retail Trade (21%), and Social & Community Services (19%).

Table 2. GDP growth: Sectoral contribution (percent)
Tabela 2. Wzrost PKB – podział na sektory (procentowy)

Sector	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**AVG FY05-FY10**
Agriculture	17%	24%	13%	6%	71%	11%	24%
Industry	34%	19%	34%	10%	-41%	30%	14%
Manufacturing	30%	28%	24%	24%	-58%	23%	12%
Services	49%	57%	53%	85%	70%	59%	62%
Real GDP (fc)	100%	100%	100%	100%	100%	100%	100%

Source: Federal Bureau of Statistics

Table 2 compares the structure of contribution to overall GDP growth for 2009-10, with the previous five years. Growth in Agriculture contributed 11% to the GDP growth for the year, while Industry accounting for 30%. What stands out from the Table is the consistently high contribution to recent growth, averaging 62% for the past six years, accounted for by the Services sector. In 2009-10, the share of services in headline growth was roughly in line with its average, at 59%.

DESCRIPTIVE ANALYSIS OF SECTOR WISE FOREIGN DIRECT INVESTMENT IN PAKISTAN

The table 3 shows the sector wise Mean, Minimum amount of foreign direct investment inflow in this decade, Maximum amount came in form of foreign direct investment in Pakistan and Standard Deviation. The average million of dollar came in form of foreign direct investment in Oil & Gas sector during the decade is 345.45 million dollars while minimum inflow in this sector was 80.7 million dollars and maximum is of 775 million dollars. In financial business that average inflow is 460.29

million dollars and minimum is (34.9) million dollars that is negative, maximum amount come in financial business is 1864.9 million dollars. Textile sector's average inflow is 30.97 million dollars, minimum in this sector is 4.6 million dollars and maximum million of dollars came in form of foreign direct investment is 59.4. In trade the average foreign direct investment inflow is 84.81 million dollars and the minimum million dollars came in this sector is 13.2 and the maximum inflow is 175.9 million dollars. In construction industry the mean inflow is 60.43 million dollars and the minimum foreign direct investment inflow in this sector is 12.5 million dollars while maximum inflow is 157.1 million dollars. Power sector is able to find out the average inflow of 97.44 million dollars, its minimum inflow is negative 14.2 million dollars and the maximum is 320.6 million dollars. Chemical industry's average inflow is of 51.38 million dollars and the minimum and maximum inflow in this sector is 10.6 and 86.1 million dollars respectively. Average foreign direct investment inflow in transport sector is 44.41 million dollars, while minimum and maximum is 8.8 and 93.2 million dollars respectively. In IT & communication the mean foreign direct investment inflow is 720.3 million dollars but foreign direct investment minimum inflow is zero; on the other hand the maximum inflow is 1937.7 million dollars. Other sectors able to attract 392.62 million dollars as mean foreign direct investment inflow; while minimum and maximum are 66.2 and 1107.2 million dollars respectively. The average total inflow of foreign direct investment towards Pakistan in this decade is 2288.1 million dollar and the minimum amount come is 322.4 million dollars while maximum is 5409.8 million dollars.

Table 3. Descriptive analysis of sector wise foreign direct investment in Pakistan
Tabela 3. Analiza opisowa sektora bezpośrednich inwestycji zagranicznych w Pakistanie

Sector	Mean	MIN	MAX	SD
Oil & Gas	345.45	80.7	775	244.0215
Financial Business	460.29	-34.9	1864.9	656.4017
Textiles	30.97	4.6	59.4	18.05758
Trade	84.81	13.2	175.9	65.99732
Construction	60.43	12.5	157.1	50.89486
Power	97.44	-14.2	320.6	110.4715
Chemical	51.38	10.6	86.1	28.49032
Transport	44.41	8.8	93.2	32.50234
Communication	720.3	0	1937.7	811.2532
Others	392.62	66.2	1107.2	381.3151
Total	2288.1	322.4	5409.8	2006.09

The Figure 1 shows the sector wise total foreign direct investment inflow, where Oil & Gas sector total foreign direct investment inflow of 3454.5 million dollars, in Financial Business that foreign direct investment inflow amount is 4602.9 million dollars. Total foreign direct investment inflow in Textile sector during this decade is 309.7 million dollars; on the other hand in Trade this foreign direct investment inflow is 848.1 million dollars, in Construction sector this foreign direct investment inflow is 604.3 million dollars. Foreign direct investment came in Power sector is 974.4 million dollars from 2000 to July 2009, while in Chemical sector total foreign direct investment inflow is 513.8 million dollars during the decade. Transport, IT & Telecom and in others sectors total foreign direct investment inflow from 2000 to July 2009 is 444.1, 7203 and 3926.2 million dollars respectively.

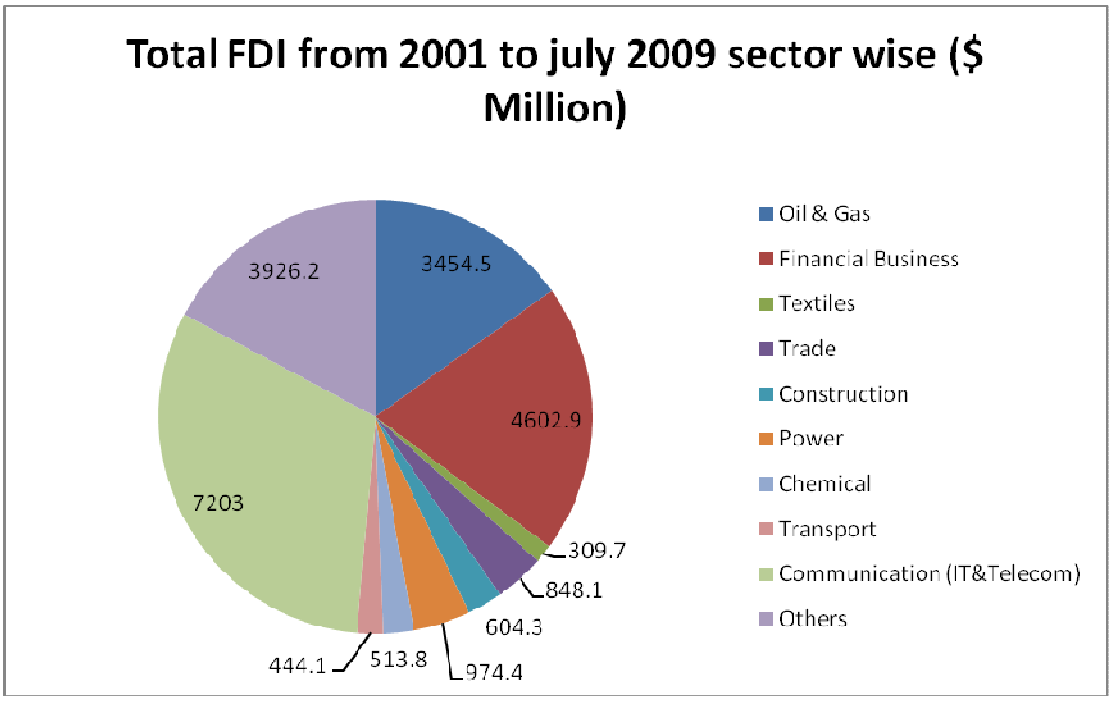

Fig. 1. Sector wise total foreign direct investment inflow
Rys. 1. Sektor inwestycji zagranicznych

REGRESSION RESULTS AND ANALYSIS

The present study analyzes the determinants of foreign investment through gravity model with the help of fixed effect and random effect model and indirectly check the causal relationship of foreign investment inflow due to gravity, in the process of measuring fixed effect and random effect on panel data, two type of methods have been applied, fixed effect model and random effect and among them four models have been developed cross section (country specific) and time effect (period specific) in both random and fixed effect models. It is an advantage to adopting these panel techniques, that we can measure the individual country inflow of foreign direct investment, it is called country specific, and foreign direct investment inflow over different time period, it is called time specific. In each method, four equations have been performed for to check the foreign direct investment inflow due to determinants and gravity. Panel data is used for analysis from 1999 to 2009. By pooling the data of 10 investing countries, the estimation of gravity model is done. For that purposes two different approaches are used fixed effect and random effect approach. In order to run regression eight explanatory variables are the part of the model: GDP, GDP Per Capita (PCGDP), GDP Growth Rate, Inflation Rate, Trade, total government expenditure (TOTGOVEXP), population growth (POPGR) and Distance. We have used gross domestic product after driving by multiplying the gross domestic product of host country and gross domestic product of investing partner. Per capita gross domestic product is also used after driving by multiplying PCGDP of host and PCGDP of investing partner. The level of significance is 1% of almost all the variables and coefficients are significant.

$$lnFDI_{it} = \alpha + \beta_1 (GDP_{it} X\ GDP) + \beta_2 (PCGDP_{it} X\ PCGDP_t) + \beta_3 (GDPGR_{it}) + \beta_4 DIS_{it}$$

$$+ \beta_5 TRADE_{it} + \beta_6 INFL_{it} + \beta_7 TOTGOVEXP_{it} + \beta_8 POPGR_{it} + \varepsilon_t$$

Table 4. Fixed Effect Dependent Variable: FDI
Tabela 4. Efekt stały zmiennej zależnej FDI

Variables	Model 1 Period Effect	Model 2 Country Specific
Intercept	--------	-473.5508 *** (-4.942229)
GDP	5.34E-35*** (8.874977)	2.99E-35 *** (2.549260)
PCGDP	9.28E-06*** (3.663355)	-2.03E-06** (-0.68213)
GDPG	12.22238*** (1.992472)	6.685504 (0.819762)
DIS	-0.021620** (-2.816098)	--------
TRADE	---------	0.118367 *** (10.68706)
INFL	---------	-24.09015 ** (2.316506)
TOTGOVEXP	--------	4.43E-10 *** (-3.013077)
POPGR	--------	32.22647** (1.949958)
R -square	0.449546	0.850364
F- Statistic	--------	32.20302
Durbin-Watson Stat	0.884482	1.458736

*** Significance at 1%, ** significance at 5%, * significance at 10%

In model 1of fixed effect we have estimated the coefficients of the basic Gravity Model which consists of the GDP, Per Capita GDP, and GDP Growth Rate and the Distance. So we skip the rest of the variable in model 1 by taking above mentioned variables. In our results of table 7.1 of first model the variable GDP is highly positively and statistically significant to the FDI which is dependent variable in our study at 1% significance level. Where as in second model variable GDP is showing the same result of having statistical positive but not highly significant as it was in first model at 1% significance level. The sign on GDP is significantly positive which shows that FDI inflow to Pakistan with a motive to occupy the market in Pakistan. Many researchers used the GDP as variable in their studies like, Tahir and Larimo, 2005 confirming the positive relationship between FDI and gross domestic product. The coefficient per capita GDP has positive and highly significant in first model while it is negative and statistically insignificant in second model at 1% level of significance. Bergstrand (1989) confirms the negative relationship between FDI and per capita GDP. This is due to the production that is labor intensive. The GDP growth rate coefficient has positive and significant when it is estimated at 1% level of significance in first model. Whereas, in second model the coefficient of GDP growth rate is statistically insignificant. GDP growth is one of the important out of other FDI determinants inflow in Pakistan. Wei, Liu, & Liu, [2005] research also confirms a positive relationship between GDP growth rate and FDI of both investing and investee countries. In our results of first fixed effect model the variable per capita gross domestic product (PCGDP) is highly positively and statistically significant to the FDI which is dependent variable in our study at 1% significance level. Where as in second model variable PCGDP is negative and statistically insignificant. The sign on PCGDP is significantly positive which shows that FDI inflow to Pakistan with a motive to occupy the market in Pakistan. Distance (DIS) coefficient has negative relationship when it is estimated in first model at 5% significance level and statistically significant. Distance is not a significant factor for the determination of FDI, results are showing this. Results are showing that DIS between Pakistan and the investing countries are in first model is negatively significant for the FDI inflow. This is because the pattern of FDI lies among U.S and U.A.E and Saudi Arabia. Portes and Rey [2005] study found out that for the FDI transaction flow distance plays a very important and significant role and confirm

the negative relationship. Trade (TRADE) coefficient has positive and highly significant in first model, when it is estimated at one % level of significance. Ismail and Yussof [2003] and Bevan and Estrin [2004] studies also verify the openness of the economies and they discuss that higher the degree of openness attracts higher FDI. As a result, the higher the intensity of openness of the Pakistani economy, it will lead to attract higher investment and degree of openness creates easiness for the investors to trade and invest in Pakistan. Results of fixed effect first model, the variable INFL is positive and statistically significant at 5% level of significance to the FDI which is dependent variable. This result is showing that if the inflation rate is high in home country that leads to increase in FDI to Pakistan. the variable Total Government Expenses (TOTGOVEXP) is statistically highly significant and negative relationship in second fixed effect model. And this showing that when government increases it expenses the foreign direct investment also increases. The government expenses could be on the development of the infrastructure like roads, financial and communication leads to add in growth part and this helps to attract foreign direct investment into Pakistan. While the independent variable, population growth (POPGR) has positive and insignificant in fixed effect second model at 5% level of significance. This is showing that the increase in population will inversely effect on foreign direct investment. POPGR variable deals the relationship with population growth rate and foreign direct investment, in lower income countries like Pakistan it is high significance and in period random model at one %, showing an inverse relationship by having negative coefficient value. However for the basic purpose of R square value is concerned to analyze the overall dissimilarity in growth rate due to our independent variable. Fixed effects, our first model the value is 0.449546, in second model value is 0.850364. These are considered significant. Durbon-Waston statistics showing that the problem of multi-Co linearity is not found in our model and also shows acceptable results in this context. The results also show the impact of determinants in different countries which are in our sample and in different time period. The impact of different determinants is not as powerful because major proportion of investment came from UAE in telecommunication sector and in financial sector. On the other hand time specific impact have no major fluctuation in the period on the study rely shows minor fluctuation due to the determinants influencing foreign direct investment.

Table 5. Random Effect Dependent Variable: FDI
Tabela 5. Efekt losowy zmiennej zależnej FDI

Variables	Model 1 Cross section Random Effect	Model 2 Period Random Effect
Intercept	-240.7175*** (-2.714741)	-188.3472 *** (-2.122474)
GDP	2.40E-35*** (2.699812)	2.51E-35 ** (2.354630)
PCGDP	1.33E-05*** (3.085656)	1.41E-05*** (3.1000)
GDPG	29.10063*** (2.504740)	27.84101 *** (2.392713)
DIS	-0.059028*** (-3.559706)	-2.617653 *** (-1.252573)
TRADE	0.055901*** (5.353344)	0.050515*** (5.327684)
INFL	59.58732** (3.059621)	71.22359 *** (3.999648)
TOTGOVEXP	3.47E-10*** (2.300026)	3.64E-10 *** (2.679628)
POPGR	-16.23978 (-0.737728)	-20.42360* (-0.975192)
R -square	0.729147	0.742319
F- Statistic	33.20189	35.52956
Durbin-Watson Stat	0.720731	0.720744

*** Significance at 1%, ** significance at 5%, * Significance at 10%

In our results of first and second model of table 7.2 showing that the variable GDP is statistically positive and significant at 1 % level of significance. The sign on GDP is significantly positive which shows that FDI inflow to Pakistan with a motive to occupy the market in Pakistan. Many researchers used the GDP as variable in their studies like, Aqeel and Nishat, [2005] also confirm the positive relationship between GDP and FDI in Pakistan. In first and second model, Coefficient PCGDP is positive and statistically significant at 1 % level of significance. Dascal, Mattas, & Tzouvelekas, [2002] study confirms the positive relationship. In first model and in second model, coefficients of GDPG are statistically significant and positive at 1 % level of significance. Cuevas, Messmacher, & Werner [2005] in their study are confirming a positive relationship. Results of first and second the variable Per Capita GDP (PCGDP) is highly positively and statistically significant to the FDI which is dependent variable in our study at 1 % significance level. In first model the coefficient of DIS is statistically significant and negative at 1 % level of significance while in second model coefficient DIS is negative and insignificant at 5% level of significance. Guerin [2006] research confirms inverse relationship among FDI and DIS. Different researchers use geographical distance in the Gravity Model as an explanatory variable like [Stone and Jeon, 1999; Portes and Rey, 2005]. Voyer & Beamish, [2004] study incorporates geographical distance that causes countries to invest outside rather than to export to those countries in order to reduce transportation and production costs. However, this low cost of production and transportation cost motivates the investing countries to invest directly to Pakistan rather than exporting. The coefficient of TRADE is statistically significant and positive at 5% level of significance in both first and second model. Research of A.M & A, [2003] confirms this. First model coefficients INFL is highly statistically significant and positive at 5% level of significance but in second model it is statistically highly significant and positive at one % level of significance. In first and second model coefficient of TOTGOVEXP is statistically significant and positive at 1% level of significance. In first and second model, coefficient POPGR is negative and statistically insignificant. Zahra, Azim, & Mahmood, [2008] uses the population growth variable to its effect on the economic development and they found the supporting result that the POPGR has a negative relationship among them. in first model value of R- square is 0.729147 and in second model R- square value is 0.742319, and these are considered significant. Durbon-Waston statistics showing that the problem of multi-Co linearity is not found in our model and also shows acceptable results in this context. The results also show the impact of determinants in different countries which are in our sample and in different time period. The impact of different determinants is not as powerful because major proportion of investment came from UAE in telecommunication sector and in financial sector. On the other hand time specific impact have no major fluctuation in the period on the study rely shows minor fluctuation due to the determinants influencing foreign direct investment. The random period specific results shows no influence on determinants of foreign direct investment, may be the reason of having no impact of these determinants is trade openness which may decrease the intensity of impact of these determinants on foreign direct investment inflow.

MODEL SELECTION CRITERIA

There are many of criteria which help to choose the best model in several alternatives models. In general likelihood ratio test considered useful for choosing between two models, where one model is a subset of other.

S.E REGRESSION

For the selection of appropriate model, S.E of regression is also recommended. In this study we included this criterion. Minimum S.E of Regressions recommended so the model which has minimum S.E regression is the most appropriate and the best model for the study.

THE BEST MODEL FOR THE STUDY

The above discussed criterion for the selection of the best model is referring the dynamic fixed cross section model appropriate for this study. The S.E Regression criterion shows the minimum value of about 225 for this model; on the other hand S.E Regression value is higher in rest of the models. So from above discussion, conclusion is that the dynamic fixed effect model in country specific case considered the most suitable and bet0ter model for concluding result and make policy implication.

CONCLUSION

This study tries to demonstrate the determinants of foreign investment in Pakistan and see the intensity of their impact on investment decision of investing country. For that purpose, 10 years data is taken, that represents top eleven countries of the world that have the highest investment in Pakistan. Two type of test is used i.e fixed and random effect to check the relationship among foreign direct investment and independent variables. In our both models distance shows a negative impact on the decision to make an investment by investing partner while GDP and GDP growth have a positive and significant impact. Gravity in this regards does not effect that much for foreign direct investment attraction because results are negative significant in this case that shows higher distance is a hurdle for the inflow of foreign investment but rest of the variables are significantly positive and related to the inflow of foreign investment except population growth which is negatively correlated.

Pakistan heavily rely on the foreign investment and one of the important country who receive about 23 billion dollars of foreign investment in this current decade and become one of the significant receiver of foreign investment comparing to the other developing countries of south Asia. In Pakistan inflation rate remain on high side and due to this higher inflation ultimately leads to lower foreign investment because foreign investors are risk averse; they never risk their expected profits from investment. Foreign investors demands high prices to cover uncertainty due to higher inflation. Inflation benefits the foreign investor in a way that country has higher inflation, the investor charge higher prices in host country and when the investor transfers its profit to its home country the conversion of host to home currency will provide them higher money that results higher profit. This could only be possible if exchange rates are appreciated. But during the current decade exchange rate in Pakistan depreciated approximately to 90% so due to this foreign direct investment decreased. Pakistan's growth was consistent in the field of oil, communication and in financial sector. This is one the reason that foreign investment in these three sectors is about 70% of the total investment comparing to the other sectors in this current decade. Change of policies for the foreign investment was also one of the reasons for higher inflow and the purpose was to cut of imports and to put the influence on the exports. Pakistan was one of the fastest growing economies with highest GDP growth of 9% of this current decade before the energy crisis and law and order situation. In Pakistani economy foreign direct investment features a very important role. Pakistan's policies are modified and amended according to the objective set by the Government for the development and for the economic situation and requirement of foreign direct investment in specific sector in the country. Therefore, to considerate the determinants of foreign direct investment are a vital element for encouraging and attracting more foreign direct investment towards Pakistan. For the supplement actions, it is necessary and important for the Pakistani government to prepare and endorse those programs that will ultimately be helpful for the import of foreign direct investment into Pakistan. This study includes the important part of its findings is to provide the suggestion to the policy makers in Pakistan, for the domestic investors and finally for the foreign investors. Foreign exchange was taken as an important determinant of foreign direct investment but it did not shows significant impact therefore it was skipped from the analysis at the same time political instability law and order situation was also ignored as the unavailability of authentic data of these sectors. In future when the data became mature of the sectors then it can be used for analysis purpose there is still a need to explore new dimension by

employing gravity model and identifying factors influencing foreign direct investment inflow the door are open for further research.

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WYZNACZNIKI INWESTYCJI ZAGRANICZNYCH W PAKISTANIE: ANALIZA MODELU GRAVITY

STRESZCZENIE. **Wstęp**: W ciągu ostatnich dwóch dekad Pakistan był jednym z najbardziej atrakcyjnych krajów wśród krajów rozwijających się, które otrzymały bezpośrednie inwestycje zagraniczne. Szczególnie w pierwszej połowie ostatniej dekady wzrost był szybki i zrównoważony w różnych gałęziach przemysłu, jak również w rolnictwie. W pakistańskiej gospodarki bezpośrednie inwestycje zagraniczne odgrywają bardzo ważną rolę. Ich zasady są jasne, jednak pewne zmiany i poprawki są dokonywane w zależności od czasu, celu, potrzeb i uwarunkowań gospodarczych w kraju.
Metody: Celem pracy było zbadanie uwarunkowań inwestycji zagranicznych w Pakistanie za pomocą modelu grawitacyjnego. Dane dotyczące inwestycji zagranicznych zostały potraktowane jako zmienna zależna natomiast zmiennymi niezależnymi były produkt krajowy brutto, produkt krajowy brutto na mieszkańca, wskaźnik wzrostu produktu krajowego brutto, stopa inflacji, handel, łączne wydatki rządu, wzrost liczby ludności oraz odległość za lata od 1999 do 2009. Na tej podstawie zbudowano panel służący do określenia przepływu inwestycji zagranicznych z różnych krajów oraz ich odległości geograficznej od Pakistanu.
Wyniki: Zastosowano dwa typy testów ze stałym i losowym wpływem w celu sprawdzenia zależności pomiędzy bezpośrednimi inwestycjami zagranicznymi a zmiennymi niezależnymi. W obu modelach otrzymano następujące zależności: odległość ma ujemny wpływ na decyzję o inwestycji przez partnera, podczas gdy wielkość produktu narodowego brutto jak i jego wzrost mają pozytywny i istotny wpływ. Grawitacja nie miała wpływu na atrakcyjność dla zagranicznych inwestycji, gdyż wyniki są ujemnie istotne w tym przypadku i wskazują, że większa odległość jest ogranicznikiem inwestycji zagranicznych, jednak pozostałe zmienne są istotnie dodatnio skorelowane z napływem inwestycji zagranicznych, z wyjątkiem wzrostu populacji, który jest skorelowany ujemnie.
Wnioski: Przeprowadzone badania potwierdziły, że istotnie silna zależność istnienia grawitacji pomiędzy Pakistanem a jego partnerami inwestującymi. Stwierdzono, że kraje leżące bliżej Pakistanu wykazują się większymi inwestycjami w Pakistanie, w związku z czym pozyskanie tych krajów w obszarze inwestycji w Pakistanie może zwiększyć szansę wzrostu ekonomicznego w Pakistanie.

Słowa kluczowe: model grawitacyjny, inwestycje zagraniczne, Pakistan.

DETERMINANTEN FÜR AUSLÄNDISCHE INVESTITIONEN IN PAKISTAN: ANALYSE EINES GRAVITY-MODELLS

ZUSAMMENFASSUNG. Einleitung: In den zwei letzten Jahrzehnten war Pakistan eines der attraktivsten Entwicklungsländer, welche direkte ausländische Investitionen in Angriff nahmen. Insbesondere verzeichnete man Mitte des letzten Jahrzehntes dort in verschiedenen Industriezweigen sowie in der Landwirtschaft einen schnellen und ausgewogenen Anstieg . Die ausländischen Investitionen spielen in der pakistanischen Wirtschaft eine sehr wichtige Rolle. Die Prinzipien der Betätigung von ausländischen Investitionen sind klar, allerdings werden gewisse Veränderungen und Korrekturen in Abhängigkeit von Zeit, Ziel, Bedarf und wirtschaftlichen Bedingungen im Inland vorgenommen.
Methoden: Das Ziel der Arbeit war es, Voraussetzungen für ausländischen Investitionen in Pakistan anhand eines Gravitationsmodell zu prüfen. Die betreffenden Daten wurden als dependente Variable behandelt, dagegen Bruttoinlandsprodukt, Bruttoinlandsprodukt pro Einwohner, Kennziffer des Anstiegs des Bruttoinlandsproduktes, Inflationsrate, Handel, Gesamtausgaben der Regierung, Anstieg der Einwohnerzahl und Bevölkerungsdichte in den Jahren 1999-2009 als indepedente Variablen aufgefasst. Auf Grund dessen wurde ein Panel aufgebaut, welches zur Darstellung der ausländischen, aus unterschiedlichen Ländern fließenden Investitionsströme und zum Aufzeigen der geographischen Entfernungen dieser Länder von Pakistan dienen kann.
Ergebnisse: Es wurden zwei Typen Tests mit festem und losmäßigem Einfluss zwecks Überprüfung der gegenseitigen Abhängigkeiten zwischen den ausländischen Direktinvestitionen und den independenten Variablen in Anspruch genommen. Bei den beiden Modellen hat man folgende Abhängigkeiten festgestellt: die Entfernung übt einen negativen Einfluss auf die Entscheidung bezügl. Investition aus, während die Größe des Bruttoinlandsproduktes sowie dessen Anstieg den jeweiligen Entschluss wesentlich positiv beeinflussen können. Die Gravitation hat die Attraktivität für ausländische Investitionen kaum

beeinflusst, denn in diesem Falle sind die Ergebnisse negativ relevant und bezeigen, dass die größere Entfernungen ausländische Investitionen einschränken. Die weiteren Variablen sind mit dem Zufluss von ausländischen Investitionen wesentlich positiv verbunden, ausgenommen den Populationsanstieg, welcher in dieser Hinsicht negativ relevant ist.
Fazit: Die durchgeführten Forschungen haben ein Vorhandensein der Gravitation zwischen Pakistan und dessen investierenden Partnern als eine wesentlich starke gegenseitige Abhängigkeit bestätigt. Es wurde dabei festgestellt, dass die Pakistan näher liegenden Länder größere Investitionen vor Ort betreiben. Im Zusammenhang damit kann die weitere Gewinnung dieser Länder für die Investitionen in Pakistan zum wirtschaftlichen Wachstum Pakistans beitragen.

Codewörter: Gravitationsmodell, ausländische Investitionen, Pakistan

Haroon Hussain
Department of Commerce,
University of Sargodha, Pakistan
e-mail: ranaharoonhussain@yahoo.com

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DYNAMIC CONFIGURING OF THE METASTRUCTURE

Katarzyna Grzybowska[1], Gábor Kovács[2]

[1)] Poznan University of Technology, Poznan, Poland, [2)]Budapest University of Technology and Economics, Budapest, Hungary

ABSTRACT. Background: A trend to create groups of enterprises can be observed; whose model of operation makes use of assets of large, small and medium sized companies. It is a higher level of organisational changes. This trend is described as network organisation. It is based on the so called supply chain. The Authors of this paper proposed authors' analysis dynamic configuration of the supply chain and presents an example. The supply chain is a metastructure. It is an intermediate form between a single enterprise (microstructure/microsystem) and the global economy (macrostructure/macrosystem). The metastructure is characterized by a dynamic holarchy of mutually cooperating holons (enterprises).
Methods: After a brief discussion of the nature of supply chain (metrastructure) and configuration of metastructures, authors present variable supply chains in the light of morphological analysis and presents an example.
Results: The key benefits of this approach are: identifying the characteristics of a supply network and modeling the flow in the entire own supply chain metastructure and possible quick adaptations to new situations.
Conclusions: Configuration of a supply chain with the use of a morphological analysis is a basic action, if its goal is to optimally model the flow of goods and implementation of quick adaptation to new situations.

Key words: supply chain, metastructure, configuration.

INTRODUCTION

Such a metrastructure [Grzybowska 2010] is a system which, at its own level of existences, is a self-functioning whole and self-regulating open system. However, it forms a constitutive element of a larger whole. It also consists of constitutive elements (parts) which function as whole systems of a lower level. Such structures have been referred to by A. Koestler as holons [Koestler 1967] regarded, at the same time, as a whole and a part which "display both the autonomous properties of wholes and the dependent properties of parts".

As reasoned by K. Wilber: there is no whole which would not constitute a part of some other whole. He described the holarchic structure as a holarchy or holonic hierarchy [Wilber 2007]. The whole nature of the systems and holism consists in the conclusion that new levels of organization are formed which cannot be reduced only to dimensions known earlier - they extend beyond the scope of the latter. But at the same time, they contain them, as earlier holons are still the constitutive elements of a new holon. Thus, they are both contained in, and extend beyond the new holon. This means that the higher levels contains basic elements of the lower level and some additional qualities (…) it is another manner of putting the notion laid down for the first time by Aristotle - the whole lower level is contained in the upper level, but the upper level is not fully contained in the lower level [Wilber 2007].

The more the supply chain expands, the less coherent the system is and the relationships within such system lack closeness. This, in turn, results in the fact that the relationships and connections in such metastructure may be more or less durable. Among the links in such structure one differentiates those permanent (so-called core supply chain) and those dynamically changing, e.g. depending on the

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task being executed (so-called satellites, temporarily connected links). Links connected temporarily become separated from the core supply chain and cooperation ends as soon as the task is completed. Supply chains keep evolving - beginning with the supply chains of a functional nature, through creative to adaptive supply chains. Such development is a result of a change in the relation of relationships, dependencies and connections existing between the enterprises in the supply chain [Grzybowska, 2009]. There are two aims of this paper. The first one is to define the term: define the term: configuration of metastructures. The second aim of this research was to propose and use the morphological analysis.

CONFIGURATION

The cooperation of enterprises (flow of materials, information and cash) within the metastructure of a supply chain (network) is a dynamic and changing process. Configuration of the supply chain may take a number of forms and depends upon the links and relationships between these links in the supply chain.

The configuration may refer to a number of aspects. It may refer to transport routes and optimization of long-distance transport and transport processes (e.g. type of transport to be used, which route will be used to transfer goods, etc.). It may also take into account the points in a networks between which the goods and transported. In such case, the analysis and optimization of resources and warehouse localization may be effected (e.g. which warehouses will be used, what costs will be related to localization of warehouses, etc.) [Niemczyk 2009].

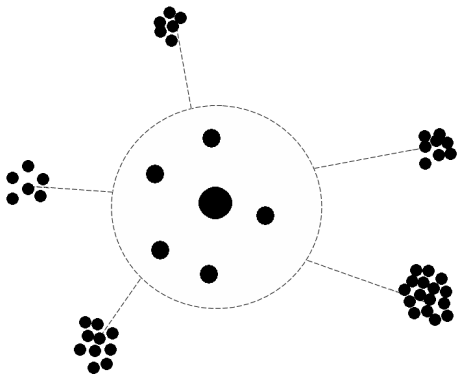
This paper defines the configuration of metastructures as a structure of connected links of a supply chain (metasystem) with dependencies existing between them. According to Ch. Chandra and J. Grabis the configuration is a system of parts of elements which give the form to the whole [Chandra and Grabis 2007]. These authors refer to the theory of systems. They point out that a supply chain is a configurable system which effectively adjusts to the environment in which it operates. They differentiate some of the key factors to correctly design the supply chain and its configuration. These are as follows [Chandra and Grabis 2007]:

- Introduction of new products or updating existing range of products and new processes or improvement of existing processes.
- Allotment of new resources or redistribution of existing resources.
- Selection of new, or reselection of existing suppliers.
- Changes in the structure of demand for manufactured products.
- Changes in production time.
- Product life cycle changes.
- Changes in obligations or relationships between links of a supply chain.

As stated by A. Niemczyk citing M. Fertsch, following rules of logistic conduct (factors) significantly affect the configuration of a network [Fertsch 2006; Niemczyk 2009]: (1) Rule of substitution, (2) Rule of complementariness, (3) Rule of distribution differentiation, (4) Rule of mixed strategy, (5) Rule of rationalization, (6) Rule of standardization, (7) Rule of consolidation, (8) Rule of deferment.

The configuration of a supply chain is one of the major decisions to be made in the scope of supply chain management. It greatly affects all other decisions of a managing nature. In the process of configuring the supply chain, a whole range of possibilities should be taken into account: from the deterministic system to stochastic systems. Ch. Chandra and J. Grabis propose a configuration of a supply chain as an integral part of a general process of supply chain management. Complexity of metastructures depends on the configuration of a supply chain. The supply network is a type of configuration in which some links are multiplied in order to deliver a variety of products.

D. Kempny notes that the configuration may be more dynamic in nature. Citing D. Birchall and L. Lyons, he presents a dynamic network with a central point consisting of a single, offensive business which is capable of connecting with similar businesses" [Kempny 2001; Birchall and Lyons 1995]. Such business is an integrator (Fig. 1). By joining a dynamic system, the members of a metastructure often contribute unique capacities (a quality of holons).



Source: Birchall and Lyons 1995; Kempny 2001

Fig. 1. Dynamic network with an offensive integrator
Rys. 1. Sieć dynamiczna ofensywnym integratorem

In the course of creating and functioning of a supply chain or supply network in accordance with the holarchic scheme, one may differentiate two significant rules that govern the process: rule of synergy and rule of elitarism (elitarism consists in participation of the best enterprises which constantly develop in their core businesses). This dynamic metastructure consisting of specialized links (nodes) - holons being a whole, is at the same time, a part of another hole. The structure that used to be a whole yesterday, tomorrow may be a part of a larger structure. Links have some common qualities. It should be underlined that these holons must retain their autonomy. Otherwise, if they lose their separateness, they disintegrate into elementary parts. At the same time, they have to gain the ability to adjust to other parts of a whole and adjust to the environment.

The metastructure of a holarchic type may disintegrate, but may also merge to form new systems. It may form new mutations and interim forms. It is a sign of intelligence and evolution. K. Wilber refers to it as a self-transcendence of holons which allows discontinuity, shifts and creative transitions.

Supply chains are created in a holarchic manner. As a result of created metastructure, more depth is created. It means that each higher level created with holons becomes more complex, higher level exceeds and contains lower levels which means that higher level is more abundant than the lower level. There is no exception to this rule.

As stated by D. Kempny "holonic network is more than just an association of businesses in which various companies operate (…) it is a system of almost organic nature in which all information is available at the same time (in real time) to all participants" [Kempny 2001]. It is a dynamic information network which allows all its nodes to make rapid decisions.

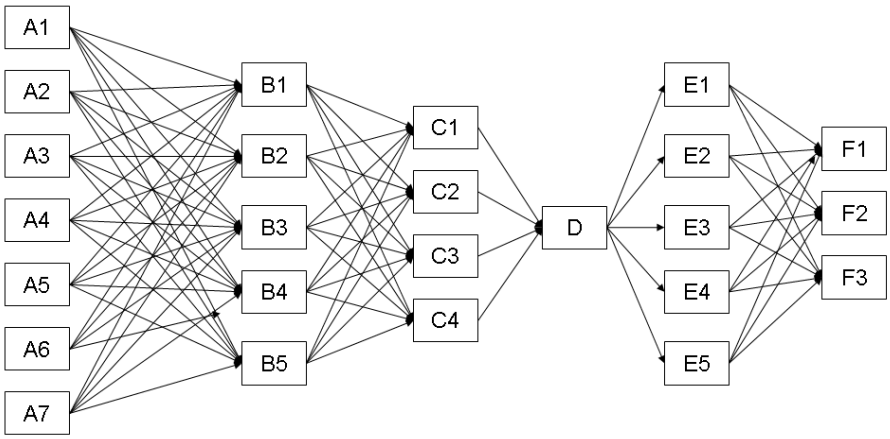
MORPHOLOGICAL ANALYSIS IN THE CONFIGURATION OF METASTRUCTURES

An unquestionably useful tool to identify the configuration manner of individual (variable) metastructures is morphological analysis. It allows to determine the number and nature of all links of a supply network.

Referring to the concept of dynamic networks with specialized nodes called holons, as laid down by D. Birchall and D. Kempny, and by analyzing the network phenomena and variable supply chains in the light of morphological analysis developed by F. Zwicky, one may come to interesting conclusions. It is a method belonging to heuristic methods which may be applied to solving complex problems of research or creative nature. A supply network may be broken down into partial elements and, subsequently, in accordance with the rules of morphological method, all solutions possible as far, and those entirely new, based on the analysis of structure of these solutions may be reached.

Determining the characteristics with the use of morphological analysis

The first stage of work is the determination of full characteristics of a supply chain - constitutive elements of a network are determined: kinds and types of suppliers, intermediate parties and recipients (Fig. 2). Knowing the characteristics of a supply network, one may proceed to the task consisting in the analysis of solutions which form a part of practice of each characteristic. Parameters for each type of link are defined and described in detail. Next, one may proceed to analysis of parameters of characteristics based on all versus one another approach.



Source: own work

Fig. 2. Determining the characteristics of a supply network
Rys. 2. Wyznaczenie charakterystyki sieci dostaw

A morphological matrix is created (Table 1). As a result of detailed analysis, combinations of various variables may be obtained (Fig. 3). The number of possible combinations may be calculated with the use of formula below:

$$\text{number of possible combinations} = \prod_{i=A}^{N} I_i$$

where:

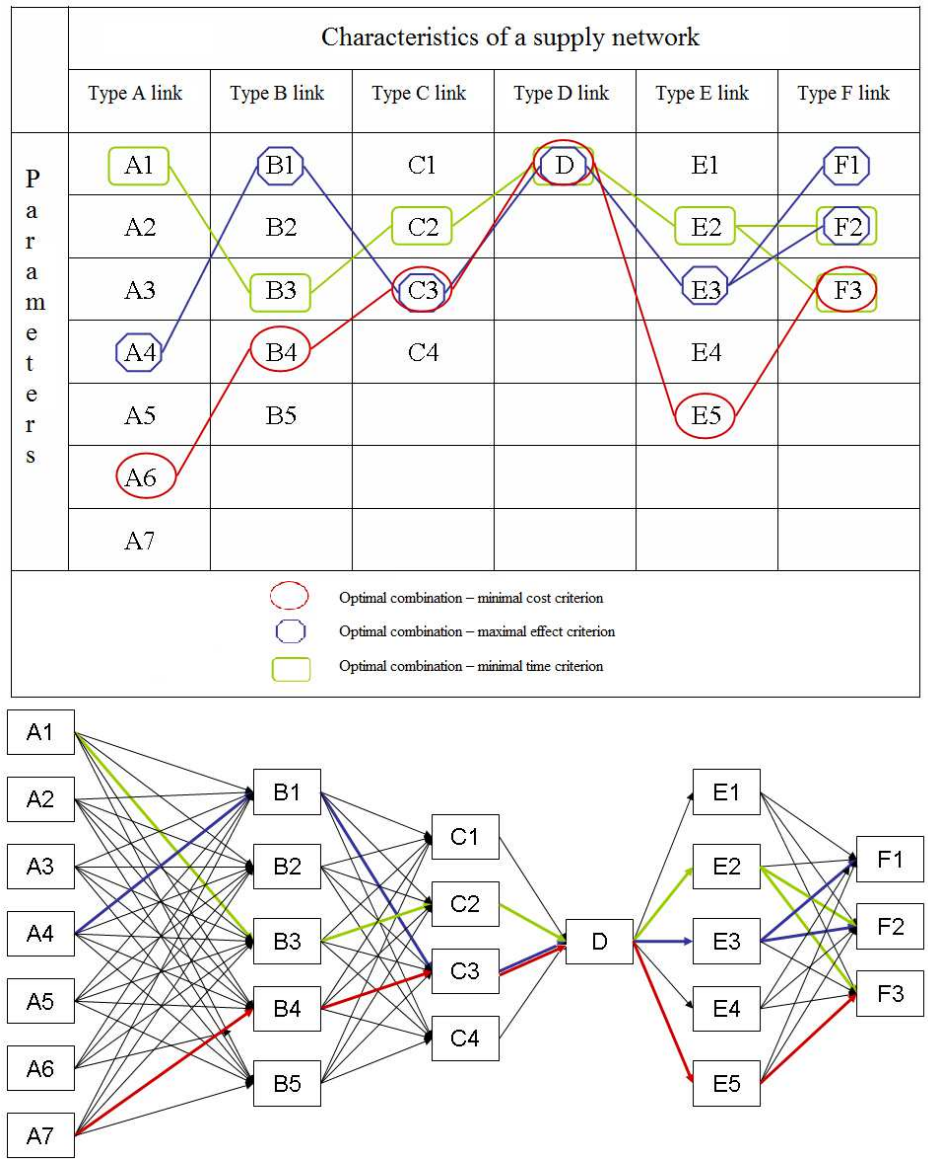
I - number of variable value *i*.

For the example shown in Table 1, the number of all combinations equals 2 100. The list of created solutions (as in example) may be long, hence some selection measures should be applied. Solutions obtained will be of possible, admissible, optimal and contradicting nature (~30%). The latter should be discarded. As a result of analysis, so-called optimal combinations are determined which is a result of analysis in terms of a specific criterion (cost-related, minimization of execution time, maximization of effects, durability, etc.).

Table 1. Morphological matrix of a supply network
Tabela 1. Macierz morfologiczna sieci dostaw

	Characteristics of a supply network					
	Type A link	Type B link	Type C link	Type D link	Type E link	Type F link
Parameters	A1	B1	C1	D	E1	F1
	A2	B2	C2		E2	F2
	A3	B3	C3		E3	F3
	A4	B4	C4		E4	
	A5	B5			E5	
	A6					
	A7					

Source: own work



Source: own work

Fig. 3. Determining the characteristics of a supply network with indication of selected combinations
Rys. 3. Wyznaczenie charakterystyki sieci dostaw ze wskazaniem wybranych kombinacji

The drafted system (Fig. 3) shows how a metastructure may undergo changes in relationships between enterprises and how such system may dynamically change. Cooperation between enterprises, depending on the criterion determined, will flexibly change.

If the final recipient presses for lower price, the cooperation within the supply chain will be affected between enterprises: *A7, B4, C3 D, E5* and *F3*. If, in turn, the client presses for time gains, cooperation will be affected in favour of a new supply chain: *A1, B3, C2, D, E2* and *F2* or *F3*.

The system presented above constitutes a flexible and variable metastructure, depending on the task specified or criterion selected. The enterprises which are "replaced" become temporary links. Links connected temporarily become separated from the core supply chain and cooperation ends as soon as the task is completed.

Benefits from configuring the supply chain (network) with the use of morphological method

A configured metastructure may be used to develop a model of a complex network of dependencies of cooperating enterprises which indication of limitations such system contains. Another action may consist in improving the synchronicity and coherence in a supply chain, planning of material flow (including emergency or extraordinary flows) in the entire supply chain. Configuration of supply chains increases the effectiveness of dynamic balancing of supply and demand between respective links of this chain, and improvement of effectiveness of all links. It also allows for specifying the method and timeline of resource planning in a dynamic manner.

The configuration of a metastructure is of particular use for the leader of a given supply chain or economic organization which manufactures the product for the final client. These organizations are particularly interested in proper functioning of an entire supply chain. Their role is to integrate suppliers and intermediate parties. Hence, configuring is useful in modeling the flow in the entire own supply chain metastructure and possible quick adaptations to new situations (example of application of the morphological analysis). By using this analysis and possibilities made available by IT systems, it is possible to carry out simulations of inclusion of a new supplier or a new key client in the supply chain metastructure.

THE DYNAMIC CONFIGURATION OF METASTRUCTURES - FLEXIBLE SUPPLY CHAIN AND AGENT'S THEORY

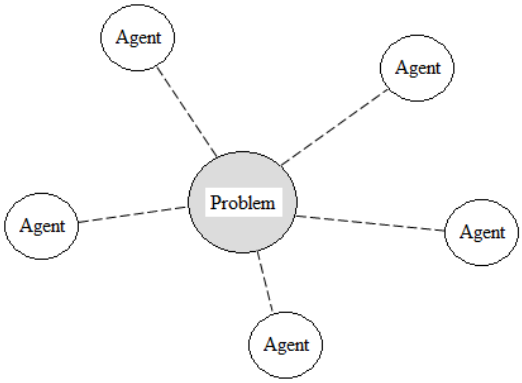
Dynamic configuring allows flexible supply chains to be created. Contrary to the most typical, permanent and stable supply chain which is created in long-term perspective and based on long-term relationships with business partners to maximize synergy effects, a flexible (called also dynamic) supply chain is very variable. It is an opposite of stable supply chains. Dynamic configuration is, in this aspect, understood as often and constant changing of business partners within a supply chain.

Another concept of a flexible supply chain is presented by H. L. Lee. He lists six premises ensuring flexibility to a supply chain. These premises are as follows [Lee 2007]: (1) Supplying business partners, on an on-going basis, with information on changes in supply and demand so that they can react and adjust to changing demand, (2) Entering into cooperation with business partners already at the stage of designing and implementation of new products, as well as designing and implementation of new technological and logistic processes, (3) Optimal product designing to use modular components in the initial phase, so as to defer finishing works (works differentiating products) until the time the clients' needs are determined, (4) Maintaining minimum resource in such amount which prevents interruptions in the supply chain due to lack of resources (particularly those inexpensive), (5) Development and implementation of a flawless logistic system by entering into collaboration with other independent economic organizations, (6) Development of a team which will be prepare and be able to implement emergency plans.

The flexibility of supply chains was described by V. Kumar, K. A. Fantazy, U. Kumar and T. A. Boyle as an ability of business partners functioning in a supply chain to easily adjust to arranging joint policy and scope of responsibility and changing one's actions according to current needs. They state that such changes allow to manufacture differentiated products at differentiated prices, quality and at variable cost.

A. Kawa proposes to pay attention to future technologies as an important factor in configuring dynamic supply chains [Kawa 2008]. He points to the agent's technology, i.e. a piece of software which remotely performs a task at a given computer workstation or in a dispersed network of computers (Internet). Referring to S. Russel and P. Norviga, A. Kawa defines a so-called agent as "anything that may be perceived as able to examine its environment with sensors and carry out actions in this environment by effectors" [Kawa 2008]. An agent - in the form of software, is able to gather information on a given subject and, most importantly, draw conclusion from such information and use them to take actions. If such software's tasks are complex, the structure of the program will be complex too. It may also be given "competences" concerning the cooperation, communication and negotiation with other agents representing other enterprises. Complexity of an agent system means that following categories of agents may be differentiated [Kawa 2008]:

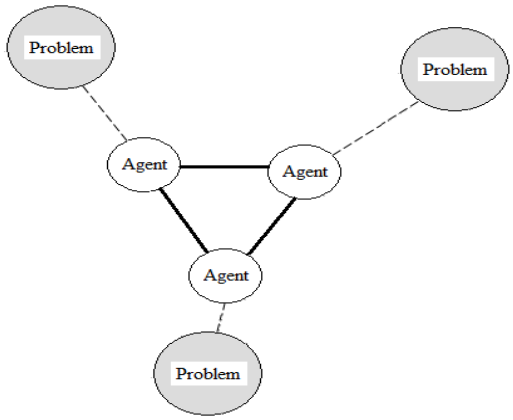
- Exploring agent which is mobile and based on indicated criteria, responsible for seeking business partners for new cooperation,
- Offering agent which represents an economic organization in placement of sales offers,
- Information agent which informs on changes in an offer (e.g. at the electronic exchange market servers),
- Negotiating agent which represents an enterprise in the process of negotiation of cooperation conditions,
- Verifying agent which verifies available and proposed cooperation scenarios.



Source: Pawlak and Małyszek 2000; Kjenstad 1998

Fig. 4. Cooperative problem solving
Rys. 4. Kooperacyjne rozwiązywanie problemów

In the literature on the subject, the authors point to two directions of research: *Cooperative Problem Solving* (CPS) and use of agent solutions (*Multi Agent Systems*, MAS). First allows to decompose metastructure into a network, in accordance with the structural division of economic organization participating in a supply chain (Fig. 4).



Source: Pawlak and Małyszek 2000; Kjenstad 1998

Fig. 5. Autonomy of agents in a Multi Agent System
Rys. 5. Autonomia agentów w systemie wieloagentowym

Second solution allows for greater autonomy of agents. Each of them solves problems based only on local goals whereas any contradictions are being removed by method of negotiations with other agents" [Pawlak and Małyszek 2000]. Local knowledge is merged with coordination knowledge. These two directions of research are presented on a simplified chart below (Fig. 5).

CONCLUSION

The aims assumed at the beginning of this paper were achieved by the consistent presentation of morphological analysis. A supply chain/network may be understood as a dynamic (variable or stable) metastructure. It is understood as a self-sustaining form. It should be noted that a metastructure enters into dependencies with other metastructures and is a component of a larger whole. The more complex the metastructure, the more stable is its nature. Hence the configuration and adjustment of individual links in a supply chain/network is that important. The problem of configuration may be perceived in the light of dependencies between elements of a system. Configuration of a metastructure with the use of a morphological analysis is a basic action, if its goal is to optimally model the flow of goods in an entire metastructure and implementation of quick adaptation to new situations.

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DYNAMICZNA KONFIGURACJA METASTRUKTUR

STRESZCZENIE. **Wstęp**: Można zaobserwować tendencję do tworzenia grup przedsiębiorstw, których model działania wykorzystuje aktywa dużych, małych i średnich przedsiębiorstw. Jest to wyższy poziom zmian organizacyjnych. Tendencja ta jest opisana jako organizacja sieci. Jest ona oparta na tzw. łańcuchu dostaw (metastrukturze). Autorka proponuje analizę dynamicznej konfiguracji łańcucha dostaw oraz przedstawia jej przykład. Łańcuch dostaw jest metastrukturą. Jest to pośrednia forma pomiędzy pojedynczych przedsiębiorstwem (mikrostruktura, mikrosystem) a ekonomią światową (makrostruktura/makrosystem). Metastruktura charakteryzuje się dynamiczną holarchią wzajemnie współpracujących holonów (przedsiębiorstw).
Metody: Po krótkiej dyskusji dotyczącej natury łańcucha dostaw (meta struktura) i konfiguracji meta struktur, autorzy przedstawiają różne łańcuchy dostaw w świetle analizy morfologicznej oraz przedstawiają przykład.
Wyniki: Kluczowymi zaletami takiego podejścia jest identyfikacja charakterystyk sieci dostaw oraz modelowanie przepływu w całej metastrukturze łańcucha dostaw jak również wdrożenie szybkiej adaptacji w nowych sytuacjach.
Wnioski: Konfiguracja łańcucha dostaw przy zastosowaniu analizy morfologicznej jest podstawowym działaniem, w sytuacjach gdy celem jest optymalnie wymodelowaniem przypływu dóbr oraz wdrożeniu szybkiej adaptacji w nowych sytuacjach.

Słowa kluczowe: łańcuch dostaw, metastruktura, konfiguracja

DYNAMISCHE KONFIGURATION VON METASTRUKTUREN

ZUSAMMENFASSUNG. Einleitung: Heutzutage beobachtet man eine Tendenz zur Bildung der Gruppen von Unternehmen, derer Wirkungsmodell die Aktiva von Groß-, Klein -und Mittelstand-Unternehmen in Anspruch nimmt. Dies bedeutet ein höheres Niveau von organisatorischen Veränderungen. Diese Tendenz wird als Organisation des Netzes beschrieben. Sie stützt sich auf die sog. Liefferkette (Metastruktur). Die Autorin schlägt die Analyse einer dynamischen

Konfiguration der Liefferkette vor und stellt ein entsprechendes Beispiel dafür dar. Die Liefferkette zeigt dabei eine Metastruktur auf. Sie bildet eine Mittelform zwischen einem einzelnen Unternehmen (Mikrostruktur/Mikrosystem) und der Weltwirtschaft (Makrostruktur/Makrosystem). Die Makrostruktur charakterisiert sich durch eine dynamische Holarchie, die eine Reihe von zusammenarbeitenden Holonen (Unternehmen) umfasst.
Methoden: Nach einer kurzen Diskussion bezüglich der Natur einer Liefferkette (Metastruktur) und der Konfiguration von Metastrukturen stellen die Autoren unterschiedliche Liefferketten angesichts der morphologischen Analyse dar und bieten ein entsprechendes Beispiel dafür dar.
Ergebnisse: Die Hauptvorteile einer solchen Vorgehensweise sind: die Identifizierung von Charakteristika der Liefferketten, ferner die Modellierung des Durchflusses innerhalb der ganzen Metastruktur einer Liefferkette sowie die Inanspruchnahme der Möglichkeit einer schnellen Anpassung an die neuen Gegebenheiten.
Fazit: Eine zweckmäßige Konfiguration der Liefferkette bei Anwendung der morphologischen Analyse macht eine grundlegende Handlung aus, in den Situationen, in denen bezweckt wird, den Güterstrom optimal zu modellieren und eine schnelle Anpassung an die neuen Gegebenheiten einzuführen.

Codewörter: Lieferkette, Metastruktur, Konfiguration

Katarzyna Grzybowska
Poznan University of Technology,
Faculty of Engineering Management,
Strzelecka 11, Poznan, Poland
e-mail: katarzyna.grzybowska@put.poznan.pl

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A MEASURE OF EMERGENCE OF A LOGISTIC GROUP INTERACTION

V. Novikov, Y. Korsuk, L. Shipulina

International University MITSO, Minsk, Belarus

ABSTRACT. Background: The nature of the relations between group members is a very important part of the integrity of the logistics process. The identification of rating among the participants is certainly the most necessary condition for the quality of the logistics process. It can distinguished four types of emergence rating: direct participation rating, direct impact rating, participation rating and impact rating.
The aim of this paper was to create the method to determine the mutual relationships among various elements of logistic group.
Methods: The technique is based on the processing of the matrix of pairwise interactions obtained on the basis of a questionnaire survey of all members of the group and expressed as a score on the selected scale of assessments. The computation algorithm is based in particular on the traveling salesman problem using an original method of optimization and is implemented in Visual Studio C #.
Results: 16 types of leaderships were distinguished and described by the use of statistical methods.
Conclusions: The developed method of calculating the measure of emergence can be used not only for a group of students, but also for the definition of the rate of emergence in any collective system.

Key words: emergence, influence rating, rating of participation, direct impact rating, rating of direct participation, traveling salesman problem, directed graph, simply connected contour, collective system, logistic cooperation, types of leaders.

INTRODUCTION

The aim of this paper was to create the method to determine the mutual relationships among various elements of logistic group.

The nature of the relations between group members is a very important part of the integrity of the logistics process. The identification of rating among the participants is certainly the most necessary condition for the quality of the logistics process. We can distinguish four types of emergence rating: direct participation rating, direct impact rating, participation rating and impact rating.

The first type of rating describes the qualitative and quantitative degree of relations between a group member and a group. This type of rating includes the fact of a direct relation of a one group member to another from the standpoint of their actions. Of course, this is important, but the fact of such a leadership does not carry the underlying mechanisms of mediated relations and serves only as a superficial measure of choice of a leader among the members. If you touch the logistically important mechanism for ensuring the quality of the logistics process, using only the rating of the direct participation can lead to dilettantism in the relations. The latter does not allow to prepare and pay attention to those members whose influence in the collective process of interaction is more important to train highly qualified specialists, and hence is more important for the effectiveness of the group. Direct participation rating can effectively affect only the efficiency of work among outsiders, but the

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use of only this rating can heavily damage a process of preparing and encouraging the leaders of the group. The latter is a prerequisite for evaluation of the management of the group, as only highly qualified professionals are able to embrace and implement into the society all the achievements of the scientific and technological process.

RESULTS AND DISCUSSION

Direct participation rating can be easily calculated on the basis of a simple questionnaire in the form of an evaluation from 0 to 9 in the nature of the relation of the i-th participant to the j-th participant. The score a_{ij} =0 means that there is no relationship of i with j. The score a_{ij} = 9 means that there is a very close relationship of i with j from the position of the utility of the j-th participant for the i-th participant. Obviously, the direct participation ratings determined by the value:

$$N_i = \frac{1}{N-1}\sum_j a_{ij}$$

determined by the size, ranked in ascending order, where N is the number of the participants in the group. Direct impact rating is opposite to the direct participation rating and is calculated as:

$$V_j = \frac{1}{N-1}\sum_i a_{ij}$$

with V_j ranking in descending order. This rating determines the average characteristic of the effect of the i-th participant on the relationship in the group, i.e. a measure of an operation of the system. This measure, as the average characteristic, reflects a sense which is well-known in economics as a Public Relation (PR), and characterizes the collective system vision of the character of its own operation.

The rating of participation is calculated on the basis of the matrix aij in a more complicated way, but it reflects the measure of emergence based not only on the indirect mechanism of impact of the individual participant on the logistic process, but on a definition of the mentality of the learning organization too. The last term in the logistic means a collective system in which the process of identity formation is provided not only by the "teachers", but also by the "students". Naturally, the learning organization should focus on the experience and knowledge not only of a "teacher", but also of those "students" whose mentality and leadership meet the aspirations of the state and the public. In this regard, the identification of participation rating is very important in terms of a critical approach to education, since this rating indicates a real, not the desired state of the "students". This is a kind of a litmus test by which, ably organizing the process, we can carry out the correction of the education system in the group influencing the ranked group of leadership with the periodic control of the leadership rating. Mathematically, the system of relations aij can be represented as a directed graph (Figure 1), where the arrow indicates the relation of i-th student to the j-student.

The problem of determining the rating of participation is almost reduced to the traveling salesman problem [1] for the *j-th* member in the direction from *i* to *j* on the edges of the graph without the last edge which locks the closed bypass circuit. The essence of the traveling salesman problem is reduced to calculating the closed bypass circuit of all the nodes of a graph which has the minimum length of the edges beginning from the node *j*. In the bypass circuit you can't follow the same edge twice. This bypass circuit is called simply connected. In our problem, the movement should be performed only on those edges, the direction of which for the current node corresponds to the direction to this node. To solve this problem, we represent a graph in the form of incidence matrix a_{ij} (Fig. 2) corresponding to the graph (Fig. 1.).

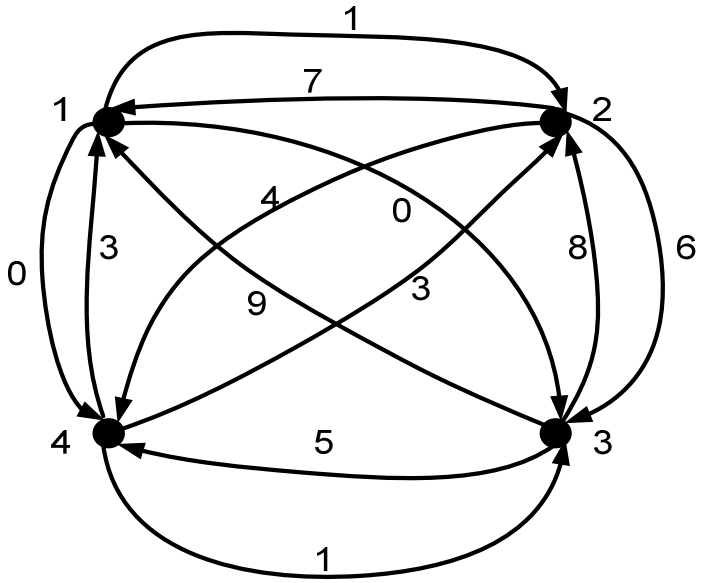

Fig. 1. Directed graph of relations
Rys. 1. Ukierunkowany wykres powiązań

The solution will be sought in the form of binary matrix x_{ij}, for which:

$$\sum_j x_{ij} = 1; \quad \sum_i x_{ij} = 1; \qquad x_{ij}=0$$

The x_{ij} solution must provide a minimum path in a sequential single circuit of all the nodes of the graph, starting from the *j-th* node with the return to the *i-th* node. In this formulation, the problem is a classical problem of the appointment, but under certain conditions, the decision may give doubly or more connected circuits, which contradicts the condition of the traveling salesman problem. To check that the circuit is simply connected it's necessary to impose an additional condition in the decision x_{ij} which cuts off the solution with multiply circuits.

	j				
i		1	2	3	4
	1	0	1	0	0
	2	7	0	6	4
	3	9	8	0	5
	4	3	3	1	0

Fig. 2. The incidence matrix
Rys. 2. Macierz częstości

Assume that you have received an interim solution x_{ij} on going from the *j-th* node, which corresponds to the column of the matrix a_{ij}. To test that the bypass circuit is simply connected you build the supply chain by the following algorithm. Fix $k = 1$. In the element of the vector Z_k you should bring the number of initial node j. According to the decision x_{ij} you should find for the column j the row i with $x_{ij} = 1$ and the number of that line you should bring into an element of the vector Z_k +1.

Next you check the condition $Z_m \neq Z_k$ +1 for $\forall m$ [1, k]. If this test is at least one match of Z_m with

Z_k +1, then you should fix the discrepancy of the solution x_{ij} according to the simply connected circuit. Otherwise $k = k$ +1, $j = i$ and for a new j perform the actions described above until k is less than the dimension of the matrix x_{ij}. If the examination doesn't reveal that the circuit is multiply, the solution x_{ij} will be initial, otherwise look for a new solution x_{ij} for assignment problem. The resulting solution x_{ij} is the maximum (minimum) according the length of edges bypass circuit S_j for the j node, which you should normalize by the formula $\frac{1}{N-1} S_j$ for the N group member in order to have the identity with the direct participation rating. Rating of participation is ranked in descending order by vector S_i for all

$j \in [1, N]$:

$$S_i = \begin{cases} \frac{maxS_j + b_{min}}{2}, & \text{если } N_j > 4 \\ \frac{minS_j + b_{max}}{2}, & \text{если } N_j < 5 \end{cases}$$

where b_{min} and b_{max} – the minimum and the maximum edge in the corresponding chain traversal.

The impact rating T_j is calculated similarly to the rating S_j, but with the condition of the bypass circuit which is opposite to the bypass condition to S_j and the recalculation by the formula:

$$T_j = \begin{cases} \frac{maxT_j + b_{max}}{2}, & \text{если } V_j > 4 \\ \frac{minTS_j + b_{min}}{2}, & \text{если } V_j < 5 \end{cases}$$

The impact rating T_j ranked in ascending order determines, in contrast to the direct impact rating V_i, a real and but not visible mechanism of operating in the system. Obviously, it is the most important not for "students", but for "teachers", as it allows to influence indirectly the members of the process.

A measure of emergence is determined by the comparative evaluation of the vectors *V, T, N, S*. Consider for systematization the extreme special cases. For the participant i we will take a leader as a value 0, and an outsider as 1. Since the number of M = 0111 means the leadership in *V* and the outsider in *T, N, S*. It is clear that M is a 4-bit binary number with 16 possible options from 0000 to 1111 in terms of [Kosareva, Zirer 2005, Scriptunova 2002].

The value of M_i = 0000 is a variant of leadership under the code name "player", as for the four types of leadership the participant i is a leader. Obviously, the "teachers" need to focus precisely on this leader in terms of his mentality of relations with other "students."

The value of M_i = 0001 describes "the player-narcissus." In this case the "teaching" staff should use all the means of advertising that leader, even more so if the group has no leader with a higher rating.

The value of M_i = 0010 describes "the player-pedantic". Obviously, such a situation characterized too strict requirements of the "teachers" to that group member.

The value of M_i = 0011 defines a "player-bear", which means his too strong advertising by "teachers."

The value of M_i = 0100 reveals a Democrat among the members of the group. To be a leader, such party must provide great mechanisms of indirect influence on the team.

The value of M_i = 0101 defines a Democrat-narcissus. From the perspective of teachers such a leader requires caution in his PR-advertising.

The value of M_i = 0110 defines a Democrat-pedant. Obviously, in this case it is necessary to take all necessary advertising impact on the group of participants from the standpoint of a moral approach to the leader.

The value of M_i = 0111 defines a Democrat-bear. In this case, the best option may be conducting of advertising company of the leader by the "teachers".

The value of M_i = 1000 characterizes the enforcer-Democrat. To become a leader this member needs measures of enabling advertising that increasingly seems to release and underscore the merits of this leader.

The value of M_i = 1001 characterizes the enforcer-narcissus. Such a leader can be promoted in the rating at the expense of decreasing its influence on the members of the group in the sense of their operation.

The value of M_i = 1010 defines an enforcer-pedant and his promotion in the rating scheme can be possible due to more democratic attitude to the participants of the process.

The value of M_i = 1011 characterizes the enforcer-bear and his promotion in the rating scheme can be possible, as in the previous case, due to a more democratic attitude to the participants of the process.

The value of M_i = 1100 defines PR-man. his promotion in the rating scheme is possible due to more moderate approach to its self-advertising.

The value of M_i = 1101 defines the narcissus. Obviously, such a leader must pay attention to the nature of his indirect relations with the group of the participants.

The value of M_i = 1110 defines a charismatic personality, who has the definition of "pedant" in his scheme of leadership. Obviously, the rating of his leadership increases by more balanced attitude toward the members of the group.

The value of M_i = 1111 describes an extremely charismatic personality, called in the system of leadership as a "bear", i.e. the party whose sense of leadership is determined only by obtaining the benefit from others.

These 16 types of leadership are extreme in grades $M^0 = \{V, T, N, S\}$. While conducting a survey we used 9-point scheme for the evaluation of relations from 0 to 9, which can be mathematically characterized by the number of 10-symmetric system of calculation from 0 to 9. Thus, under certain $M^0 = \{V, T, N, S\}$ the rating of leadership is determined by the sorting in ascending numerical value of M^0. In addition for any numeric value of M^0 you can easily identify an indicative type of a leader. In this case, you have to convert the number of M^0 into the number of M by the following rule: each grade M_i^0 of the number M^0 corresponds to a value of 0 of the grade M_i, if $M_i^0 \le 4$ and M_i=1, if $M_i^0 \ge 5$. Here is an example for M^0=7483: since 7>4, M_0=1, since 4<5, M_1=0, since 8>5, M_2=1 since 3<5, M_3=0.The result is a number M = 1010, which corresponds to the enforcer-pedant.

Implementation of the proposed method obviously depends on the meaning of the questionnaire. We have considered the description proposed above on the basis of the usefulness of the *j-th* participant for the *i-th* participant. But this method can be used, for example, for identifying the leadership of tolerance, i.e., the degree of sociability of the group members in non-business relationship.

Implementation of the proposed method requires special software and can be solved in the environment of Visual Studio C # [Novikov, Balytko, Korsuk 2011] with the additional algorithms for programming the supply chain of the definition whether the circuit is simply connected in the traveling salesman problem and by sorting the options in the problem of the assignment (Listing 1).

Listing 1.

```
using System; using System.Collections.Generic; using System.ComponentModel;
using System.Data; using System.Drawing; using System.Linq;
using System.Text; using System.Windows.Forms; using System.IO;
namespace WindowsFormsApplication7
{
   public partial class Form1 : Form
   {
```

```
public int[,] a=new int[200,200];  public int[,] b = new int[200, 200];
public decimal[,] bbb = new decimal[18, 18];
public bool[,] xx = new bool[200, 200];  public bool[,] xxx = new bool[18, 18];
public decimal[] c = new decimal[200]; public decimal[] yc = new decimal[200];
public int[] Nc = new int[200];  public int[] jjc = new int[200];
public int n;  public string DFF, RFF, FFF;
public int[] z = new int[200]; public int Dl; public int TMM = 0;
byte jf=5; // длина блока
   public Form1()
{ InitializeComponent(); }

private void button1_Click(object sender, EventArgs e)
{
   int i0,i1,k0;  string sss,ss1; string[] buf;
   if (Convert.ToByte(maskedTextBox1.Text) < 4) maskedTextBox1.Text = "4";
   if (Convert.ToByte(maskedTextBox1.Text) > 7) maskedTextBox1.Text = "7";
   jf = Convert.ToByte(maskedTextBox1.Text);
   OpenFileDialog MyDialog = new OpenFileDialog();
   if (MyDialog.ShowDialog() == DialogResult.OK)
   {   DFF = MyDialog.InitialDirectory; FFF = MyDialog.FileName;
      StreamReader fr = new StreamReader(MyDialog.FileName);
      string st = "", st1;
      while ((st1 = fr.ReadLine()) != null) st += st1+"\r";
      fr.Close();
      i0 = st.IndexOf("<matrix>")+9;   i1 = st.IndexOf("</matrix>") - 1;
      sss = st.Substring(i0, i1 - i0 + 1);   i0 = sss.IndexOf("\r") +1;
      Boolean kod = true; k0 = 0;
      while (kod)
       {
          i1 = sss.IndexOf("\r",i0)-1;  ss1 = sss.Substring(i0,i1-i0+1);
          buf = ss1.Split(';');  n = buf.Length-1;
          for (int i = 1; i < n; i++) a[k0, i-1] = Convert.ToInt32(buf[i]);
          k0++; i0 = i1 + 2;
          if (i0 >= sss.Length) kod = false;
       }
      n--;
   }  }

private void button2_Click(object sender, EventArgs e)
{
   decimal hhhh;   int kkkk;
   b = a;
   int[] NNN = new int[50];  int SNN = n;
   if (Convert.ToByte(maskedTextBox1.Text) < 4) maskedTextBox1.Text = "4";
   if (Convert.ToByte(maskedTextBox1.Text) > 7) maskedTextBox1.Text = "7";
   jf = Convert.ToByte(maskedTextBox1.Text);
   for (int i = 0; i < 50; i++)
       {
       if (SNN < jf) { NNN[i] = SNN; SNN = 1; break; }
       NNN[i] = jf; SNN -= NNN[i];
```

```
    if (SNN == 0) { SNN = i + 1; break; }
    if (SNN <= i+1) { for (int j = 0; j < SNN; j++) NNN[j]++; SNN=i+1; break; }
    if (SNN < jf) { NNN[i + 1] = SNN; SNN = i + 2; break; }
     }
for (int i = 0; i < n; i++) { b[i, i] = 0; Nc[i] = i + 1; }
for (int i = 0; i < n; i++)
{
   c[i] = 0;
   for (int j = 0; j < n; j++) c[i] += b[i, j];
   yc[i] = c[i] / (n - 1);
   c[i] = Math.Round(yc[i])*10;
}
for (int i = 0; i < n - 1; i++)
   for (int j = i + 1; j < n; j++)
   {
      if (yc[i] > yc[j])
      {
         hhhh = yc[i]; yc[i] = yc[j]; yc[j] = hhhh;
         hhhh = c[i]; c[i] = c[j]; c[j] = hhhh;
         kkkk=Nc[i]; Nc[i]=Nc[j]; Nc[j]=kkkk;
         for (int k = 0; k < n; k++)
         {
            kkkk=b[i,k]; b[i,k]=b[j,k]; b[j,k]=kkkk;
         }
         for (int k = 0; k < n; k++)
         {
            kkkk=b[k,i]; b[k,i]=b[k,j]; b[k,j]=kkkk;
         } } }
int Nath = 0; int Kon = NNN[0]; Dl = NNN[0];
for (int kop = 0; kop < SNN;kop++ )
{
   bbb[0, 0] = 0;
   for (int i0 = 1; i0 <= Dl; i0++)
      for (int i1 = 1; i1 <= Dl; i1++)
         bbb[i0, i1] = b[Nath + i0 - 1, Nath + i1 - 1];
   for (int i0 = 1; i0 <= Dl; i0++)
      {
      bbb[i0,0]=0;
      for (int i1 = 0; i1 < Nath; i1++) bbb[i0, 0] += b[Kon + i0 - 1, i1];
      if (Nath > 0) bbb[i0, 0] = Math.Round(bbb[i0, 0] / Nath);
      }
   for (int i0 = 1; i0 <= Dl; i0++)
   {
      bbb[0, i0] = 0;
      for (int i1 = 0; i1 < Nath; i1++) bbb[0, i0] += b[i1,Kon + i0 - 1];
      if (Nath > 0) bbb[0, i0] = Math.Round(bbb[0, i0]/Nath);
      if (Nath == 0) bbb[0, i0] = 9;
   }
      for (int mmm = 1; mmm <= Dl; mmm++)
      {
```

```
            decimal func = 1000000, func0 = -10000; ;
            decimal ff, fg0 = 10000, fg1 = -10000, bb0, bb1, hhh, bmin=0,bmax=0;
            bool kod = true;
            while (XXXX0(ref kod))
            {
               if (gg(Dl+1, mmm))
               {
                  for (int i = 0; i <= Dl; i++) xxx[i, mmm] = false;
                  ff = 0; bb0 = 1000; bb1 = -1000;
                  for (int i = 0; i <= Dl; i++) for (int j = 0; j <= Dl; j++)
                     {
                       if (xxx[i, j])
                         {
                   if (bb0 > bbb[i, j]) bb0 = bbb[i, j];  if (bb1 < bbb[i, j]) bb1 = bbb[i, j];
                  ff += bbb[i, j];
                         }
                     }
                  hhh = ff * (bb1 - bb0);
                  if (hhh > fg1) { func = ff; fg1 = hhh; bmin = bb0; }
                  hhh = ff * (9-bb1 + bb0);
                  if (hhh < fg0) { func0 = ff; fg0 = hhh; bmax = bb1; }
               }  }
if (c[mmm+Nath-1] < 50) c[mmm+Nath-1] += Math.Round((func0 / Dl+bmax)/2);
if (c[mmm+Nath-1] >= 50) c[mmm+Nath-1] += Math.Round((func / Dl+bmin)/2);
         }
      Nath = Kon;  Kon += NNN[kop + 1];  Dl = NNN[kop + 1];
   }

      decimal kk;
      for (int j = 0; j < n; j++)
      {
         kk = 0;
         for (int i = 0; i < n; i++) kk += b[i, j];
         yc[j] = (9 * (n - 1) - kk) / (n - 1);
         c[j] += Math.Round(yc[j]) * 1000;
      }

   for (int i = 0; i < n - 1; i++)
      for (int j = i + 1; j < n; j++)
      {
         if (yc[i] > yc[j])
         {
            hhhh = yc[i]; yc[i] = yc[j]; yc[j] = hhhh;
            hhhh = c[i]; c[i] = c[j]; c[j] = hhhh;
            kkkk = Nc[i]; Nc[i] = Nc[j]; Nc[j] = kkkk;
            for (int k = 0; k < n; k++)
            {
               kkkk = b[i, k]; b[i, k] = b[j, k]; b[j, k] = kkkk;
            }
            for (int k = 0; k < n; k++)
```

```
                {
                    kkkk = b[k, i]; b[k, i] = b[k, j]; b[k, j] = kkkk;
                }
            } }
        Nath = 0;  Kon = NNN[0]; Dl = NNN[0];
        for (int kop = 0; kop < SNN; kop++)
        {
            bbb[0, 0] = 0;
            for (int i0 = 1; i0 <= Dl; i0++)
                for (int i1 = 1; i1 <= Dl; i1++)
                    bbb[i0, i1] = b[Nath + i0 - 1, Nath + i1 - 1];
            for (int i0 = 1; i0 <= Dl; i0++)
            {
                bbb[i0, 0] = 0;
                for (int i1 = Kon; i1 < n; i1++) bbb[i0, 0] += b[Kon + i0 - 1, i1];
                if (Kon < n) bbb[i0, 0] = Math.Round(bbb[i0, 0] / (n-Kon));
                if (Kon == n) bbb[i0, 0] = 9;
            }
            for (int i0 = 1; i0 <= Dl; i0++)
            {
                bbb[0, i0] = 0;
                for (int i1 = Kon; i1 < n; i1++) bbb[0, i0] += b[i1, Kon + i0 - 1];
                if (Kon < n) bbb[0, i0] = Math.Round(bbb[0, i0] / (n-Kon));
                            }
            for (int mmm = 1; mmm <= Dl; mmm++)
            {
                decimal func = -1000000, func0 = 100000;
                decimal ff, fg0 = 10000, fg1 = -10000, bb0, bb1, hhh, bmax = 0, bmin = 0; ;
                bool kod = true;
                while (XXXX0(ref kod))
                {
                    if (g(Dl+1, mmm))
                    {
                        for (int i = 0; i <=Dl; i++) xxx[mmm, i] = false;
                        ff = 0; bb0 = 1000; bb1 = -1000;
                        for (int i = 0; i <=Dl; i++) for (int j = 0; j <=Dl; j++)
                            { if (xxx[i, j]) {
                              if (bb0 > bbb[i, j]) bb0 = bbb[i, j]; if (bb1 < bbb[i, j]) bb1 = bbb[i, j];
                                ff += bbb[i, j];
                                } }
                        hhh = ff* (9-bb1 + bb0);
                        if (hhh > fg1) { func = ff; fg1 = hhh; bmax = bb1; }
                        hhh = ff * (bb1 - bb0);
                        if (hhh < fg0) { func0 = ff; fg0 = hhh; bmin = bb0; }
                    }
                }
    if (c[mmm+Nath-1] >= 4100) c[mmm+Nath-1] += Math.Round(9  - (func / Dl+bmax)/2) *
100;
    if (c[mmm+Nath-1] < 4100) c[mmm+Nath-1] += Math.Round(9  - (func0 / Dl+bmin)/2) *
100;
```

```
            }
            Nath = Kon;  Kon += NNN[kop + 1]; Dl = NNN[kop + 1];
        }
        b_Click();
    }
    private bool STHETH0(bool kl)
    {
        if (kl) { for (int i = 0; i <= Dl+1; i++) jjc[i] = 0; return true; }
        else
        {
            jjc[0]++;
            for (int i = 0; i <= Dl + 1; i++)
                if (jjc[i] >= Dl + 1) { jjc[i + 1]++; jjc[i] = 0; }
                    else break;
            if (jjc[Dl+1] == 1) return false;
            else return true;
        }
    }
    private bool XXXX0(ref bool kod)
    {
        bool ku;
        if (kod) { ku = STHETH0(true); kod = false; }
        ku = STHETH0(false);
        do
        {
            for (int i = 0; i <= Dl; i++) for (int j = 0; j <= Dl; j++) xxx[i, j] = false;
            for (int i = 0; i <= Dl; i++) xxx[jjc[i], i] = true;
            for (int i = 0; i <= Dl; i++) { int kt = 0; for (int j = 0; j <= Dl; j++) if (xxx[i,
j])kt++; if (kt != 1) goto da; }
            return true;
        da: ku = STHETH0(false);
        } while (ku);
        return ku;
    }
    private void b_Click()
    {
        int kkkk; decimal hhhh; string FileName;   int i1 = FFF.LastIndexOf(".");
        StreamReader frr = new StreamReader(FFF);
        FFF = FFF.Substring(0, i1);  FFF += ".out"; FileName = FFF;
        StreamWriter fr = new StreamWriter(FileName);
        string st = "", st1;
        while ((st1 = frr.ReadLine()) != null) st += st1 + "\r\n";
        frr.Close();
        st += "\r\n\r\n";
        string sas;
        for (int i = 0; i < n-1; i++)
            for (int j = i+1; j < n; j++)
            {
                if (Nc[i] > Nc[j])
                    {
```

```
                    kkkk = Nc[i]; Nc[i] = Nc[j]; Nc[j] = kkkk;
                    hhhh = c[i]; c[i] = c[j]; c[j] = hhhh;
                  }
              }
          for (int i = 0; i < n ; i++) { sas = String.Format("{0,4:0000}",c[i]);
                    st += Convert.ToString(Nc[i]) + ".  " + sas + "\r\n"; }
          decimal ggg = 0, ggg1 = 0,gggm=0,gggp=0,ggg0=0;
          decimal[] C0 = new decimal[200];
          for(decimal ikk=1000; ikk>=1; ikk=Math.Round(ikk/10))
      {
          ggg = 0;
          for (int i = 0; i < n; i++)
            {
              C0[i] = c[i] % ikk; c[i] = Math.Floor(c[i] / ikk);
            }
          for (int i = 0; i < n; i++) ggg += c[i];
          ggg = Math.Round(ggg/n);
          for (int i = 0; i < n; i++)
             ggg1 += (ggg - c[i]) * (ggg - c[i]);
ggg1 = Math.Round(Convert.ToDecimal(Math.Sqrt(Convert.ToDouble(ggg1))/(n-1)));
 ggg0 += ggg * ikk;  gggm += (ggg - ggg1)*ikk;  gggp += (ggg + ggg1)*ikk;
          for (int i = 0; i < n; i++) c[i]=C0[i];
      }
          sas = "\r\n\r\n-----       " + String.Format("{0,4:0000}", gggm) + "\r\n";
          st += sas;
          sas = "00000     " + String.Format("{0,4:0000}", ggg0) + "\r\n";
          st += sas;
          sas = "+++++    " + String.Format("{0,4:0000}", gggp) + "\r\n";
          st += sas;
           fr.Write(st);
          fr.Close();
  }
  public bool gg(int a, int n)
  {
     int i;   z[0] = n;   int m = n; bool kk = true;
       for (i = 1; i < a; i++)
     {
        for (int j = 0; j < a; j++)
        if (xxx[m,j])
           {
            m = j; z[i] = j; goto a2;
           }
     kk = false; return kk;
     a2: for (int ii = 0; ii < i - 1; ii++)
              if (z[ii] == m) return false;
     }
     return kk;
  }
  public bool g(int a, int n)
  {
```

```
            int i;  z[0] = n;   int m = n;  bool kk = true;
              for (i = 1; i < a; i++)
            {
               for (int j = 0; j < a; j++)
                 if (xxx[j,m]) {  m = j; z[i] = j; goto a2; }
            kk = false; return kk;
            a2: for (int ii = 0; ii < i - 1; ii++)
                        if (z[ii] == m) return false;
            }
            return kk;
} }}
```

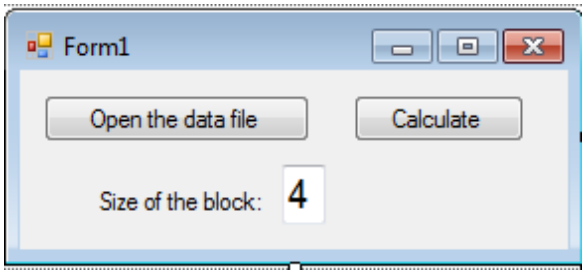

Fig. 3. Dialog window of the program
Rys. 3. Okno dialogowe programu

When you run the program it has the only dialog window in Figure 3. When you push the button "to open the data file," the reading if the matrix data from file is performed. When you push the button "calculate", the calculation and recording of the results to a file with a name that is identical to the data file into the same folder are performed. The number "size of the block" is indicated before calculation and means the length of the block clustering. Then smaller this number, then greater is the accuracy and less the calculation time. The maximum block length is limited by the conditions of the time of getting result.

The data file contains a list of a group and a matrix of relationships typed in a notebook. An example of the data file is shown in Listing 2.

Listing 2.

<Persone>

1. Ivanov Ivan Ivanovich
2. Petrov Petr Petrovich
3. Cidorov Cidor Cidorovich
4. Krivitski Nikolya Evgen'evich
5. Ermakov Eremej Pavlovich
6. Glaburda Irina Nikolaevna

</Persone>

<matrix>

0 ; 1; 2 ; 3 ; 4; 5 ; 6 ;

1 ; 0; 8 ; 8 ; 5; 4 ; 6 ;

2 ; 9; 0 ; 6 ; 4 ; 0 ; 6 ;

3 ; 9; 9 ; 0 ; 5 ; 7 ; 7 ;

4 ; 9; 9 ; 9 ; 0 ; 4 ; 8 ;

5 ; 6; 4 ; 9 ; 5 ; 0 ; 6 ;

6 ; 7; 9; 7 ; 6 ; 5 ; 0 ;

</matrix>

As its final results, the program displays the list of the four-digit numbers for the each party to the file with the extension .out inside the folder that contains the executable code.

The proposed program was reliably tested and validated on the data from a group of 26 students. The test was based on survey of all students in the group, who were given an identical questionnaire with the single question: "Set as a score from 0 to 9 the usefulness of the business relationships with each of the students (0 - no business relationships, 9 - business relationships are extremely useful for me). The final result correlates very well with the practical observations of the group during a period of 6 months [5].

The methods of calculating the measure of emergence can be used not only for a group of students, but also for the definition of the rate of emergence in any collective system.

SUMMARY

The computer programme was developed, which enables to determine the ranking of dependencies among all members of the group. The programme was tested by the use of a few examples and can be used in practical implementations.

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POMIAR POWSTAWANIA RELACJI W OBRĘBIE GRUPY LOGISTYCZNEJ

STRESZCZENIE. **Wstęp:** Istota zależności pomiędzy członkami grupy jest ważnym elementem spójności procesu logistycznego. Identyfikacja oceny poszczególnych uczestników jest bez wątpienia najważniejszym warunkiem zapewnienia jakości procesu logistycznego. Można wyróżnić cztery rodzaje ocen relacji: bezpośredniego uczestnictwa, bezpośredniego wpływu, uczestnictwa oraz wpływu.
Celem pracy było opracowanie metody ustalania wzajemnych zależności pomiędzy poszczególnymi elementami grupy logistycznej.
Metody: Zastosowana metoda jest oparta na macierzy wzajemnych interakcji, jakie zostały otrzymane w wyniku badania ankietowego, obejmującego wszystkich członków grupy i przedstawionego wartościowo na podstawie przyjętej skali pomiarowej. Algorytm wyliczeniowy został w głównej mierze oparty na problemie przedstawiciela handlowego w podróży służbowej jak oryginalna metoda optymalizacji przy użyciu Visual Studio C #.
Wyniki: Zostało zidentyfikowanych i opisanych 16 typów przywódczych poprzez zastosowanie odpowiednich metod statystycznych.
Wnioski: Uzyskana metoda oceny może być stosowana nie tylko w przypadku grupy studentów ale również w każdym innym złożonym systemie.

Słowa kluczowe: powstanie, ocena wpływu, ocena uczestnictwa, ocena bezpośredniego wpływu, ocena bezpośredniego uczestnictwa, problem przedstawiciela handlowego w podróży, wykres dedykowany, prosty profil, system złożony, współpraca logistyczna, typy przywódców.

RELATIONSENTSTEHUNG UND DEREN MESSUNG INNERHALB EINER LOGISTIK-GRUPPE

ZUSAMMENFASSUNG. Einleitung: Das Wesen der gegenseitigen Abhängigkeiten zwischen den Mitgliedern einer Gruppe stellt ein wichtiges Element der Kohärenz eines logistischen Prozesses dar. Die Ermittlung und Beurteilung dessen einzelnen Teilnehmer bildet zweifelsohne die wichtigste Voraussetzung für die Gewährleistung der Qualität innerhalb jedes Logistik-Prozesses. Die Beurteilung der einzelnen auftretenden Relationen lassen sich in vier Arten unterscheiden: als direkte Beteiligung, direkte Beeinflussung, Beteiligung, Beeinflussung.
Das Ziel der Arbeit war es, eine Methode für die Festlegung von gegenseitigen Abhängigkeiten zwischen den einzelnen Bestandselementen einer Logistik-Gruppe auszuarbeiten.
Methoden: Die angewandte Methode stützt sich auf die Matrix der gegenseitigen Zusammenhänge, die anhand eines Umfrage-Verfahrens, welches alle Mitglieder der Gruppe umfasst und wertmäßig auf Grund einer in Anspruch genommenen Messungsskala projiziert wird, ermittelt wurden. Der Logarithmus für die erfolgte Messung bezog sich hauptsächlich auf den Fall eines auf Dienstreisen befindlichen Handelsvertreters, wobei dafür das Programm des Visual Studio C # als originale Optimierungsmethode angewendet wurde.
Ergebnisse: Es wurden 16 Leader-Typen unter Anwendung unterschiedlicher statistischer Methoden identifiziert und beschrieben.
Fazit: Die ausgearbeitete Bemessungsmethode kann nicht nur im Falle einer Studentengruppe, sondern auch in jedem komplexeren System angewendet werden..

Codewörter: Entstehung, Beurteilung einer Beeinflussung, Beurteilung einer Beteiligung, Beurteilung einer direkten Beeinflussung, Beurteilung einer direkten Beteiligung, Problemfall eines auf Dienstreise befindlichen Handelsvertreters, einfaches Profil, komplexes System, logistische Interaktion, Leader-Typen.

Novikov Vasiliy
International University „MITSO”
220099, Belarus, Minsk, Kazintsa St. 21/2
e-mail: vanovikov@tut.by

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AN EOQ MODEL FOR TIME DEPENDENT WEIBULL DETERIORATION WITH LINEAR DEMAND AND SHORTAGES

Umakanta Mishra[1], Chaitanya Kumar Tripathy[2]

[1)] P.K.A.College of Engg. Chakarkend, Bargarh, India, [2)] Sambalpur University, Sambalpur, India

ABSTRACT. Background. The study of control and maintenance of production inventories of deteriorating items with and without shortages has grown in its importance recently. The effect of deterioration is very important in many inventory systems. Deterioration is defined as decay or damage such that the item cannot be used for its original purpose.
Methods: In this article order level inventory models have been developed for deteriorating items with linear demand and Weibull deterioration. In developing the model we have assumed that the production rate and the demand rate are time dependent. The unit production cost is inversely proportional to demand. Inventory-production system has two parameters Weibull deterioration.
Results and conclusions: Two models have been developed considering without shortage cases and with shortage case where the shortages are completely backlogged. The objective of the model is to develop an optimal policy that minimizes the total average cost. Sensitivity analysis has been carried out to show the effect of changes in the parameter on the optimum total average cost.

Key words: demand, Weibull deterioration, unit production cost, shortage.

INTRODUCTION

In recent years, many researchers are interested in the study of control and maintenance of production inventories of deteriorating items with and without shortages because most physical goods deteriorate over time. The effect of deterioration is very important in many inventory systems. Deterioration is defined as decay or damage such that the item cannot be used for its original purpose. Food items, drugs, pharmaceuticals, radioactive substances are examples of items in which sufficient deterioration can take place during the normal storage period of the units and consequently this loss must be taken into account when analyzing the system. Research in this direction began with the work of Whitin [1957] who considered fashion goods deteriorating at the end of a prescribed storage period. Ghare and Schrader [1963] developed an inventory model with a constant rate of deterioration. An order level inventory model for items deteriorating at a constant rate was discussed by Shah and Jaiswal [1977]. Aggarwal [1978] reconsidered this model by rectifying the error in the work of Shah and Jaiswal [1977] in calculating the average inventory holding cost. In all models discussed above, the demand rate and the deterioration rate were assumed to be constant, the replenishment rate was infinite and shortage in inventory ware not allowed.

Researchers started to develop inventory systems allowing time variability in one or more than one parameters. Dave and Patel [1981], He, Wang and Lai [2010] and Chuang [2012] discussed an inventory model for replenishment. This was followed by another model by Dave [1986] with variable instantaneous demand, discrete opportunities with shortages. Bahari-Kashani [1989] discussed a heuristic model with time-proportional demand. An Economic Order Quantity (EOQ) model for

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deteriorating items with shortages and linear trend in demand was studied by Goswami and Chaudhuri [1991] and Meher, Panda and Sahu [2012]. On all these inventory systems, the deterioration rate was considered to be constant.

Berrotoni [1962] observed, while discussing the difficulties of fitting empirical data to mathematical distributions, that both leakage failure of dry batteries and life expectancy of ethical drugs could be expressed in term of Weibull distribution. In both cases, the rate of deterioration increased with age or the longer the items remained unused, the higher the rate at which they failed. At some point in time, all units that had not been used would have failed. Perhaps the work of Berrotoni [1962] prompted Covert and Philip [1973] to develop an inventory model for deteriorating items with variable rate of deterioration. They used the two-parameter Weibull distribution to represent the distribution of deterioration. Two-parameter Weibull distribution deterioration is a generalized form of exponentially decaying functions. The main reason for choosing the Weibull distribution deterioration lies in its convenient generalized properties. The novelty we will be taking into consideration in this research is that the time of deterioration is a random variable following the two-parameter Weibull distribution. This distribution can be used to model either increasing or decreasing rate of deterioration, according to the choice of the parameters. The instantaneous rate function for a two-parameter Weibull distribution is given by:

$$Z(t) = \alpha\beta t^{\beta-1}$$

where α is the scale parameter, $\alpha > 0$; β is the shape parameter , $\beta > 0$; t is time of deterioration $t > 0$.

It is seen that the two-parameter Weibull distribution is appropriate for an item with decreasing rate of deterioration only if the initial rate of deterioration is extremely high. Similarly, this distribution can also be used for an item with increasing rate of deterioration only if the initial rate is approximately zero.

Another class of inventory models has been developed by different researchers with time-dependent deterioration rate. Mishra [1975] analyzed an inventory model with a variable rate of deterioration, finite rate of replenishment for no shortage case, but only a special case of the model was solved under very restrictive assumptions. Deb and Chaudhuri [1986] studied a model with a finite rate of production and a time-proportional deterioration rate, allowing backlogging. Goswami and Chaudhuri [1992] assumed that the demand rate, production rate and deterioration rate were all time dependent. Detailed information regarding inventory modelling for deteriorating items was given in the review articles of Nahmias [1982] and Rafaat [1991]. An order-level inventory model for deteriorating items without shortages has been developed by Jalan and Chaudhuri [1999].

Further related works in this line are due to Papachristos and Skouri [2000], Goyal and Giri [2001], Giri [et al. 2003], Ghosh [et al. 2006], Roy and Chaudhuri [2009] and Tripathy and Mishra [2011], Tripathy and Pradhan [2011a], Tripathy and Mishra [2010], Tripathi [2011], Tripathy and Pradhan [2011b], as well as Tripathi and Kumar [2011].

In this paper, we have tried to developed EOQ models for time-dependent deteriorating items with linear demand rate. The production rate is finite and proportional demand rate. The unit production cost is assumed to be inversely proportional to the demand rate. The first model discussed here is for without shortage case and then the model is extended to cover the case of inventory with shortages which are completely backlogged. The procedure of solving the model is illustrated with the help of two numerical examples. Sensitivity analysis has been carried out to show the effect of changes in the parameter on the optimum total average cost.

MODEL I: MODEL FOR WITHOUT SHORTAGE CASE

We need the following assumptions and notation for developing our inventory model.

(i) Lead time is zero.

(ii) $R = f(t) = a + bt$: Demand rate at any time t where, $a \geq 0,\ b > 0,\ t \geq 0$

(iii) $K = \delta f(t)$: Production rates where $(\delta > 1)$, is a constant.

(iv) $\theta(t) = \alpha\beta t^{\beta-1}$: Deterioration rate which follows a two parameter Weibull distribution, where $\alpha(0 < \alpha << 1)$ is the scale parameter, $\beta > 1$ is the shape parameter. It is assumed that the deterioration of units increases with time $t > 0$.

(v) c_1 : Constant holding cost per item per unit of time.

(vi) c_2 : Infinite shortage cost i.e. shortages are not permitted.

(vii) c_3 : Constant deterioration cost per unit per unit of time.

(viii) C : Total average cost for a production cycle.

(ix) $v = \alpha_1 R^{-\gamma}$: Unit production cost which is inversely related to the demand rate where $\alpha_1 > 0$, $\gamma > 0$ *and* $\gamma \neq 2$.

Here we have,

$$\frac{dv}{dR} = -\alpha_1 \gamma R^{-(\gamma+1)} < 0,$$

$$\frac{d^2v}{dR^2} = \alpha_1 \gamma(\gamma+1) R^{-(\gamma+2)} > 0.$$

Hence, we observe that the marginal unit cost of production is an increasing function of *R*. As increase in demand rate results in decreases of the unit cost of production at an increasing rate. This encourages the manufacturer to produce more as the demand for the item increases.

At initial time $t = 0$, the production starts with zero inventory and the production stops as the stock reches level S at time $t = t_1$. Due to demand and deterioration inventory level gradually diminishes during the time period $t_1 \le t \le t_2$ which ultimately falls to zero at time $t = t_2$, after which the next cycle begains. During the early stage of inventory, the intensity of deterioration is very low because t is small. However, the intensity increases with time, but $\theta(t)$ remains bounded for $t >> 1$ since $0 < \alpha << 1$.

Let $Q(t)$ be the inventory level of the system at any time $t\,(0 \le t \le t_2)$. The differential equations governing the instantaneous states of $Q(t)$ in the interval $[0, t_2]$ are given by

$$\frac{dQ(t)}{dt} + \theta(t)\,Q(t) = K - f(t), \qquad 0 \le t \le t_1. \tag{1}$$

$$\frac{dQ(t)}{dt} + \theta(t)\,Q(t) = -f(t), \qquad t_1 \le t \le t_2. \tag{2}$$

Using $\theta(t) = \alpha\beta t^{\beta-1}$ and $f(t) = a + bt$, (1) and (2) become respectively

$$\frac{dQ(t)}{dt} + \alpha\beta t^{\beta-1} Q(t) = (\delta - 1)(a + bt), \qquad 0 \le t \le t_1. \tag{3}$$

with the conditions $Q(0) = 0$ and $Q(t_1) = S$, and

$$\frac{dQ(t)}{dt} + \alpha\beta t^{\beta-1}\, Q(t) = -(a + bt), \qquad t_1 \le t \le t_2. \tag{4}$$

with the conditions $Q(t_1) = S$ and $Q(t_2) = 0$.

The solution of equation (3) using $Q(0) = 0$, is

$$Q(t) = (\delta - 1)\left\{ a\left(t - \alpha t^{\beta+1} + \frac{\alpha t^{\beta+1}}{\beta+1} \right) + b\left(\frac{t^2}{2} + \frac{\alpha t^{\beta+2}}{\beta+2} - \frac{\alpha t^{\beta+2}}{2} \right) \right\}, \qquad 0 \le t \le t_1. \tag{5}$$

As $0 < \alpha << 1$, neglecting powers of α higher than the first, this approximation is followed throughout the subsequent calculations. The solution of (4) using the condition

$Q(t_1) = S$, is

$$Q(t) = S\left\{1+\alpha\left(t_1^{\beta} - t^{\beta}\right)\right\} + a\left\{t_1 - t + \frac{\alpha}{\beta+1}\left(t_1^{\beta+1} - t^{\beta+1}\right) + \alpha\left(t^{\beta+1} - t_1 t^{\beta}\right)\right\}$$

$$+ b\left\{\frac{t_1^{2}}{2} - \frac{t^{2}}{2} + \frac{\alpha}{\beta+2}\left(t_1^{\beta+2} - t^{\beta+2}\right) + \frac{\alpha}{2}\left(t^{\beta+2} - t_1^{2} t^{\beta}\right)\right\}, \qquad t_1 \le t \le t_2. \qquad (6)$$

Since $Q(t_2) = 0$, we get from equation (6),

$$S\left\{1+\alpha\left(t_1^{\beta} - t_2^{\beta}\right)\right\} + a\left\{t_1 - t_2 + \frac{\alpha}{\beta+1}\left(t_1^{\beta+1} - t_2^{\beta+1}\right) + \alpha\left(t_2^{\beta+1} - t_1 t_2^{\beta}\right)\right\}$$

$$+ b\left\{\frac{t_1^{2}}{2} - \frac{t_2^{2}}{2} + \frac{\alpha}{\beta+2}\left(t_1^{\beta+2} - t_2^{\beta+2}\right) + \frac{\alpha}{2}\left(t_2^{\beta+2} - t_1^{2} t_2^{\beta}\right)\right\} = 0$$

Neglecting powers of α higher than the first, after simplification this result reduces to

$$S = a\left\{t_2 - t_1 + \frac{\alpha}{\beta+1}\left(t_2^{\beta+1} - t_1^{\beta+1}\right) + \alpha\left(t_1^{\beta+1} - t_1^{\beta} t_2\right)\right\} + b\left\{\frac{t_2^{2}}{2} - \frac{t_1^{2}}{2} + \frac{\alpha}{\beta+2}\left(t_2^{\beta+2} - t_1^{\beta+2}\right) + \frac{\alpha}{2}\left(t_1^{\beta+2} - t_1^{\beta} t_2^{2}\right)\right\}$$

Therefore

$$Q(t) = \begin{cases} (\delta-1)\left\{a\left(t - \alpha t^{\beta+1} + \frac{\alpha t^{\beta+1}}{\beta+1}\right) + b\left(\frac{t^2}{2} + \frac{\alpha t^{\beta+2}}{\beta+2} - \frac{\alpha t^{\beta+2}}{2}\right)\right\}, & \text{if} \quad 0 \le t \le t_1 \\ S\left\{1+\alpha\left(t_1^{\beta} - t^{\beta}\right)\right\} + a\left\{t_1 - t + \frac{\alpha}{\beta+1}\left(t_1^{\beta+1} - t^{\beta+1}\right) + \alpha\left(t^{\beta+1} - t_1 t^{\beta}\right)\right\} & \\ + b\left\{\frac{t_1^{2}}{2} - \frac{t^{2}}{2} + \frac{\alpha}{\beta+2}\left(t_1^{\beta+2} - t^{\beta+2}\right) + \frac{\alpha}{2}\left(t^{\beta+2} - t_1^{2} t^{\beta}\right)\right\}, & \text{if} \quad t_1 \le t \le t_2 \end{cases} \qquad (7)$$

Thus the total inventory in the cycle is $\int_0^{t_1} Q(t)dt + \int_{t_1}^{t_2} Q(t)dt$

$$= (\delta-1)\left\{a\left(\frac{t_1^{2}}{2} - \frac{\alpha t_1^{\beta+2}}{\beta+2} + \frac{\alpha t_1^{\beta+2}}{(\beta+1)(\beta+2)}\right) + b\left(\frac{t_1^{3}}{6} + \frac{\alpha t_1^{\beta+3}}{(\beta+2)(\beta+3)} - \frac{\alpha t_1^{\beta+3}}{2(\beta+3)}\right)\right\}$$

$$+ a\left\{\frac{t_2^{2}}{2} + \frac{t_1^{2}}{2} + t_1 t_2 + \frac{\alpha}{\beta+1}\left(t_2^{\beta+3} - t_1 t_2^{\beta+2} + t_1^{\beta+3} - t_1^{\beta+2} - \frac{t_2^{\beta+2}}{\beta+2} + \frac{t_1^{\beta+2}}{\beta+2} + t_2 t_1^{\beta+1} - t_2 t_1^{\beta+2}\right) + \alpha\left(2t_2 t_1^{\beta+1}\right.\right.$$

$$\left.\left. - \frac{t_2^{\beta+2}}{\beta+1} + \frac{2t_2 t_1^{\beta+1}}{\beta+1} + \frac{t_2^{\beta+2}}{\beta+2} - \frac{t_1^{\beta+2}}{\beta+2} - \frac{t_1 t_2^{\beta+1}}{\beta+1}\right)\right\} + b\left\{\frac{t_2^{3}}{3} + \frac{t_1^{3}}{6} - \frac{t_2^{2} t_1}{2} + \frac{\alpha}{\beta+2}\left(t_2^{\beta+3} - t_1 t_2^{\beta+2} - \frac{t_2^{\beta+2}}{\beta+2} + \frac{t_1^{\beta+2}}{\beta+2}\right)\right.$$

$$\left. + \frac{\alpha}{2}\left(\frac{t_2^{\beta+3}}{\beta+3} - \frac{t_1^{\beta+3}}{\beta+3} - \frac{t_2^{\beta+3}}{\beta+1} + \frac{t_2^{2} t_1^{\beta+1}}{\beta+1}\right)\right\}$$

Total number of deteriorated items in $[0, t_2]$ is given by production in $[0, t_1]$ – Demand in $[0, t_2]$, i.e.

$$\delta\int_0^{t_1}(a+bt)dt - \int_0^{t_2}(a+bt)dt = a\left(\delta t_1 - t_2\right) + \frac{1}{2}b\left(\delta t_1^{2} - t_2^{2}\right) \qquad (8)$$

Since the production in $[u,\ u+du]$ is *Kdu*, the cost of production in $[u, u+du]$ is:

$$K\nu\,du = \frac{\alpha_1\delta R}{(a+bu)^{\gamma}}du = \frac{\alpha_1\delta}{(a+bu)^{\gamma-1}}du.$$

Hence the production cost in $[0,t_1]$ is given by

$$\int_0^{t_1}\frac{\alpha_1\delta}{(a+bu)^{\gamma-1}}du = \frac{\alpha_1\delta}{b(\gamma-2)}\left[a^{2-\gamma}-(a+bt_1)^{2-\gamma}\right], \qquad \gamma\neq 2. \tag{9}$$

Now the total average cost of the system is

$$C = \frac{1}{t_2}\Bigg[c_1(\delta-1)\left\{a\left(\frac{t_1^{\,2}}{2}-\frac{\alpha t_1^{\,\beta+2}}{\beta+2}+\frac{\alpha t_1^{\,\beta+2}}{(\beta+1)(\beta+2)}\right)+b\left(\frac{t_1^{\,3}}{6}+\frac{\alpha t_1^{\,\beta+3}}{(\beta+2)(\beta+3)}-\frac{\alpha t_1^{\,\beta+3}}{2(\beta+3)}\right)\right\}$$

$$+c_1a\left\{\frac{t_2^{\,2}}{2}+\frac{t_1^{\,2}}{2}+t_1t_2+\frac{\alpha}{\beta+1}\left(t_2^{\,\beta+3}-t_1t_2^{\,\beta+2}+t_1^{\,\beta+3}-t_1^{\,\beta+2}-\frac{t_2^{\,\beta+2}}{\beta+2}+\frac{t_1^{\,\beta+2}}{\beta+2}+t_2t_1^{\,\beta+1}-t_2t_1^{\,\beta+2}\right)+\alpha\Bigg(\ 2t_2t_1^{\,\beta+1}$$

$$-\frac{t_2^{\,\beta+2}}{\beta+1}+\frac{2t_2t_1^{\,\beta+1}}{\beta+1}+\frac{t_2^{\,\beta+2}}{\beta+2}-\frac{t_1^{\,\beta+2}}{\beta+2}-\frac{t_1t_2^{\,\beta+1}}{\beta+1}\Bigg)\right\}+c_1b\left\{\frac{t_2^{\,3}}{3}+\frac{t_1^{\,3}}{6}-\frac{t_2^{\,2}t_1}{2}+\frac{\alpha}{\beta+2}\left(t_2^{\,\beta+3}-t_1t_2^{\,\beta+2}-\frac{t_2^{\,\beta+2}}{\beta+2}+\frac{t_1^{\,\beta+2}}{\beta+2}\right)\right.$$

$$\left.+\frac{\alpha}{2}\left(\frac{t_2^{\,\beta+3}}{\beta+3}-\frac{t_1^{\,\beta+3}}{\beta+3}-\frac{t_2^{\,\beta+3}}{\beta+1}+\frac{t_2^{\,2}t_1^{\,\beta+1}}{\beta+1}\right)\right\}+c_3a(\delta t_1-t_2)+\frac{1}{2}c_3b\left(\delta t_1^{\,2}-t_2^2\right)$$

$$+\frac{\alpha_1\delta}{b(\gamma-2)}\left[a^{2-\gamma}-(a+bt_1)^{2-\gamma}\right]\Bigg] \tag{10}$$

Optimum values of t_1 and t_2 for minimum average cost 'C' are the solutions of the equations

$$\frac{\partial C}{\partial t_1}=0 \text{ and } \frac{\partial C}{\partial t_2}=0. \tag{11}$$

Provided

$$\frac{\partial^2 C}{\partial t_1^{\,2}}>0,\quad \frac{\partial^2 C}{\partial t_2^{\,2}}>0 \quad\text{and}\quad \frac{\partial^2 C}{\partial t_1^{\,2}}\frac{\partial^2 C}{\partial t_2^{\,2}}-\frac{\partial^2 C}{\partial t_1\partial t_2}>0.$$

Equation (11) is

$$\frac{\partial C}{\partial t_1} = c_1(\delta-1)\left\{a\left(t_1-\alpha t_1^{\,\beta+1}+\frac{\alpha t_1^{\,\beta+1}}{\beta+1}\right)+b\left(\frac{t_1^{\,2}}{2}+\frac{\alpha t_1^{\,\beta+2}}{\beta+2}-\frac{\alpha t_1^{\,\beta+2}}{2}\right)\right\}$$

$$+c_1a\Bigg[t_1+t_2+\frac{\alpha}{\beta+1}\left\{(\beta+3)t_1^{\,\beta+2}-t_2^{\,\beta+2}-(\beta+2)t_1^{\,\beta+1}+t_1^{\,\beta+1}-(\beta+2)t_1^{\,\beta+1}t_2+(\beta+1)t_1^{\,\beta}t_2\right\}$$

$$+\alpha\left\{2(\beta+1)t_2t_1^{\,\beta}+2t_1^{\,\beta}t_2t_1^{\,\beta+1}-\frac{t_2^{\,\beta+1}}{\beta+1}\right\}\Bigg]+c_1b\left\{\frac{t_1^{\,2}}{2}-\frac{t_2^{\,2}}{2}+\frac{\alpha}{\beta+2}\left(t_1^{\,\beta+1}-t_2^{\,\beta+2}\right)+\frac{\alpha}{2}\left(t_2^{\,2}t_1^{\,\beta}-t_1^{\,\beta+2}\right)\right\}$$

$$+c_3a\delta+c_3b\delta t_1+\alpha_1\delta(a+bt_1)^{1-\gamma}=0 \tag{12}$$

$$\frac{\partial C}{\partial t_2} = -\frac{1}{t_2^{\,2}}\Bigg[c_1(\delta-1)\left\{a\left(\frac{t_1^{\,2}}{2}-\frac{\alpha t_1^{\,\beta+2}}{\beta+2}+\frac{\alpha t_1^{\,\beta+2}}{(\beta+1)(\beta+2)}\right)+b\left(\frac{t_1^{\,3}}{6}+\frac{\alpha t_1^{\,\beta+3}}{(\beta+2)(\beta+3)}-\frac{\alpha t_1^{\,\beta+3}}{2(\beta+3)}\right)\right\}$$

$$+c_1a\left\{\frac{t_1^{\,2}}{2}+\frac{\alpha}{\beta+1}\left(t_1^{\,\beta+3}-t_1^{\,\beta+2}+\frac{t_1^{\,\beta+2}}{\beta+2}\right)-\frac{\alpha t_1^{\,\beta+2}}{\beta+2}\right\}+c_1b\left\{\frac{t_1^{\,3}}{6}+\frac{\alpha t_1^{\,\beta+2}}{(\beta+2)(\beta+2)}-\frac{\alpha t_1^{\,\beta+3}}{2(\beta+3)}\right\}$$

$$+c_3a\delta t_1+\frac{1}{2}c_3b\delta t_1^{\,2}+\frac{\alpha_1\delta}{b(\gamma-2)}\left[a^{2-\gamma}-(a+bt_1)^{2-\gamma}\right]\Bigg]+c_1a\Bigg[\frac{1}{2}+\frac{\alpha}{\beta+2}\Bigg\{\ (\beta+2)t_2^{\,\beta+1}-(\beta+1)t_1t_2^{\,\beta}$$

$$-\frac{(\beta+1)t_2^{\beta}}{\beta+2}\Bigg\}+\alpha\Bigg\{\frac{(\beta+1)t_2^{\beta}}{\beta+2}-\frac{\beta t_1 t_2^{\beta-1}}{\beta+1}-t_2^{\beta}\Bigg\}\Bigg]+c_1 b\Bigg[\frac{2t_2}{3}-\frac{t_1}{2}+\frac{\alpha}{\beta+2}\Bigg\{(\beta+2)t_2^{\beta+1}-(\beta+1)t_1 t_2^{\beta}$$

$$-\frac{(\beta+1)t_2^{\beta}}{\beta+2}\Bigg\}+\frac{\alpha}{2}\Bigg\{\frac{(\beta+2)t_2^{\beta+1}}{\beta+3}-\frac{(\beta+2)t_2^{\beta+1}}{\beta+1}+\frac{t_1^{\beta+1}}{\beta+1}\Bigg\}\Bigg]-\frac{1}{2}bc_3=0 \qquad (13)$$

MODEL II: MODEL FOR WITH SHORTAGE

Here we develop an order-level model for deteriorating items with a finite rate of replenishment allowing shortages, which are completely backlogged. We will use the same notation and assumption of model-I replacing (vii) by: c_2 be the constant shortage cost per unit per unit of time. Initially at time $t=0$ we start with zero inventories. Then the production starts and continues up to time $t=t_1$ when the stock reaches level S after meeting the demand during this period. Inventory accumulated in $[0,t_1]$ after meeting the demands is used in $[t_1,t_2]$. The stock reaches the zero level at time $t=t_2$. Now shortages start to develop and accumulate to the level P at $t=t_3$. Production starts at time t_3. The running demands as well as the backlog for $[t_2,t_3]$ are satisfied in $[t_3,t_4]$. The inventory again reaches the zero level at time $t=t_4$, Then the next cycle starts. Our objective is to determine the optimum values of C, t_1, t_2, t_3 and t_4 subject to the assumptions stated above.

$Q(t)$ be the instantaneous inventory level at any time $t\,(0\le t\le t_4)$. Thus the instantaneous states of $Q(t)$ is governed by the following differential equations:

$$\frac{dQ(t)}{dt}+\alpha\beta t^{\beta-1}Q(t)=(\delta-1)(a+bt), \qquad 0\le t\le t_1. \qquad (14)$$

Subject to the conditions $Q(0)=0$ and $Q(t_1)=S$.

$$\frac{dQ(t)}{dt}+\alpha\beta t^{\beta-1}Q(t)=-(a+bt), \qquad t_1\le t\le t_2. \qquad (15)$$

Subject to the conditions $Q(t_1)=S$ and $Q(t_2)=0$.

$$\frac{dQ(t)}{dt}=-(a+bt), \qquad t_2\le t\le t_3. \qquad (16)$$

Subject to the conditions $Q(t_2)=S$ and $Q(t_3)=-S$.

$$\frac{dQ(t)}{dt}=(\delta-1)(a+bt), \qquad t_3\le t\le t_4. \qquad (17)$$

Subject to the conditions $Q(t_3)=-P$ and $Q(t_4)=0$.

Following the derivation as in section 2 we get the solutions of (14) and (15) similar to (7). The solutions of (16) and (17) using conditions $Q(t_2)=0$ and $Q(t_4)=0$ will be

$$Q(t)=a(t_2-t)+\frac{b}{2}\left(t_2^{\,2}-t^2\right), \qquad t_2\le t\le t_3. \qquad (18)$$

and

$$Q(t)=a(\delta-1)(t-t_4)+\frac{b}{2}(\delta-1)(t^2-t_4^{\,2}), \qquad t_3\le t\le t_4. \qquad (19)$$

As there is no inventory during the period $[t_2, t_4]$, there is no deterioration. Hence total number of deteriorated items in $[0, t_4]$ is the same as given in (8).

Total shortage during $[t_2, t_4]$ is

$$\int_{t_2}^{t_4} -[Q(t)]dt = \int_{t_2}^{t_3} [-Q(t)]dt + \int_{t_3}^{t_4} -[Q(t)]dt$$

$$= \frac{a}{2}\left[{t_2}^2 - 2t_2t_3 + \delta {t_3}^2 + (\delta-1){t_4}^2 - 2(\delta-1)t_4t_3\right] + \frac{b}{6}\left[2{t_2}^3 - 3{t_2}^2t_3 + \delta {t_3}^3 + 2(\delta-1){t_4}^3 - 3(\delta-1){t_4}^2t_3\right]$$

And the production cost during $[t_3, t_4]$ is,

$$\int_{t_3}^{t_4} Kvdu = \alpha_1\delta\int_{t_3}^{t_4} (a+bu)^{1-\gamma}du = \frac{\alpha_1\delta}{b(\gamma-2)}\left[(a+bt_3)^{2-\gamma} - (a+bt_4)^{2-\gamma}\right], \qquad \gamma \neq 2.$$

Therefore the production cost during $[0, t_4]$ is

$$\frac{\alpha_1\delta}{b(\gamma-2)}\left[a^{2-\gamma} - (a+bt_1)^{2-\gamma} + (a+bt_3)^{2-\gamma} - (a+bt_4)^{2-\gamma}\right], \qquad \gamma \neq 2.$$

Thus the total average cost of the system during $[0, t_4]$ is,

$$C = \frac{1}{t_4}\left[c_1(\delta-1)\left\{a\left(\frac{{t_1}^2}{2} - \frac{\alpha {t_1}^{\beta+2}}{\beta+2} + \frac{\alpha {t_1}^{\beta+2}}{(\beta+1)(\beta+2)}\right) + b\left(\frac{{t_1}^3}{6} + \frac{\alpha {t_1}^{\beta+3}}{(\beta+2)(\beta+3)} - \frac{\alpha {t_1}^{\beta+3}}{2(\beta+3)}\right)\right\}\right.$$

$$+ c_1a\left\{\frac{{t_2}^2}{2} + \frac{{t_1}^2}{2} + t_1t_2 + \frac{\alpha}{\beta+1}\left({t_2}^{\beta+3} - t_1{t_2}^{\beta+2} + {t_1}^{\beta+3} - {t_1}^{\beta+2} - \frac{{t_2}^{\beta+2}}{\beta+2} + \frac{{t_1}^{\beta+2}}{\beta+2} + t_2{t_1}^{\beta+1} - t_2{t_1}^{\beta+2}\right) + \alpha\left(2t_2{t_1}^{\beta+1}\right.\right.$$

$$\left.\left. - \frac{{t_2}^{\beta+2}}{\beta+1} + \frac{2t_2{t_1}^{\beta+1}}{\beta+1} + \frac{{t_2}^{\beta+2}}{\beta+2} - \frac{{t_1}^{\beta+2}}{\beta+2} - \frac{t_1{t_2}^{\beta+1}}{\beta+1}\right)\right\} + c_1b\left\{\frac{{t_2}^3}{3} + \frac{{t_1}^3}{6} - \frac{{t_2}^2t_1}{2} + \frac{\alpha}{\beta+2}\left({t_2}^{\beta+3} - t_1{t_2}^{\beta+2} - \frac{{t_2}^{\beta+2}}{\beta+2} + \frac{{t_1}^{\beta+2}}{\beta+2}\right)\right.$$

$$\left.\left. + \frac{\alpha}{2}\left(\frac{{t_2}^{\beta+3}}{\beta+3} - \frac{{t_1}^{\beta+3}}{\beta+3} - \frac{{t_2}^{\beta+3}}{\beta+1} + \frac{{t_2}^2{t_1}^{\beta+1}}{\beta+1}\right)\right\} + \frac{\alpha_1\delta}{b(\gamma-2)}\left[a^{2-\gamma} - (a+bt_1)^{2-\gamma} + (a+bt_3)^{2-\gamma} - (a+bt_4)^{2-\gamma}\right]\right.$$

$$+ \frac{c_2a}{2}\left[{t_2}^2 - 2t_2t_3 + \delta {t_3}^2 + (\delta-1){t_4}^2 - 2(\delta-1)t_4t_3\right] + \frac{c_2b}{6}\left[2{t_2}^3 - 3{t_2}^2t_3 + \delta {t_3}^3 + 2(\delta-1){t_4}^3 - 3(\delta-1){t_4}^2t_3\right]$$

$$\left. + c_3a(\delta t_1 - t_2) + \frac{1}{2}c_3b\left(\delta {t_1}^2 - t_2^2\right)\right], \gamma \neq 2 \qquad (20)$$

The required optimum values of t_1, t_2, t_3 and t_4 which minimize the cost function C can be obtained from the solution of the following equations,

$$\frac{\partial C}{\partial t_1} = 0,\ \frac{\partial C}{\partial t_2} = 0,\ \frac{\partial C}{\partial t_3} = 0 \text{ and } \frac{\partial C}{\partial t_4} = 0. \qquad (21)$$

Provided these values of $t_i (i = 1,2,3,4)$ obtain above equation satisfy the conditions $D_i > 0 (i = 1,2,3,4)$, where D_i is the Hessian determinant of order i given by:

$$D_i = \begin{vmatrix} c_{11} & c_{12} \ldots\ldots & c_{1i} \\ c_{21} & c_{22} \ldots\ldots & c_{2i} \\ : & : & : \\ : & : & : \\ c_{i1} & c_{i2} \ldots & c_{ii} \end{vmatrix}$$

$$c_{ij} = \frac{\partial^2 C}{\partial t_i \partial t_j} \qquad (i, j = 1,2,3,4)$$

We can expand the equations of (21) as follows,

$$\frac{\partial C}{\partial t_1} = c_1(\delta - 1)\left\{a\left(t_1 - \alpha {t_1}^{\beta+1} + \frac{\alpha {t_1}^{\beta+1}}{\beta+1}\right) + b\left(\frac{{t_1}^2}{2} + \frac{\alpha {t_1}^{\beta+2}}{\beta+2} - \frac{\alpha {t_1}^{\beta+2}}{2}\right)\right\}$$

$$+ c_1 a\left[t_1 + t_2 + \frac{\alpha}{\beta+1}\left\{(\beta+3){t_1}^{\beta+2} - {t_2}^{\beta+2} - (\beta+2){t_1}^{\beta+1} + {t_1}^{\beta+1} - (\beta+2){t_1}^{\beta+1}t_2 + (\beta+1){t_1}^{\beta}t_2\right\}\right.$$

$$\left. + \alpha\left\{2(\beta+1)t_2{t_1}^{\beta} + 2{t_1}^{\beta}t_2 - {t_1}^{\beta+1} - \frac{{t_2}^{\beta+1}}{\beta+1}\right\}\right] + c_1 b\left\{\frac{{t_1}^2}{2} - \frac{{t_2}^2}{2} + \frac{\alpha}{\beta+2}\left({t_1}^{\beta+1} - {t_2}^{\beta+2}\right) + \frac{\alpha}{2}\left({t_2}^2{t_1}^{\beta} - {t_1}^{\beta+2}\right)\right\}$$

$$+ c_3 a\delta + c_3 b\delta t + \alpha_1\delta(a + bt_1)^{1-\gamma} = 0 \qquad (22)$$

$$\frac{\partial C}{\partial t_2} = c_1 a\left[t_1 + t_2 + \frac{\alpha}{\beta+1}\left\{(\beta+3){t_2}^{\beta+2} - (\beta+2)t_1{t_2}^{\beta+1} - {t_2}^{\beta+1} + {t_1}^{\beta+1} - {t_1}^{\beta+2}\right\} + \alpha\left\{2{t_1}^{\beta+1} - \frac{(\beta+2){t_2}^{\beta+1}}{\beta+1}\right.\right.$$

$$\left.\left. + {t_2}^{\beta+1} - t_1{t_2}^{\beta} + \frac{2{t_1}^{\beta+1}}{\beta+1}\right\}\right] + c_1 b\left\{{t_2}^2 - t_1t_2 + \frac{\alpha}{\beta+1}\left((\beta+3){t_2}^{\beta+2} - (\beta+2)t_1{t_2}^{\beta+1} - {t_2}^{\beta+1}\right)\right.$$

$$\left. + \frac{\alpha}{2}\left({t_2}^{\beta+2} - \frac{(\beta+3){t_2}^{\beta+2}}{\beta+1} + \frac{2t_2{t_1}^{\beta+2}}{\beta+1}\right)\right\} + ac_2(t_2 - t_3) + bc_2({t_2}^2 - t_2t_3) - c_3a - c_3bt_2 = 0 \qquad (23)$$

$$\frac{\partial C}{\partial t_3} = c_2 a\left[\delta t_3 - t_2 - (\delta - 1)t_4\right] + \frac{c_2 b}{2}\left[\delta {t_3}^2 - {t_2}^2 - (\delta - 1){t_4}^2\right] - \alpha_1\delta(a + bt_3)^{1-\gamma} = 0 \qquad (24)$$

and

$$\frac{\partial C}{\partial t_4} = -\frac{1}{{t_4}^2}\left[c_1(\delta - 1)\left\{a\left(\frac{{t_1}^2}{2} - \frac{\alpha {t_1}^{\beta+2}}{\beta+2} + \frac{\alpha {t_1}^{\beta+2}}{(\beta+1)(\beta+2)}\right) + b\left(\frac{{t_1}^3}{6} + \frac{\alpha {t_1}^{\beta+3}}{(\beta+2)(\beta+3)} - \frac{\alpha {t_1}^{\beta+3}}{2(\beta+3)}\right)\right\}\right.$$

$$+ c_1 a\left\{\frac{{t_2}^2}{2} + \frac{{t_1}^2}{2} + t_1t_2 + \frac{\alpha}{\beta+1}\left({t_2}^{\beta+3} - t_1{t_2}^{\beta+2} + {t_1}^{\beta+3} - {t_1}^{\beta+2} - \frac{{t_2}^{\beta+2}}{\beta+2} + \frac{{t_1}^{\beta+2}}{\beta+2} + t_2{t_1}^{\beta+1} - t_2{t_1}^{\beta+2}\right) + \alpha\left(2t_2{t_1}^{\beta+1}\right.\right.$$

$$\left.\left. - \frac{{t_2}^{\beta+2}}{\beta+1} + \frac{2t_2{t_1}^{\beta+1}}{\beta+1} + \frac{{t_2}^{\beta+2}}{\beta+2} - \frac{{t_1}^{\beta+2}}{\beta+2} - \frac{t_1{t_2}^{\beta+1}}{\beta+1}\right)\right\} + c_1 b\left\{\frac{{t_2}^3}{3} + \frac{{t_1}^3}{6} - \frac{{t_2}^2t_1}{2} + \frac{\alpha}{\beta+2}\left({t_2}^{\beta+3} - t_1{t_2}^{\beta+2} - \frac{{t_2}^{\beta+2}}{\beta+2} + \frac{{t_1}^{\beta+2}}{\beta+2}\right)\right.$$

$$\left. + \frac{\alpha}{2}\left(\frac{{t_2}^{\beta+3}}{\beta+3} - \frac{{t_1}^{\beta+3}}{\beta+3} - \frac{{t_2}^{\beta+3}}{\beta+1} + \frac{{t_2}^2{t_1}^{\beta+1}}{\beta+1}\right)\right\} + \frac{\alpha_1\delta}{b(\gamma-2)}\left[a^{2-\gamma} - (a + bt_1)^{2-\gamma} + (a + bt_3)^{2-\gamma}\right]$$

$$\left. + \frac{c_2 a}{2}\left[{t_2}^2 - 2t_2t_3 + \delta {t_3}^2\right] + \frac{c_2 b}{6}\left[2{t_2}^3 - 3{t_2}^2t_3 + \delta {t_3}^3\right] + c_3 a(\delta t_1 - t_2) + \frac{1}{2}c_3 b\left(\delta {t_1}^2 - t_2^2\right)\right] + \frac{c_2 a}{2}[\delta - 1] \qquad (25)$$

NUMERICAL EXAMPLES

Example-1: Consider $a = 8000$, $b = 80$, $c_1 = 4, c_3 = 60$, $\alpha = 0.01$, $\beta = 32$, $\alpha_1 = 16$, $\gamma = 0.8$ and $\delta = 5$ in appropriate units. By the help of Mathematica 5.1, we obtain the optimum solution for t_1 and t_2 of Equation (12) and (13) of Model-I, as $t_1^* = 1.39585$ and $t_2^* = 0.0881263$. Putting t_1^* and t_2^* in (10), we get the optimum average cost as $C^* = 39186600$.

Example-2: Consider $a = 8000$, $b = 80$, $c_1 = 4, c_2 = 400, c_3 = 60, \alpha = 0.01$, $\beta = 32, \alpha_1 = 16$, $\gamma = 0.8$ and $\delta = 5$ in appropriate units. By the help of Mathematica 5.1, we obtain the optimum solution for t_1, t_2, t_3 and t_4 of Equation (22)-(25) of Model-II as $t_1^* = 1.3057$, $t_2^* = 0.0630253$, $t_3^* = 1.29626$ and $t_4^* = 1.60219$. Putting t_1^*, t_2^*, t_3^* and t_4^* in (20), we get the optimum average cost as $C^* = 3882610$.

SENSITIVITY ANALYSIS

Table 1. The summary of the sensitivity analysis when shortage is not permitted
Tabela 1. Podsumowanie analizy wrażliwości, w przypadku gdy braki nie są dopuszczne

Parameter	% Change	t_1^*	t_2^*	C^*
a	+50	1.39582	0.0879105	58783300
	+25	1.39584	0.0879968	78985000
	-25	1.39588	0.0883921	29388200
	-50	1.39594	0.0887738	19589600
b	+50	1.39589	0.0884499	39180100
	+25	1.39587	0.0882881	39183400
	-25	1.39583	0.0879645	39189900
	-50	1.39581	0.0878028	39193200
c_1	+50	1.37953	0.0873744	39905300
	+25	1.38681	0.087713	39539700
	-25	1.40773	0.0886577	38854700
	-50	1.42482	0.0894039	38563800
c_3	+50	1.41265	0.0888746	58123400
	+25	1.40504	0.0885385	48646500
	-25	1.38422	0.0875933	29747200
	-50	1.36831	0.086339	20333100
α	+50	1.37862	0.0873913	39008000
	+25	1.38634	0.0877217	39087900
	-25	1.40821	0.0886481	39315600
	-50	1.42582	0.0893836	39500600
β	+50	1.26053	0.0572185	54651400
	+25	1.31376	0.0694663	46867000
	-25	1.53962	0.1196	31750300
	-50	1.85897	0.180803	25142600
α_1	+50	1.39586	0.0881265	39190500
	+25	1.39586	0.0881264	39188500
	-25	1.39585	0.0881262	39184700
	-50	1.39585	0.0881261	39182800
γ	+50	1.39585	0.088126	39179200
	+25	1.39585	0.088126	39180200
	-25	1.39589	0.0881282	39225200
	-50	1.39614	0.0881395	39458600
δ	+50	1.39454	0.136574	38010300
	+25	1.39506	0.112353	38471300
	-25	1.39721	0.0638857	40446500
	-50	1.40011	0.0396085	43256500

Table 2. The summary of the results when shortage is permitted
Tabela 2. Podsumowanie analizy wrażliwości, w przypadku gdy braki są dopuszczne

Parameter	% Change	t_1^*	t_2^*	t_3^*	t_4^*	C^*
	+50	1.30545	0.0627687	1.28755	1.59218	5810750
a	+25	1.30555	0.0628722	1.29108	1.59624	4846650
	-25	1.30595	0.0632788	1.30481	1.61201	2918670
	-50	1.30645	0.0637925	1.32236	1.63214	1955050
	+50	1.30620	0.0634873	1.31364	1.62257	3896440
b	+25	1.30596	0.0632647	1.30541	1.61295	3889470
	-25	1.30538	0.0627482	1.28508	1.58889	3875860
	-50	1.3049	0.0623699	1.26845	1.56884	3869390
	+50	1.28972	0.0616404	1.30032	1.6076	3901160
c_1	+25	1.29688	0.0622994	1.29788	1.60439	3890840
	-25	1.3172	0.0638555	1.29599	1.60165	3879820
	-50	1.33362	0.064873	1.29827	1.60424	3879560
	+50	1.3124	0.0669311	1.05714	1.30316	4708070
c_2	+25	1.30934	0.0652184	1.15706	1.42816	4318250
	-25	1.30133	0.0601288	1.51315	1.87311	3383250
	-50	1.29659	0.0566277	1.95771	2.4274	2792670
	+50	1.31611	0.0603377	1.62877	2.01708	4792530
c_3	+25	1.31127	0.0615268	1.46377	1.81127	4357670
	-25	1.29887	0.0648439	1.11777	1.37925	3349630
	-50	1.28964	0.0670109	0.915741	1.12677	2727140
	+50	1.28951	0.062438	1.28678	1.59052	3857560
α	+25	1.29676	0.062702	1.29103	1.59575	3868800
	-25	1.31732	0.0634426	1.30306	1.61056	3900500
	-50	1.33386	0.0640314	1.31274	1.62249	3925890
	+50	1.1962	0.0411447	1.22803	1.52255	3777820
β	+25	1.23904	0.0498266	1.25489	1.55389	3819060
	-25	1.42352	0.0852584	1.36861	1.68687	3993770
	-50	1.68695	0.128721	1.53166	1.87934	4242310
	+50	1.30546	0.0628674	1.28759	1.59141	3882290
α_1	+25	1.30558	0.0629467	1.29193	1.59681	3882430
	-25	1.30582	0.0631032	1.30058	1.60756	3882830
	-50	1.30595	0.0631805	1.30488	1.61291	3883100
	+50	1.30617	0.0633205	1.31274	1.6227	3883690
γ	+25	1.30609	0.0632727	1.31004	1.61934	3883960
	-25	1.30355	0.0616149	1.22238	1.51027	3886490
	-50	1.28508	0.0460192	0.719419	0.8857	4571920
	+50	1.31468	0.105706	1.68616	1.92709	4890050
δ	+25	1.31061	0.0841612	1.49773	1.76472	4419500
	-25	1.29924	0.042317	1.0688	1.43945	3243350
	-50	1.28926	0.0219905	0.786866	1.29352	2416700

To study the effect of changes in the system parameters a, b, c_1, c_2, c_3, α, β, , α_1, γ and δ on optimal cost derived by the above proposed method a sensitivity analysis has been performed considering the two numerical examples given at section-4 above. Sensitivity analysis has been done by changing(increasing or decreasing) one parameter at a time by 25% and 50% and keeping the remaining parameters at their original values. Table 1 and Table 2 summarize these results.

Based on the results of Table 1, the following observations can be made.

(i) An increase on the values of any one of the parameters a, c_1, c_3, α_1 and β will result in an increase on C^*.

(ii) An increase in the values of any one of the parameters b, α, γ, and δ will result in an decrease on C^*.

On the results of Table 2, the following observations can be made.

(i) An increase on the values of any one of the parameters a, b, c_1, c_2, c_3 and δ will result in an increase on C^*.

(ii) An increase in the values of any one of the parameters α, β, α_1 and γ will result in an decrease on C^*.

CONCLUSIONS

Inventory models for deteriorating items with Weibull deterioration rate, time dependent demand rate and unit cost of production have been developed in this paper. The two-parameter Weibull distribution is appropriate for an item with decreasing rate of deterioration only if the initial rate of deterioration is extremely high. Similarly, this distribution can also be used for an item with increasing rate of deterioration only if the initial rate is approximately zero. So these models are not very much relevant for the items which don't confirm these conditions of deterioration. Further it is observed from the sensitivity analysis that the model with shortages and backlogging is considered to be better economically. Potential future research work in this line can be done by further extending the models for items having quadratic demand or power demand with three parameter Weibull distribution..

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MODEL EOQ USZKODZEŃ WEIBULLA ZE ZMIENNĄ ZALEŻNĄ CZASU ORAZ LINIOWYM POPYTEM I BRAKAMI

STRESZCZENIE. **Wstęp**: W ostatnim czasie coraz większego znaczenia nabierają prace badawcze z zakresu kontroli i utrzymania zapasów towarów łatwo psujących się. Problem psucia się towarów jest bardzo istotnym zagadnieniem w wielu systemach magazynowania. Psucie się definiowane jest jako obniżenie jakości lub uszkodzenia, które powodują, że dany towar nie może być użyty zgodnie z jego pierwotnym przeznaczeniem.
Metody: W pracy opracowano model oparty na systemie poziomu zamówienia dla towarów łatwo psujących się, charakteryzujących się popytem liniowym oraz uszkodzeń Weibulla. Przy opracowaniu modelu założono, że wielkość produkcji i popytu jest zależną czasu. Jednostkowy koszt produkcji jest odwrotnie proporcjonalny do popytu. System produkcyjno-magazynowy obejmuje dwa parametry uszkodzeń Weibulla.
Wyniki i wnioski: Zostały opracowane dwa modele, jeden przeznaczony dla sytuacji bez braków oraz drugi uwzględniający braki, które przyczyniają się do powstawania zaległości. Celem modelu było opracowanie optymalnego sposobu postępowania minimalizującego średni koszt całkowity. Przedstawiono analizę wrażliwości celem wykazania wpływu zmian parametrów na optymalny średni koszt całkowity.

Słowa kluczowe: popyt, uszkodzenie Weibulla, jednostkowy koszt produkcji, braki.

EIN EOQ-MODELL FÜR DIE WEIBULL-BESCHÄDIGUNGEN MIT DER ABHÄNGIGEN VARIABLEN DER ZEIT BEI LINEARER NACHFRAGE UND MANGELWAREN

ZUSAMMENFASSUNG. Einleitung: Forschungsarbeiten im Bereich der Kontrolle und Aufrechterhaltung der Bestände von leicht verderbenden Waren gewinnen in der letzten Zeit deutlich an Bedeutung. Das Problem des Warenverderbs stellt in vielen Lagerungssystemen einen wesentlichen Schwerpunkt dar. Das Verderben selbst wird als Verminderung der Qualität oder Beschädigung definiert. Die Veränderung der Parameter ist die Ursache dafür, dass die verdorbene Ware ihrem primären Verwendungszweck gemäß nicht mehr angewendet werden darf.
Methoden: Im Rahmen der Arbeit hat man ein Modell ausgearbeitet, welches gestützt ist auf das Niveau der Bestellung der leicht verderbenden Waren, die sich durch die lineare Nachfrage und Weibull-Beschädigungen charakterisieren. Beim Konzipieren des Modells hat man angenommen, dass die Produktions- und Nachfragegröße eine Variable der Zeit darstellen. Die Produktionskosten pro Einheit sind umgekehrt proportional zur Nachfrage. Das Produktions -und Lagerungssystem umfasst zwei Parameter der Weibull-Beschädigungen.
Ergebnisse und Fazit: Es wurden zwei Modelle bearbeitet; das eine vorgesehen für die Situation ohne Mangelwaren, das andere für die Situation mit solchen Mangelwaren, die die Entstehung von Rückständen verursachen. Dem Ziel des Modell-Konzeptes lag Bearbeitung einer optimalen Verfahrensweise für die Minimalisierung der durchschnittlichen Gesamtkosten zugrunde. Dabei stelle man die Analyse der Empfindlichkeit zwecks Aufzeigen der Beeinflussung der optimalen, durchschnittlichen Gesamtkosten durch die Veränderung der relevanten Parameter dar.

Codewörter: Nachfrage, Weibull-Beschädigung, Produktionskosten pro Einheit, Mangelwaren.

Umakanta Mishra
Department of Mathematics,
P.K.A.College of Engg. Chakarkend, Bargarh-768028, India
e-mail: umakanta.math@gmail.com
Chaitanya Kumar Tripathy
Department of Statistics, Sambalpur University
Jyoti Vihar, Sambalpur-768019, India
e-mail: c.tripathy@yahoo.com

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THE EFFICIENCY OF THE PRODUCTION – THE ANALYSE OF PROBLEMS BASED ON THE LITERATURE RESEARCH

Adam Koliński

Poznan School of Logistics, Poznan, Poland

ABSTRACT. Background: The production efficiency is one of the most important problems of the present-day logistics, both at operational as well as strategic levels. Increasing the level of the efficiency of the production process can be achieved in many ways.
The reason of the selection of the issues covering the problems of the production efficiency is the lack of a comprehensive model for analyzing the efficiency of the production process, both in the scientific literature and in the business practice.
Methods: The main aim of this paper is to systematize the process of obtaining input data for the assessment model of the production efficiency. The methodology for building the assessment model of production efficiency at the initial stage of the analysis was presented.
Results and conclusions: The basic goal of a preliminary analysis of the model is to coordinate decision-making targets at all levels of the management. The presented assumptions should be regarded as a preliminary analysis, indispensable for the multivariate analysis of the production process efficiency, focused on the operational level.

Key words: production efficiency, production controlling, balancing of resources, production capacity.

INTRODUCTION

The issue of the production efficiency, despite many efforts and attempts, has not been so far comprehensively presented and developed. At present, companies operating in the dynamically changing environment, take decisions, which have very often the negative influence on the efficiency of individual processes. The main reasons of such a situation are unclear procedures for the evaluation of the efficiency. According to the Author, the issue of the evaluation of the production process is the very important component of the effective business management, which requires the deeper analysis. The development of an effective model for the evaluation of the efficiency of the production process requires the detailed and reliable preparation of input data, which are indispensable factor of the efficiency of the further analysis.

The main aim of this paper is to prepare the algorithm of the processes of the acquirement of input data for the model of the evaluation of the production efficiency. On the basis of the literature research as well as observations in business practice of manufacturing companies, it should be noted that the basic data, necessary to create the multivariate model of the evaluation of the efficiency of the production process, should be generated from the three main ranges:

- The selection of a suitable production management concept,
- Balancing of production resources and production capacities,
- The analysis of the performance of the evaluated production process.

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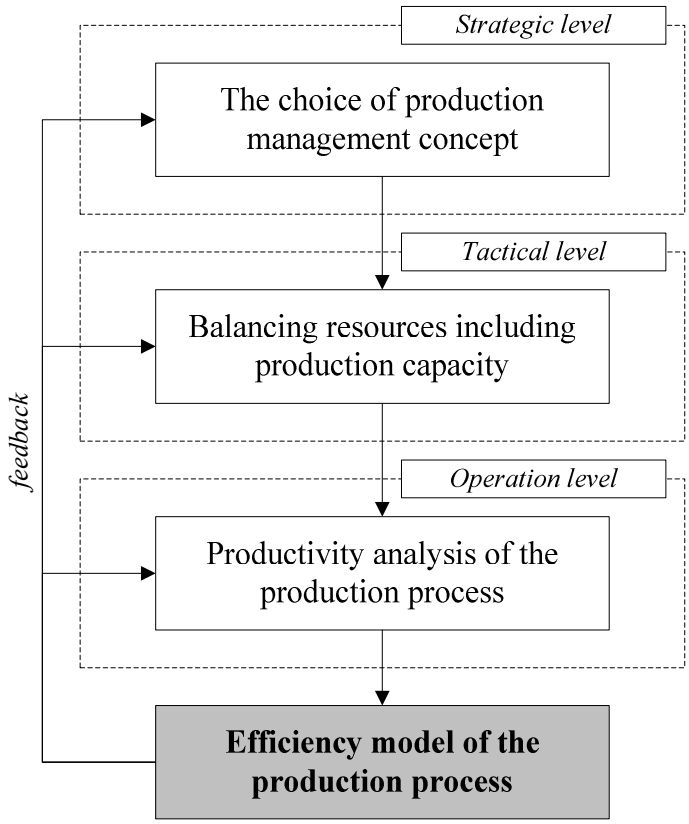
Deliberately structured analytical ranges can be seen as an algorithm of the preliminary analysis of the efficiency, which refers to three levels of the management: strategical, tactical and operational. For this reason, the comprehensive analysis of the evaluation of the efficiency should be supported by the preliminary researches conducted at all decision-making levels in the company. The schema of the preliminary analysis of the efficiency is shown on the Figure 1.



Source: own work

Fig. 1. The schema of the preliminary analysis of the efficiency of the production process
Rys. 1. Schemat wstępnej analizy efektywności procesu produkcyjnego

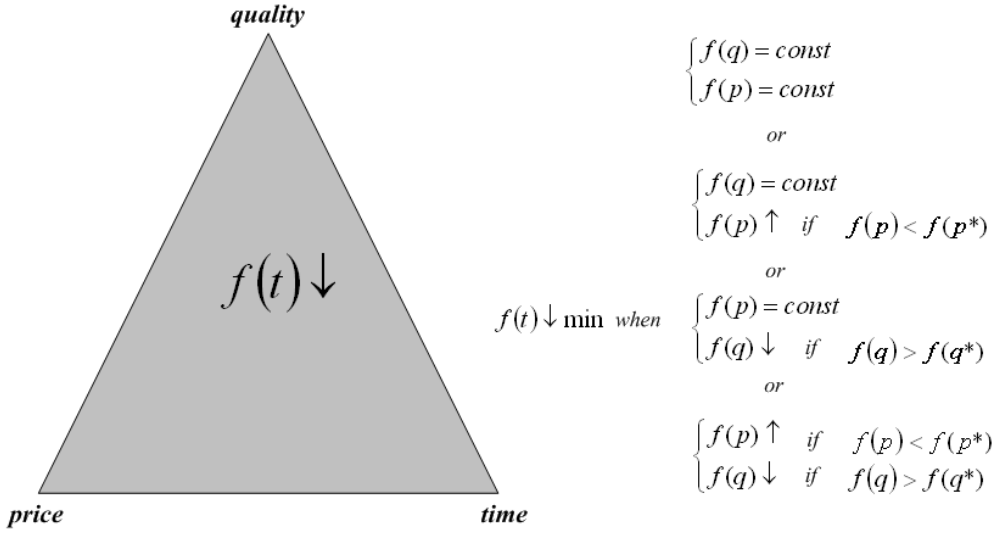
The schema of the preliminary analysis of the efficiency, presented on the Figure 1, was varied in terms of decision-making minuteness associated with the level of the management of the enterprise. The selected analytical ranges must be closely related to each other, complementary and support the realization of the fundamental aims of the company. Therefore, as presented on the figure, the use of feedbacks was proposed, which enables the reference of the analysis of the efficiency of the production process to the current organizational reality.

THE SELECTION OF CONCEPT OF THE PRODUCTION MANAGEMENT

It should be remembered during analyzing the production efficiency at the strategical level that the production company can compete on the global market basing its strategy on one of three factors:

- Time (t),
- Price (p),
- Quality (q).

The strategy of the competiveness consists sometimes in the fulfilment of the customer order in the shortest possible time and in keeping other factors of the competiveness at a reasonable level. The analysis of the efficiency of the production in the pricing strategy consists mainly in the evaluation the profitability of the fulfilment of the order, for which the completion time should be minimized. It should be remembered that the price strategy can be realised when simultaneously the quality and the price are maintained at the level accepted by the client. The idea of the time strategy and its impact on other factors affecting the competiveness of the company is presented on the Figure 2.



f(p*), f(q*) – function level accepted by the customer

Source: Trojanowska, Koliński 2011

Fig. 2. The time strategy
Rys. 2. Strategia czasowa

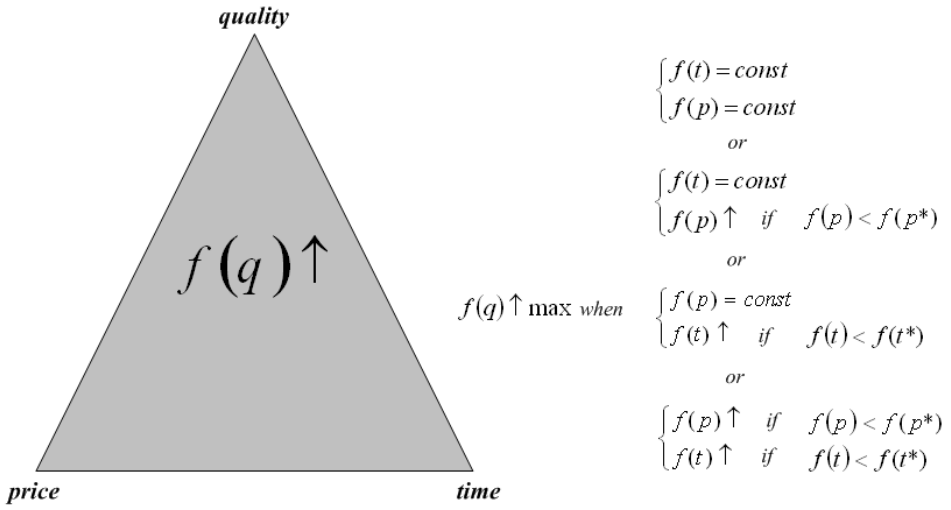
The fundamental relationships between the time function and a function of a quality and a price were presented on the figure 2. The following variants can be obtained on the assumption of minimizing of the time function:

- Minimization of the time function can be obtained while the previous level of the price function and the quality function is maintained,
- Minimization of the time function can cause a decrease of the quality function, but only to the level accepted by a client and simultaneously at the maintained level of the price function,
- Minimization of the time function can cause an increase of the price function, but only to the level accepted by a client and simultaneously at the maintained level of the quality function,
- Minimization of the time function can cause an increase of the price function, but only to the level accepted by a client and simultaneously with the decrease of the quality function, but not bigger than the level accepted by a client.

Other variants were not taken into consideration during the analysis of the time strategy, due to the fact that e.g. the increase of the quality level (assuming, that the current one is at least the accepted one) is inefficient in unchanged production conditions, because it has negative impact on the time function. It should be mentioned, that the management of a company, using the time strategy, prefers to keep other factors of the competiveness not higher than at the level accepted by a client.

The strategy of the quality competiveness consists in ensuring the quality, even at the expense of time or a price. The strategy of the quality competiveness is a specific strategy, which is related to

designing for the order and based on the building a customer brand trust. The company, which wants to be quality competitive, has to have a strong brand and a well established market position. The idea of the quality strategy and its impact on other factors affecting the competitiveness of a company was shown on the Figure 3.



f(p*), f(t*) – function level accepted by the customer

Source: Trojanowska, Koliński 2011

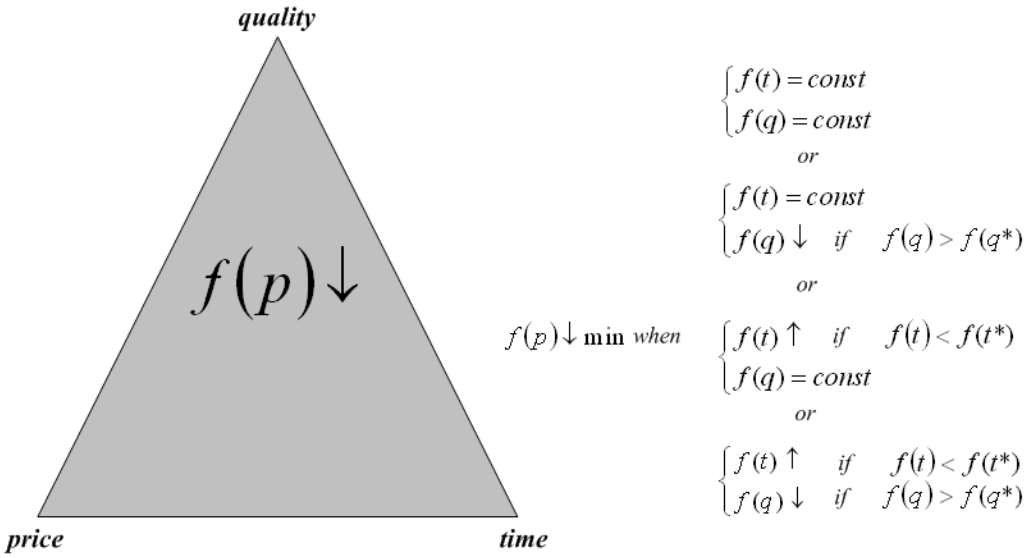
Fig. 3. The quality strategy
Rys. 3. Strategia jakościowa

The basic relationships between the quality function and the function of time and price were presented on the Figure 3. The following variants can be distinguished, based on the assumption of the increase of the quality level, which at the same time, does not exceed the quality level expected by a client:

- Keeping the current level of the price function and time function,
- Increase of the price function and the simultaneous the increase of the time function,
- Increase of the price function and simultaneously keeping the time function at the unchanged level,
- Keeping the price function at the previous level and the simultaneous increase of the time function.

Other variants were not taken into consideration during this case, due to the fact that e.g. while assuming the maintenance of the quality level, the reduction of the price is an illogical operation and even often does not enable the realization of this strategy.

The strategy related to the price competition consists in obtaining a competitive advantage by offering attractively priced products, while keeping all other factors at an acceptable level. The price competition in production companies is possible through the appropriate, low-cost approach to the production management. The idea of a price strategy implementation and its influence on other factors of the competitiveness is shown on the Figure 4.

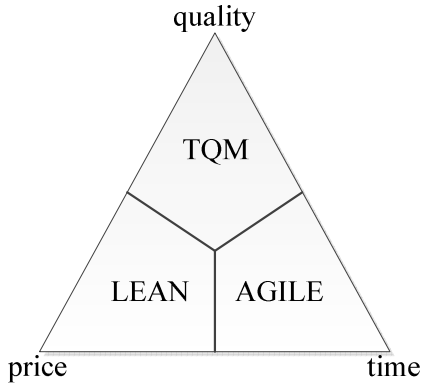


f(q*), f(t*) – function level accepted by the customer

Source: Trojanowska, Koliński 2011

Fig. 4. The price strategy
Rys. 4. Strategia cenowa

The choice of the right strategy has a significant impact on the operational activities of the company. The appropriate translation of the strategy into the tactical and operational levels is the key element, which has an influence on the evaluation of the efficiency of the company. The focus on the chosen strategy forces the implementation of an adequate system of indicators of efficiency assessment, according to the chosen strategy. The discussed strategies can be presented by the use of three main concepts of the production management. The proposal to use the concept of the production management in line of a particular competition strategy is shown on the Figure 5.



Source: Trojanowska, Koliński 2011

Fig. 5. The comparison of concepts of production management with strategies of the company competitiveness
Rys. 5. Zestawienie koncepcji zarządzania produkcją ze strategiami konkurencyjności przedsiębiorstwa

The main assumption of the idea presented on the Figure 5 is the conviction, that the Lean Manufacturing concept focuses on the implementation of the price strategy by the reduction of expenditures, which can be achieved by the reduction of the level of costs. The implementation of Agile Manufacturing concept can in turn support the realization of the time strategy. This concept concentrates on the flexible adaptation of a process to the expectations of customers [Trzcieliński 2007]. The quality strategy is consistent with main assumptions of TQM concept. Due to the growing importance of TQM concept, the quality has become an integral part of the strategy of companies, which obtain the business success in today's very demanding market. The production company, using the quality as an competitive advantage in the market, focuses all its efforts on providing clients the reliable goods of the high quality, even it can sometimes lead to the failure to keep the agreed terms of delivery or the need to increase the production costs.

The practices of companies shown that the management team is willing to look for alternative solutions to improve the efficiency of production process in the company. This results in many attempts of hybrid solutions of various strategies of the competiveness [Meade, Kumar, Houshyar 2006]. The diversification of the production is one of the most effective ways of hybrid management of the production at the strategical level [Koliński 2010]. The most frequently analyzed possibilities of the improvement of the competitiveness are:

- The increase of the quality and simultaneously the reduction of a price,
- The increase of the quality and simultaneously the reduction of lead-time of an order,
- The reduction of the price level and simultaneously the reduction of lead-time of an order.

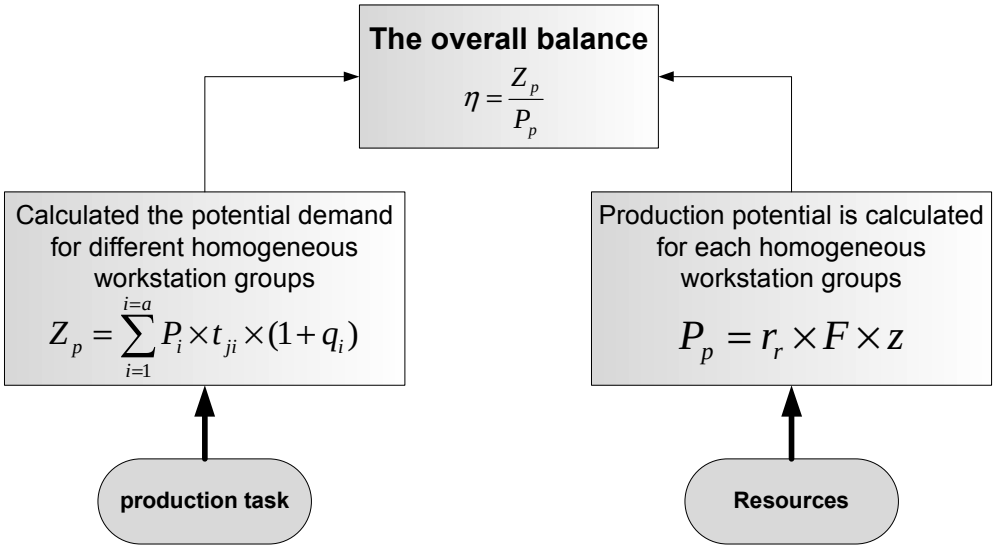
The Author's researches related to the level of the use of various management concepts in business practice [Koliński, Trojanowska, Kolińska 2011] only confirm the thesis that the management teams of companies decide to choose one of the analyzed concepts of the production management, and at the same time constantly looking for opportunities to increase the efficiency of the production process.

BALANCING OF PRODUCTION RESOURCES

The issue of balancing is an element of the efficiency analysis of wide use in the business practice. It is one of effective instruments to assess and analyze the potential possibilities to eliminate shortages of resources, bottlenecks, queues, bottlenecks in the production process, as well as surplus of resources and expenditures in relation to the particular market situation [Sliwczyński 2011]. The maintenance of unnecessary or excessive production resources (e.g. defective manufacturing equipment, excessive stocks of works in progress, low level of the utilization of production capacities) has a negative impact on the efficiency of the production process. However, it should be remembered that, the deliberate maintenance of the surplus of production resources can be caused by the strategy of the competiveness adopted by the management of the company (e.g. flexibility and speed of the response to customer needs – the strategy consistent with the Agile Manufacturing concept).

The basic model of balancing of operational tasks and available production capacities (production potentials) in a given period of time, for a homogenous group of workstations, enabling the mutual substitution of machines during the implementation of production process, is presented on the Figure 6.

The balancing of tasks with production potential focuses on the analysis of the ratio of necessary production capacities (requirements of potential) of a specific production cell (e.g. workstation) in a given planning period and the potential of this cell in the same planning period. The basis variant of balancing the production resources is presented on the Figure 6. The detailed characterization of parameters used in this model, is presented in the Table 1.



Source: Koliński, Golińska 2011a

Fig. 6. The model of balancing of production resources
Rys. 6. Model bilansowania zasobów produkcyjnych

Table 1. The identification of the potential or redundant resources in the production process
Tabela 1. Zidentyfikowanie potencjału lub zasobów nadmiarowych w procesie produkcyjnym

Basic concepts	Characterization	Formula
Production task	Total quantity of production planned to be realised in a given period (assortment and production programmes)	-
Requirement of potential	Quantity of potential needed to realise a specific production task	$Z_p = \sum_{i=1}^{i=a} P_i \times t_{ji} \times (1+q_i)$ P_i – production programme for an assortment a – assortment t_{ji} – time of a single operation conducted on the product q_i – coefficient q for the product
Production resources	Each material factor having impact on the realization of production plan	-
Production potential (production capacities)	Quantity of resources , which could be used in production in a given period of time, calculated according to adopted method of using the resources	$P_p = r_r \times F \times z$ r_r – amount of workstations in a homogenous group of workstations F – fund of time for a workstation z – amount of working shifts during a working day

Source: own work based on Głowacka-Fertsch, Fertsch [2004]

The method of solving the problem of balancing of resources depends on possibilities to identify the structure of the production process already at the moment when the decision to realise the planned production order is undertaken. In such cases, the balancing process covers the analysis of resources, which limit the whole analyzed process, so called bottlenecks. The aggregation of orders is a method to obtain some savings associated with the minimization of production preparation time and the possibility to reduce the average load of workstation in a given planning period. Such situation allows accepting new production orders (in form of customers' orders) without changing the existing production plan [Fertsch 1998] and which has a direct impact on the efficiency of balancing of production resources. The problem arises when a company is not able to cover the market demand for manufactured goods, while the sale of each of them is profitable for a company. It must be remembered that, the critical resource (regardless of the specific character of factors, which limit the production efficiency) determines the sales value and the achieved profit as well as the level of utilization of other resources.

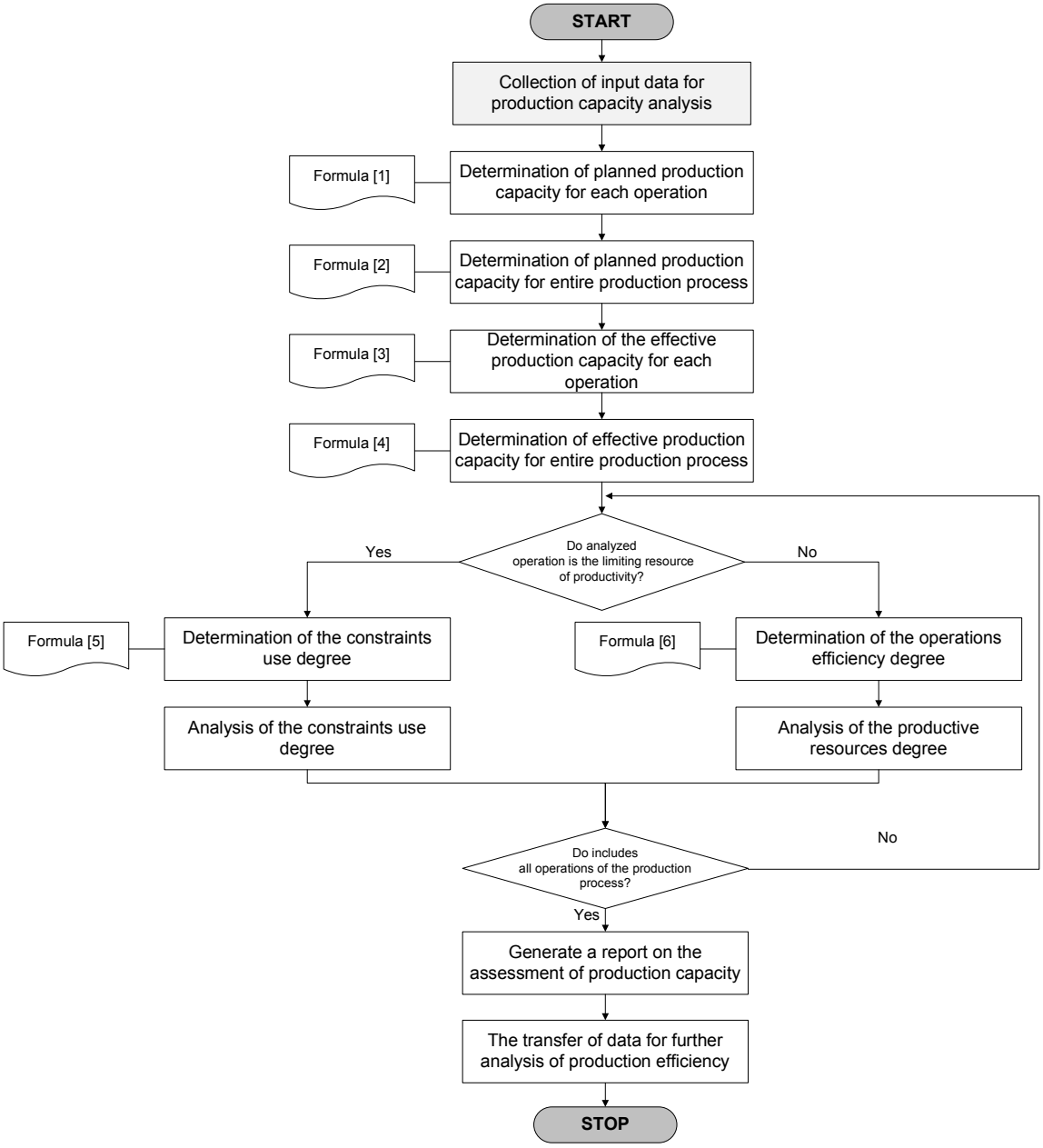
Making the detailed analysis of purposes of balancing of resources and the most often used methods to eliminate problems associated with this issue, it can be concluded that, the presented problems of an effective balancing of production resources are determined by factors, which influence both on the organisation of the production process as well as the efficiency of cause-effect relationships throughout the whole supply chain. The key factor of balancing is to determine the requirements for individual resources in the same measures or units. However, the selection of a right measure in case of very developed process structures is a very difficult task. The analysis and the evaluation of an efficiency of the conducted production process should be the subsequent stage after successful balancing of resources.

THE ANALYSIS OF PRODUCTION CAPACITY

The determination of the capacity is one of the most important factors, which influence the efficiency of the evaluation of the production efficiency at the operation level. The method of determining the capacity depends on the assumed level of accuracy of conducted analysis of resources in terms of efficiency. The capacity is a very significant problem in terms of production efficiency, because it is based on the process of matching the available capacity of all available resources to planned demand, which absorbs the analyzed production resources.

It should be desired during the analysis of the efficiency of the production process to increase of the productivity through the maximum utilization of available tools in a given time (e.g. depending on the number of planned changes in production). However it should be remembered that, the increase of production capabilities could be only reached, when the additional workstations involved, are fully utilized. This situation entails a lower level of investment as well as a high indicator of resources utilization, but at the same time it also reduces the volumes of production [Waters 2002]. According to the Author, the reliable and unambiguous assessment of productivity is difficult due to the lack of comprehensive indicators, which enable to determine it. The productivity is analyzed not only at the level of a workstation, but also of a particular operation, as well as for the entire production process. It should be noted that the efficiency of production resources is defined as the maximum quantity of products, which can be produced in a specified period of time.

The presented scientific deliberations related to the maintenance of excessive unused production capacities, confirm only the ambiguity and the complexity of the issue of the production efficiency. The algorithm of an effective analysis and the evaluation of the efficiency of production process has been developed. It is presented in the Figure 7. A detailed description of the stages of the analysis of production efficiency is presented later in this article, based on a practical example of the use of the analysis of the production efficiency, published by the Author in [Kolinski, Golińska 2011b].



Source: own work

Fig. 7. The general schema of the analysis of production capacity
Rys. 7. Ogólny schemat analizy wydajności produkcji

The planned production capacity refers usually to ideal conditions, ignoring any breakdowns or disruptions in the production process [Waters 2002]. The planned production capacity does not include the unproductive time, associated with the deliberately planned breaks. In order to calculate the planned production capacity of the entire production process, it is necessary first to determine the capacities of individual operations. In case of the production operation, which is performed on several workstations, its production capacity is calculated as a sum of the capacities of individual separated workstations. The following formula presents above-mentioned assumptions and dependencies:

$$W_{PO} = \sum_{i=1}^{n} \frac{t_{d_i}}{t_{j_i}} \qquad [1]$$

where:

W_{PO} – the planned production capacity of the operation,

t_{di} – available production time for the workstation j,

t_{ji} – unit execution time for the operation performed on the workstation j,

n – quantity of workstations.

Based on the presented dependencies, the production capacity of individual operations should be determined. And the determination of the production capacity of the entire production process should be the subsequent step of the analysis. The production capacity of the entire process is determined by the productivity of the operation, which is the smallest one. The discussed relationship can be presented by the following function:

$$f(W_{PP}) = \min(W_{PO1}, W_{PO2}, ..., W_{PO_n}) \qquad [2]$$

where:

W_{PP} – the planned production capacity of the production process,

W_{PO1} – the planned production capacity of the first operation,

W_{POn} – the planned production capacity of the *n* operation.

The effective production capacity is a more realistic indicator, which determines the production expectations in normal conditions [Waters 2000]. The determination of the indicator of the effective production capacity is based on the similar ideology, which was presented in case of the analysis of the planned production capacity. The effective production capacity of the operation is the sum of productivities of all workstations, where it is performed. The following formula presents above-mentioned assumptions and dependencies:

$$W_{EO} = \sum_{i=1}^{n} \frac{t_{d_i} - t_{b_i}}{t_{j_i}} \qquad [3]$$

where:

W_{EO} – the effective production capacity of the operation,

t_{di} – available production time for the workstation j,

t_{bi} – unproductive time for the workstation j (breaks, maintenance, etc),

t_{ji} – unit execution time for the operation performed on the workstation j,

n – quantity of workstations.

It should be noted, that the operation of the lowest production capacity, limits the efficiency of the entire production process. Therefore the effective efficiency of the entire production process can be presented by the following formula:

$$f(W_{EP}) = \min(W_{EO1}, W_{EO2}, ..., W_{EO_n}) \quad [4]$$

where:

W_{EP} – the effective production capacity of the production process,

W_{EO1} – the effective production capacity of the first operation,

W_{EOn} – the effective production capacity of the *n* operation.

The determination of the effective level of the utilization of individual operations of the production process concerns the ratio between the real production efficiency and the effective production capacity of the operation. The determination of the utilization rate of the operation is useless in case of operations, limiting the production process, because it is almost 100%. In case of other operations, the determination of the level of the effective utilization of the operation enables the further analysis of the utilization of individual workstations. According to the Author, two measures should be distinguished depending on the impact of a given operation on the efficiency of the entire production process:

- The degree of the effective utilization of the operation/workstation,
- The degree of the utilization of the limiting factor.

The analysis of the degree of the effective utilization of the operation, which is the limitation of the production process, is pointless due to the fact, that this degree is equal or almost equal to 100% according to the concept of bottlenecks in the production process. The utilization ratio of the limitation can be interpreted as follows:

$$\text{utilization ratio of the limitation} = \frac{\text{effective efficiency of production process}}{\text{planned efficiency of the operation}} \quad [5]$$

The very important part of the analysis of the production efficiency and the estimation of bottleneck's efficiency is the analysis of the possibility of reducing the unproductive time (e.g. by reducing the number of changeovers or by the increase of production batch volumes) and its impact on the production efficiency. It should be mentioned, that each optimization of the limitation has a positive effect on the production efficiency, because it increases the effective efficiency of the entire production process. Due to that, the particular focus should be placed on optimization activities related to bottlenecks' performance and loads. Therefore it is worth to be aimed, that the detailed production planning, oriented on bottlenecks, should be the basis for the estimation of the efficiency of the limitation [Domański, Hadaś 2010]. According to the scientific literature, the theory of constraints both in the area of production planning and management [Goldratt, Cox 2004] as well as in economic aspects [Corbett 1998] is widely proposed to be used. According to the Author, the implementation of basic tools of the theory of constraints could be effectively used to build a comprehensive model for the estimation of the efficiency of the production process.

The utilization ratio of limitation can be interpreted as follows:

$$\text{effective utilization ratio of the operation} = \frac{\text{effective efficiency of production process}}{\text{planned efficiency of the operation}} \quad [6]$$

Similarly, the analysis of the utilization ratio for the individual workstations can be conducted. However in this case, the uniform utilization of all workstations should be secured. It should be also noted, that the smaller the value of the level of the utilization of a particular workstation, the greater probability of the necessity of the diversification of tasks or works at this workstation. Therefore analyzing the production efficiency it should be concluded that, too big diversity of operations performed at one workstation has a negative impact on its efficiency ratio. This is due to the increase of changeover times (unproductive time), which consequently decreases the effective production efficiency.

SUMMARY

The issues presented in this paper, cover the research results obtained by the Author, both on the ground of the business practice and the literature review. The theoretical deliberations, detailed described in this paper, were presented in the form of an algorithm and correlated with various decision-making levels of the company, in accordance with the main aim of this paper. The presented solution should be treated as a proposal how to obtain the reliable input data, indispensable for the further comprehensive analysis and the estimation of the efficiency of the production process. The issues of the efficiency are widely discussed in the scientific literature, but there is still lack of a comprehensive method, which enables the multivariate analysis and the estimation of the production process. When building a model for the evaluation of the efficiency, the correlation of all levels of business management should be taken into consideration. The ecological aspect of the production, gaining lately the special attention, should be also considered. The implementation of IT systems, supporting the management process, is a practical problem related to the process of building the production efficiency model. The functionalities of such supporting systems enable to obtain and analyze all aspects necessary to fulfil a comprehensive analysis. Therefore, it seems to be reasonable, to prepare a separate IT tool, which will focus on a comprehensive analysis of the production process efficiency and which should be considered as the future direction of researches in this area.

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OCENA EFEKTYWNOŚCI PRODUKCJI - ANALIZA PROBLEMU W ŚWIETLE LITERATURY

STRESZCZENIE. **Wstęp:** Efektywność produkcji jest jednym z najważniejszych problemów współczesnej logistyki, zarówno na poziomie operacyjnym, jak i strategicznym. Podniesienie poziomu efektywności procesu produkcyjnego można osiągnąć na wiele sposobów.
Wybór problematyki efektywności produkcji jest spowodowany brakiem opracowanego kompleksowego modelu służącego do analizy efektywności procesu produkcyjnego, zarówno w literaturze przedmiotu, jak również w praktyce przedsiębiorstw.
Metody: Głównym celem artykułu jest usystematyzowanie procesów uzyskania danych wejściowych do modelu oceny efektywności produkcji. W artykule przedstawiono metodologię budowy modelu oceny efektywności produkcji na wstępnym etapie analizy.
Wyniki i wnioski: Podstawowym założeniem wstępnej analizy modelu jest skoordynowanie celów decyzyjnych na wszystkich poziomach zarządzania. Przedstawione założenia należy traktować jako wstępną analizę niezbędną do wielowariantowej oceny efektywności procesu produkcyjnego, skoncentrowaną na poziomie operacyjnym.

Słowa kluczowe: efektywność produkcji, controlling produkcji, bilansowanie zasobów, wydajność produkcji.

BEWERTUNG DER PRODUKTIONSEFFIZIENZ - ANALYSE DES PROBLEMS IM LICHTE DER GEGENSTANDSLITERATUR

ZUSAMMENFASSUNG. Einleitung: Die Produktionseffizienz stellt eines der wichtigsten Probleme der gegenwärtigen Logistik, sowohl auf dem operativen, als auch auf dem strategischen Niveau, dar. Die Erhöhung der Effizienz eines Produktionsprozesses kann unterschiedlich erreicht werden.
Die betreffende Auswahl der Problematik der Produktionseffizienz ist auf den sowohl in der Gegenstandsliteratur, als auch in der Unternehmenspraxis bestehenden Mangel eines komplexen, der Analyse der Effizienz des Produktionsprozesses dienenden Modells zurückzuführen.
Methoden: Das Ziel des vorliegenden Artikels ist es, die für die Gewinnung von Input-Daten für das Modell zur Bewertung der Produktionseffizienz dienenden Prozesse zu systematisieren. Im Text des Artikels wurde die Methodologie für den

Aufbau eines für die Bewertung der Produktionseffizienz brauchbaren Modells in der einleitenden Etappe der Analyse dargestellt.
Ergebnisse und Fazit: Eine grundlegende Zielsetzung der einleitenden Analyse des Modells ist es, die Entscheidungsziele auf allen Managements-Ebenen weitgehend zu koordinieren. Die dargestellten Annahmen sind als eine einleitende, für die Mehrvarianten-Bewertung der Effizienz eines Produktionsprozesses unentbehrliche und auf das operative Niveau konzentrierte Analyse aufzufassen.

Codewörter: Produktionseffizienz, Produktionscontrolling, Bilanzierung von Beständen, Produktionsleistung

mgr inż. Adam Koliński
Poznan School of Logistics
ul. Estkowskiego 6, 61-755 Poznan, Poland
e-mail: adam.kolinski@wsl.com.pl

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EFFICIENCY OF URBAN CONGESTION PROBLEM SOLVING

Zbyszko Pawlak

Poznań School of Logistics, Poznan, Poland

ABSTRACT. Background: Traffic congestion is nowadays probably one of the greatest problems of urban transportation systems and infrastructure. Unfortunately, it frequently happens that road work investments connected with the construction of new and re-construction of old road networks, contrary to original intentions, fails to improve urban transportation or even deteriorate it significantly.
Methods: The article presents an analysis of some methods of easing urban traffic congestion. Instrumental methods such as city center parking tolls usually do not bring about situation improvement. Introducing a faster and relatively comfortable public transportation competitive with commuting by cars is more efficient.
Results and conclusions: The results of the research also reveal that the frequently applied method of road broadening does not lead to increasing their capacity as it fuels the preference for using private cars, instead of means of mass transportation. Consequently, the number of cars driving in towns and cities is larger and the level of congestion boosts. Uncoordinated individuals striving towards achieving their personal optimum are not always achieving optimum for the whole community. Communities as a result of that tendency must pay the Price of Anarchy. Therefore, the better mass transportation functions, the more persons start using it and simultaneously there will be fewer cars in the network of streets and transportation routes - with the resultant lower level of congestion.

Key words: flow of persons in cities and towns, urban traffic congestion, instruments of urban management, price of anarchy.

INTRODUCTION

A phenomenon of congestion resulting from the division of cities and towns into various functional areas and the necessity for the movement of people arising from there seems to be present in pertinent literature almost as an axiom [Rodrigue, Comtois, Slack 2006]. It is nowadays probably one of the greatest problems of urban transportation systems and infrastructure. Traffic congestion is usually defined as an excessive increase in the number of vehicles on roads which may lead to the overloading of transportation networks [Pawlak Z. 2007] and the appearance of numerous social, economic and environmental problems connected with it and consequently may even result in the stoppage of flows. Unfortunately, it frequently happens that road work investments connected with the construction of new and re-construction of old road networks, contrary to original intentions, fail to improve urban transportation or even deteriorate it significantly.

INSTRUMENTAL EASEMENT OF URBAN CONGESTION

The research carried out worldwide reveals that workers' and students' commuting is a dominant factor increasing urban congestion [Asensio 2002]. This poses a difficult dilemma - How can this problem be solved? Some researchers suggest that the best solution would be a more concentrated

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urban spatial structure [Nijkamp, Ouwersloot, Rienstra 1997]. Others, however, point out [Downs 2004] to a general need to change work time hours in order to diminish the number of commuters in traffic peak hours. Both approaches seem to be very radical and require very dramatic changes in the urban spatial structure, transformations of social and economic relations and even reversing advanced decentralization processes. In the light of so extreme approaches a rational adaptation of already existing urban modelling factors seems to be more feasible. Therefore, providing environment-friendly, speedy and relatively comfortable public transportation which would be able to compete with cars is considered reasonable and implementable.

Undoubtedly, one of the possible solutions facilitating the easement of traffic congestion problems is altering preferences of a significant part of car users and directing them towards other (alternative) means of transportation. Although the advantages of public transportation such as safety, environmental-friendliness and better transportation capacity are commonly known, the opinions of sceptics who claim that the impact of means of mass transportation on the total efficiency of urban transportation network may be limited for instance by the level of transportation infrastructure development.

Against all appearances, road works carried out in most cities and towns all around the world and aiming at broadening the streets do not result in increasing road capacity. In accordance with the Lewis-Mogridge Position [Bell, Wichiensin 2012] - traffic expands to meet the available road space. Thus, road capacity gains subsist for a few months the longest, and sometimes they disappear even within a few weeks. The problem of congestion comes back and drivers are stuck in traffic jams on a larger number of road lanes. The research carried out by the author in the urban agglomeration of Poznań (Poland) which focused among others on the dynamics of the flow of persons in transport corridors [Pawlak 2011], reveals that the number of vehicles going on a given street during peak hours equals the number of road lanes multiplied by 1300. Thus, the observation that additional lanes attract additional vehicles is confirmed. Therefore, the system of urban road infrastructure shall be considered as a unity rather than a set of separate sections. It should also be borne in mind that an excess of road investments, especially carried out at the same time, in city centers very often paralyses towns and cities. Inhabitants, who affect urban space vitality, lose their place and privileges due to them. For instance, they have to continuously wait at traffic lights, walk along narrow pavements and breathe exhaust fumes. Vehicles and public space are hard to harmonize - especially in often historic city centers.

Among instruments which may be used to encourage (or discourage) people to commute individually in cars which are most frequently applied by authorities of towns and cities there are the following ones:

- introduction of efficient public transportation such as commuter trains with Park & Ride systems,
- collection of congestion charges,
- increase in parking tolls, and
- simultaneous introduction of congestion charges and park tolls increases.

The research carried out by the author has revealed that additional instruments regulating flows [Pawlak 2011], may reduce modelled level of cars used for the purpose of commuting even below 20% of initial traffic volume. Sometimes it is enough to implement efficient public transportation to make a major part of commuters resign from using their cars. Congestion charges have also a greater impact on the reduction of the number of cars used than parking tolls. Consequently, it should come as no surprise that the combination of both solutions results in a synergy effect, that is to say, the final result of their implementation is better than their direct sum. It should be borne in mind, however, that the accrual is not significant, as a rule, as it usually refers to the same group of people. It frequently happens that inhabitants prefer using their own cars for commuting despite the introduction of congestion charges in urban areas. If that is the case, some other instruments need to be applied. One of such instruments is a parking toll. Copenhagen may serve as an example of an efficient solution implemented in this respect. In this Danish city parking tolls are calculated so as to have 10% of

parking spaces left free. When the percentage decreases, parking tolls are increased. The authorities of Copenhagen do not try to provide the inhabitants of city centers with parking spaces as it is not the task of municipalities. The fact that someone owns a car is not a prerequisite for a right to a parking space (even next to one's house). The inhabitants of Tokyo have understood this principle very well for a long time as before having a car registered its owner must indicate the place where the car is to be parked.

THEORETICAL AND PRACTICAL EFFICIENCY OF REDUCING URBAN CONGESTION

In accordance with a theoretical approach of Downs-Thomson and Pigou-Knight-Downs [Downs 2004] the average speed of a person travelling by car in urban areas depends on the average speed (door-to-door speed) of a person travelling by means of public transportation. In other words, the better public transportation is, the more persons will use it and consequently there will be less cars present on the network of streets and urban communication tracks and as a result there will be fewer traffic jams. Therefore, depriving drivers of one lane and reserving it for buses or tram tracks solely, in fact, decreases rather than increases traffic jams (congestion). It directly results from the capacity of certain street lanes. It may be easily calculated that people gathered in cars and stuck in huge traffic jams may be easily transported for instance in a few trams. In accordance with the results of the research undertaken by the author of this paper for the agglomeration of the city of Poznań (Poland) there are about 167 people in one tram during peak hours, and at the same time there are on average 6 persons sitting in 5 cars (1.2 person per car). Both the tram and cars in question occupy the same transportation space on roads.

Providing efficient public transportation may be a very beneficial tool of improving urban passenger transportation systems. But the mere presence of buses, trams or commuter trains does not lead automatically to balancing the systems better. The term balancing encompasses multi-aspectual optimization which results from a long-term interaction among economic and non-economic efficiency factors. Ignoring those factors, especially the social culture and behavioural traditions, may lead to a failure of municipal policy aiming at diminishing urban congestion. For instance, drivers in countries where people are strongly attached to their cars, e.g. the USA, may be less receptive to the idea of travelling by means of public transport only because such means are available. Thus, it may even lead to the increase of the number of cars on roads and consequently it may boost the level of congestion. This situation is called Braess's paradox [Quinet, Vickerman 2004] (it consists in the fact that adding extra capacity, extra link to a transportation network results in the increase of the general social transportation cost) and may constitute a very serious obstacle to balancing urban passenger transportation. There are, therefore, situations in which increasing the capacity of the urban road and street network brings about the lengthening of the average flow time and decreasing general efficiency of the transportation network.

For instance, let us assume that we have a network with four vertexes and four edges. Each edge represents a road and the cost connected with travelling along the road is expressed in time needed to do so. It is obvious that the drive time for a given road depends on the road's quality (mainly the number of junctions).

Let us assume that the routes N-W and E-S are safe and have a high capacity and the average time needed to cover the routes does not depend on the number of vehicles and amounts to $t_1 = 30$ minutes. The route N-E and W-S are local roads of a lower capacity in case of which the time needed to drive depends linearly on the number of vehicles and amounts in minutes to $t_2 = P/100$, where P is the number of vehicles present on the network. For calculation purposes P=2000 vehicles.

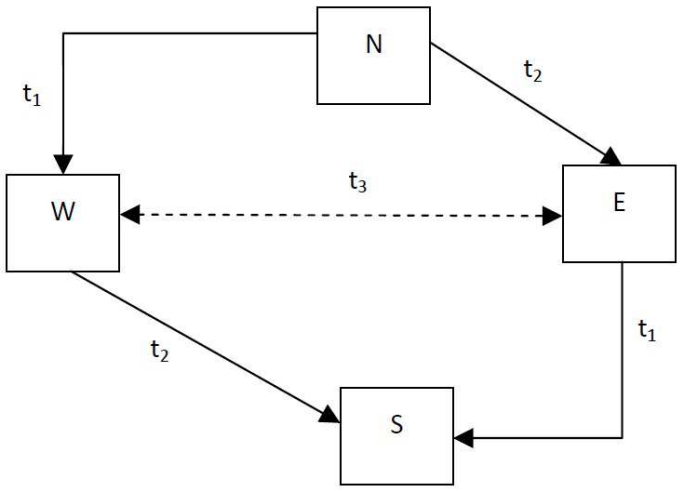

Fig. 1. Road network
Rys. 1. Sieć dróg

Let us now calculate the average drive time (T) between N and S. As both routes (through E and W) are identical as far as the cost and length are concerned, each driver aims at minimizing his own cost. That is why there is a high distribution probability that one half of drivers will choose route E and the other half route W.

So let us calculate now the average drive time:

for N-W-S it amounts to: $T_{NWS} = t_1 + 0{,}5\ t_2$

T_{NWS} = 30 min + 10 min = 40 min

and for N-E-S it amounts to: $T_{NES} = 0{,}5\ t_2 + t_1$

T_{NES} = 10 min + 30 min = 40 min

Let us assume that a new high-capacity road has been built between E and W. In order to simplify the calculation and show the result more clearly let us assume that in the case of that new road the drive time amounts to t_1=5 minutes and is irrespective of the number of vehicles.

Let us now repeat the calculation for the new route (T`).

Travelling from N to S each driver will be able to choose either route N-E or N-W. As the number of cars in the network is P=2000, the worst time scenario in the case of route N-E amounts to:

$T`_{NE} = t_2$ = 20 min

and in the case of route N-W amounts to:

$T`_{NW} = t_1$ = 30 min

Thus, all the drivers will choose the first variant. Next, they will face a similar dilemma and out of the two E-W-S ($T`_{EWS} = t_3 + t_2$ = 25 min) or E-S ($T`_{ES} = t_1$ = 30 min) they will choose E-W-S, to minimise their personal drive time.

The average total drive time from N to S along the N-E-W-S route will amount now to:

$T`_{NEWS} = t_2 + t_3 + t_2$ = 20 min + 5 min + 20 min = 45 min

It may easily be noted that after the construction of a new route the average drive time increased (deteriorated) by 5 minutes. None of the drivers will change his route as the initial routes N-E-S or N-W-S take now:

$T`_{NES} = T`_{NWS} = t_1 + t_2$ = 30 min + 20 min = 50 min

that is 5 minutes more,

and the route N-E-W-S shall take:

$T`_{NWES} = t_1 + t_3 + t_1$ = 30 min + 5 min + 30 min = 65 min

that is 20 minutes more which constitutes 25 minutes more from the shortest time (amounting to 40 min) in the case of T_{NES} and T_{NWS} present before the construction of a new road.

The analysis presented above shows that uncoordinated individuals aiming at achieving their own personal optimum are not always contributing to achieving optimum for the whole community. That is why society must pay the so-called Price of Anarchy (PoA) [Youn, Gastner, Jeong 2008], connected with the lack of coordination between certain individuals.

In order to limit the impact of the Price of Anarchy, in many European cities (with London in the lead) derivative methods are introduced. They include closing some streets and collecting charges for driving in city centers. The latter shall be calculated in order to balance preferences of individuals to achieve efficient balance (social optimum) in this respect.

CONCLUSIONS

To sum up, contrary to expectations in the majority of cities and towns all around the world investments connected with constructing new and developing old roads, fail to improve transportation or even make the situation worse.

The reduction of traffic congestion problems is usually achieved by changing preferences of the largest possible number of car users and convincing them to use alternative means of mass transportation.

But, the introduction of the efficient network of public transportation does not seem to be sufficient encouragement for the majority of commuters who prefer their own cars. The research reveals that congestion charges have a stronger influence on diminishing the number of private car users than parking tolls. Therefore, the combination of the two solutions gives the effect of synergy that is to say the end result of their application is better than their direct sum. It should be emphasized here, however, that the accrual is usually not very significant as it refers to the same group of people. Moreover, not taking into consideration factors connected with social culture and traditional behaviours may result in a failure of municipal policy striving towards decreasing urban congestion.

Social costs of traffic congestion in urban areas are often increased by the so-called Price of Anarchy which stems from the fact that individuals (users of cars) pursue their personal optimum which is usually not the same as social optimum for the community of a given city or town (municipality).

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EFEKTYWNOŚĆ ROZWIĄZYWANIA PROBLEMÓW KONGESTII DROGOWEJ

STRESZCZENIE. **Wstęp:** Kongestia drogowa jest obecnie jednym z najpoważniejszych problemów miejskich systemów komunikacyjnych i ich infrastruktury. Zdarza się inwestycje w infrastrukturę drogową, połączone z budową nowych lub przebudową starych połączeń drogowy, nie przynosi oczekiwanych rezultatów, tzn. nie przynosi poprawy stanu komunikacji miejskiej a nawet go pogarsza.
Metody: W artykule poddano analizie niektóre metody łagodzenia kongestii drogowej w obszarach zurbanizowanych. Metody instrumentalne, na przykład opłaty za parkowanie w centrach miast, nie przynoszą zwykle poprawy sytuacji. Bardziej skuteczne okazuje się wprowadzenie szybkiego i względnie komfortowego transportu publicznego, który byłby w stanie konkurować z przejazdami samochodami osobowymi.
Wyniki i wnioski: Z badań wynika również, że stosowane często poszerzanie dróg, nie prowadzi wcale do zwiększenia ich przepustowości, gdyż wzmaga preferencje do używania samochodów prywatnych, zamiast środków komunikacji zbiorowej. W konsekwencji, prowadzi to do powiększenia liczby pojazdów poruszających się po mieście i tym samym wzrostu poziomu kongestii. Nieskoordynowane jednostki dążące do osiągnięcia swojego osobistego optimum, nie zawsze osiągają w ten sposób optimum dla całej społeczności, która musi w konsekwencji płacić tzw. cenę anarchii. Im lepiej zatem będzie funkcjonowała komunikacja zbiorowa, tym więcej osób będzie jej używać, a tym samym w sieci ulic i tras komunikacyjnych miasta będzie mniej samochodów - z czego wyniknie mniejszy poziom kongestii.

Słowa kluczowe: przepływy ludności w miastach, drogowa kongestia miejska, instrumenty zarządzania miastem, cena anarchii

EFFIZIENZ DER PROBLEMLÖSUNG VON ÜBERFÜLLTEN VERKEHRSSTRAßEN

ZUSAMMENFASSUNG. Einleitung: Überfüllte Straßen stellen heutzutage eines der ernsteren Probleme für städtische Verkehrssysteme und deren Infrastruktur dar. Es kommt vor, dass die Investitionen in die Straßeninfrastruktur verbunden mit Aufbau von neuen oder Umbau von alten Straßenverbindungen, keine erwarteten Resultate mit sich bringen, d.h. keine Verbesserung des städtischen Kommunikationssystems und sogar dessen Verschlechterung zur Folge haben.
Methoden: Im vorliegenden Beitrag wurden einige Methoden für die Milderung der mit überfüllten Straßen verbundenen Nachteile in den urbanisierten Ballungsgebieten einer weitgehenden Analyse unterzogen. Die instrumentalen Methoden wie etwa Parkgebühren in den Stadtzentren bewirken gewöhnlich keine Verbesserung der Situation. Es stellt sich dagegen heraus, dass die Einführung von schnellen, relativ komfortablen, öffentlichen Transportmitteln, die mit dem Transport mittels PKWs zu konkurrieren vermögen, viel wirksamer wird.
Ergebnisse und Fazit: Aus den betreffenden Forschungen geht hervor, dass die oft forcierte Verbreiterung von Verkehrsstraßen auch zu keiner Vergrößerung deren Kapazitäten führt, sondern bei Reisenden den Gebrauch von PKWs statt der Inanspruchnahme von öffentlichen Verkehrsmitteln steigern lässt. In Folge dessen führt das zur Erhöhung der Anzahl von den in der Stadt verkehrenden PKWs und gleichzeitig zum Anstieg des Stauverkehrs in Stadtzentren. Unkoordiniertes Verhalten von Privatpersonen, die nur ihr persönliches Wohl anstreben, verfehlt dadurch das Optimum der ganzen Verkehrsgemeinschaft, welche in der Konsequenz den sog. Anarchie-Preis zu bezahlen hat. Je besser also das öffentliche Verkehrswesen in Funktion tritt, desto mehr Personen es in Anspruch nehmen, wodurch es auch im Straßenverkehrsbetz weniger Privatautos geben wird - was im Endeffekt das Niveau der Verkehrs-congestion senken lässt.

Codewörter: Personenfluss in Städten, überfüllte Verkehrsstraßen, Instrumente für städtisches Verkehrsmanagement, Anarchie-Preis

Zbyszko Pawlak
Poznań School of Logistics
ul. Estkowskiego 6
61-755 Poznań
e-mail: Zbyszko.Pawlak@wsl.com.pl

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LOGISTIC SERVICE PROVIDERS AND SUSTAINABLE PHYSICAL DISTRIBUTION

Stef Weijers, Hans-Heinrich Glöckner, Reinder Pieters

HAN University of Applied Sciences, The Netherlands

ABSTRACT. **Background:** Logistic Service Providers main concern was to ensure reliability for a low price (Christopher, 2005). Dutch Logistic Service Providers still have these two aspects at the top of their list, but also have to take in a new aspect: sustainability. 88% Of the investigated Logistic Service Providers have included sustainability in the company's goals. These Logistic Service Providers have developed different strategies to achieve a higher level of sustainability. This paper presents the results of a study into what Logistic Service Providers say what they are doing, or intend to do, to improve sustainability for their transport services. In this way insight is given in the attitude of Dutch Logistic Service Providers towards sustainability and how they intend to translate this into business practise: internal solutions or new methods incorporating external partners.
Methods: Various methods of the investigations were used, among which the analysis of the statements about the sustainabilityon the websites of various companies as well as the questionnaire per Internet. The research covered 50 largest logistics companies operating in the Netherlands and 60 companies that competed for the award "Lean and Green" advertised in the Netherlands. In addition, the Internet survey was answered by 41 companies that belong to the network of our university.
Results: The investigation has shown that sustainability is handled by the logistics company as an integral part of the corporate strategy. In contrast, shippers depend in the choice of logistics services primarily on such classical aspects as the reliability or the price and the sustainability play a minor role.
Conclusions: Trying to find methods to improve the sustainability, Dutch logistics service providers, in the first place, look for solutions that increase the efficiency and therefore the cost reduction potential. Solutions, which require the involvement of clients, were less often implemented, although there is a willingness of the cooperation among other logistics service providers, to reduce the transport kilometers. There is very little willingness on the side of logistics service providers to involve clients into their environmental programs. Further researches on this topic are planned.

Key words: Logistic service providers, sustainability, strategy.

INTRODUCTION

Sustainability is becoming an important aspect for Logistic Service Providers anywhere. But how do the Logistic Service Provider and the shipper work together to make the chain more sustainable? This research investigates how (Dutch) Logistic Service Providers handle the practical aspects of sustainability in order to achieve a higher level of sustainability. Do they opt for internal solutions (e.g. fleet replacement or ensuring that their chauffeurs drive more environmentally friendly) or for external solutions (e.g. setting up new networks or improving the cooperation with shippers or business competitors)? Our assumption is that solutions involving external partners require more effort than internal solutions but are more constructive.

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RESEARCH METHODOLOGY

To answer these questions this research focuses on the leading Dutch Logistic Service Providers, due to their size or because they are forerunners in making transportation more sustainable. The first group consists of the fifty largest Logistic Service Providers operating in the Netherlands and were found in the top 50 of 2011 (Dijkhuizen, 2011). The second group consists of 60 Logistic Service Providers who participated in the award scheme "lean and green" between 2008-2010 (website Connekt).

The first group covers those Logistic Service Providers who, due to their size, can be considered to dominate the Dutch market and the second group covers the frontrunners for sustainable freight transportation in the Netherlands. First the websites of these Logistics Service Providers were scrutinized for information on sustainability. If no information was found, specific questions were asked by email on their standpoint on sustainability. All emails were quickly responded and the answers provided covered the questions

These results were compared with the answers respondents have given to a web survey which was held to investigate Logistic Service Providers and their attitude on sustainability in 2010. A request to participate in this survey was sent to 82 Logistic Services Providers, who have connections with our University through work placements schemes etc. 61 Accepted this request and of these 41 successfully filled in the survey completely. There is an overlap between the three target groups: 22 of the top 50 also participated in the "lean and green" award and 9 of the top 50 were also respondents of the survey. The web survey contains 14 respondents who were also in the top 50 and 18 who participated in the lean and green award scheme. 12 participants were part of both lists at the same time. The results are what the Logistics Service Providers say what they are doing to increase sustainability; what they are actually doing will be the subject of a next research.

THE ECOLOGICAL IMPACT OF THE TRANSPORT SECTOR

What makes freight transportation services sustainable is altogether not clear. So it follows that what makes a Logistic Service Provider more sustainable is not clearly cut. This could be due to a lack of a generally accepted definition of sustainable transportation (Pezzey, 1997). The definition of the Brundtland Commission (World Commission, 1987) is often taken as the basis for a definition (Jeon and Amekudzi, 2005), but this is difficult to translate into hard, measurable facts. As most trucks still employ an implosion engine, it could be stated that every litre of gasoline used for transportation today will not be available for future generations. So the Brundtland based definitions fail to be realistic and usable (yet).

When discussing sustainable transportation, the attention focuses on reducing exhaust gases. The main exhaust gases are carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter (PM) (Francke, Annema and Wouters, 2009). There are more polluting exhaust gases concerning transportation like carbon monoxide (CO) and hydrocarbons (HC) (Meulen and Kindt, 2010), but these two gases were never mentioned on the research websites or by the respondents of the survey.

When discussing sustainable transportation, almost all attention in literature on sustainable freight transportation, (Dutch) government information on this subject and in the researched target groups is concentrated on CO_2 reduction. The other gases are hardly mentioned. As for the transport sector itself, just two Logistic Service Providers mention the four main gases, but do not show how they are trying to reduce all of them. As for this research, it was decided to follow this lead as well and to concentrate on CO_2.

In 2008, transportation is responsible for 21% of all CO_2 production within the Netherlands. The main part (79%) of this figure is taken up by road transport (private and freight). The remainder is divided amongst inland shipping (5%), air transportation (2%) and sea transport (14%). Within road

transport, freight transport has a share of 36% (Meulen and Kindt, 2010). These figures show that the Dutch freight transport sector does produce a considerable amount (6%) of CO_2 and that Dutch Logistic Service Providers should consider their responsibility to control, or even better lower, the amounts of CO_2 produced. This responsibility is certainly taken up by the transport sector. Within the top 50 41 (82%) Logistic Service Providers mention sustainability as one of their company's goals on their websites. Those who did not mention sustainability were contacted and asked if they could provide additional information. Three of them did reply and based on their information the number of Logistics Service Providers who endorse sustainability has risen to 43 (86%). This equals the results of the web survey. Here 36 respondents (88%) stated that they endorse sustainability. These numbers are high! It can be stated that sustainability has become one of the major aspects influencing Logistic Service Providers' behaviour. It also shows that within the transport sector sustainability is not a unique selling point anymore. It has become a common feature.

SUSTAINABILITY AND SHIPPERS

But how important is sustainability for the customers of Logistic Service Providers?

Table 1. Main selection criteria according to shippers
Tabela 1. Główne kryteria wyboru według przewoźników

Selection criteria	Weight price =100
Price	100
Reliability	94
Service	72
Sustainability	45
Innovation	33

A survey of Van der Meulen and Kindt (2010) amongst shippers found that they used certain criteria when selecting a Logistic Service Provider. The main criteria were price, reliability, service, sustainability and innovation. When asked to rank these criteria, the results were in favor of price with sustainability far below (see table 1). This choice is supported by literature which often states that the choice for a logistic aspect, such as transportation, is usually determined by two things:

1. effectiveness like speed and reliability and
2. efficiency (low cost) (Christopher, 2005, Visser, 2010).

The web survey gives a similar impression. 32 (78%) of the respondents say cost is the most important issue with transportation and 34 (83%) do not think that the customer is willing to pay for sustainability.

Simply put, the customer especially requires "more value for less money" (Dorp, Kempe and Commandeur, 1992 p 23). The question is whether in the current era this is still valid. There is a trend amongst (final) customers to demand a higher level of socially responsible behavior from the supply chain partners (Maloni and Brown, 2006).

The portfolio model of Kraljic (1983) can be used to understand the shipper's choice better. Kraljic determines an item purchased by four criteria, as shown in Table 2.

Transportation cost takes up 10% till 25% of the overall costs for a product (Goor and Ploos van Amstel, 2009). The higher this percentage, the more transportation will become a leverage item with price as the main determining factor. Reliability is a quality aspect and makes transport a strategic purchase item. Transportation is rarely seen as a bottleneck item. Only if a transport requires vehicles with very specific conditions, due to the size or weight of the transported item. So this aspect can be

ignored. For those shippers for whom transportation is not determined by these three aspects, nothing specific can be said.

Table 2. Purchasing transport service and the portfolio model of Kraljic
Tabela 2. Model Kraljica port folio i usług transportowych

Kraljic's label	Main selection criteria	Decision
Leverage Items	Price	the product or service purchased determines the final price of the end product substantially. The purchaser will opt for the lowest cost.
Strategic Items	Quality	one specific aspect needs absolutely to be fulfilled by the item or service purchased.
Bottleneck Items	Availability	this product or service will not (always) be available. The purchaser will have to acquire potential sources for this product or service.
Non Critical Items	Nothing specific	As nothing specific determines this purchase, the purchaser's decision is not clearly cut.

Sustainability could make transportation more expensive (specific engines, new software may have to be bought etc.) or lengthen the delivery time (alternative modes for road transportation can take longer). Both aspects conflict with the two main aspects for transportation as seen by the shipper (Christopher, 2005). For sustainability to become an aspect of a strategic item some things will have to change:

- sustainability is enforced by government regulation;
- sustainability is set as a priority by the (final) customer or
- sustainability is taken to the top of the shipper's company values.

If nothing really will change, sustainability will just be a side aspect beside the main two criteria when drawing up Service Level Agreements (SLA) when selling or purchasing transport services.

AWARD SCHEMES

Hardly any specific information is to be derived from the information on the websites of the Top 50 on how the Logistic Service Providers want to achieve their goals on sustainability. What can be found are the networks or award programs in which they cooperate. Many awards programs have been set up to encourage and support sustainability within the transport sector. They offer the participants a chance to be compared to a standard and competitors. For customers and interested stakeholders an award scheme creates trust on the Logistic Service Provider's performance in the field of sustainability. The web survey found that 22 (54%) of the respondents believe award schemes form an essential part of the shipper's appreciation for Logistic Service Providers' level of sustainability.

For the transport sector, the website of the Environmental Forum registers 61 awards schemes for the UK alone. In the Dutch top 50, many Logistic Service Providers have joined international environmental award schemes like e.g.: Dow Jones Sustainability World and Europe Index (8%), World Business Council for Sustainable Development (14%) or United Nations Global Compact (24%). Other schemes which were mentioned are the FTSE4Good Global Index (2%), FLEXpledge (2%), Carbon Trust Standard (2%), Green Supply Chain Award (2%), Electronic Industry Citizenship Coalition (2%) and Responsible Care® (2%). Some awards are linked to specific industries. For example, the goal of Responsible Care® is to seek continuous improvement in health, safety and

environment of the chemical industry's stakeholders (website ICCA). Five companies (10%) have joined more than one international environmental award scheme. Taking this into account, there is a participation rate of 42% for the top 50 Logistic Service Providers for international environmental award schemes.

For the top 50 companies, the involvement rate in international environmental award schemes is for the numbers: 1-10 (90%); 11-20 (50%); 21-30 (40%); 31-40 (20%) and 41-50 (10%). It seems that award schemes are particularly interesting for the larger Logistic Service Providers. Looking at the national origin of the Logistic Service Provider 14 (74%) of the 19 Non-Dutch companies have joined an international award scheme compared to 7 (23%) of the 31 Dutch companies. Beside these award schemes, 14 Logistic Service Providers (28%) mention they have an ISO14001 certification. This should indicate an environmental awareness within the company.

In the Netherlands an interesting award scheme "lean and green" was introduced in 2008. This scheme focuses on shippers, transporters (1PL to 4PL) and city councils. Lean and green wants to encourage businesses to grow to a higher level of sustainability. They hold that becoming greener will reduce the environmental impact, while simultaneously saves cost. Since the introduction in 2008 the award scheme has gained popularity and 28 shippers, 59 Logistic Service Providers and 1 City council have joined the award scheme (April 2011). It is expected that this group will increase in time and it has the potential of becoming the leading standard for sustainable transportation in the Netherlands. Members have to write a plan, which contains precise CO_2 targets for 2012/2015 and determine green key performance indicators (website Connekt).

LOGISTIC SERVICE PROVIDERS AND SUSTAINABILITY

The websites of the top 50 companies were not very informative on how the Logistic Service Providers wanted to enhance sustainability. But all participants of the lean and green award scheme have to describe how they want to achieve their goals. The list of tools Logistic Service Providers intend to use include aspects like:

- "Het nieuwe rijden" (new driving style), a training for truck drivers to enhance awareness how driving (gear changing, braking, speed etc.) has an impact on the level of CO2 production;
- Buying new and less polluting vehicles;
- Reducing energy consumption in warehouses;
- Controlling tire pressure;
- Monitoring driving speed;
- Using more alternative modes of transportation;
- Using more bio fuels;
- Improving loading capacity;
- Buying electric vehicles;
- Increasing efficiency;
- Reducing kilometers driven;
- Avoiding empty hauls
- Etc.

It is not surprising to see that Logistic Service Providers take a variety of approaches to reach sustainability. It is wise to identify and take these aspects which have the greatest impact on sustainability. These are unique to every Logistic Service Provider and its business (Szekely and Knirsch, 2005). So solutions for this aspect may also be expected to depend on the actual situation.

In order to get a better grasp on all these aspects, four categories were created:

Internal approach - Aspects which can be organized by the Logistic Service Provider himself.

External approach - Aspects which need cooperation with others outside the own organization (e.g. shippers, governments, competitors, stakeholders etc.).

Innovating - Aspects previously unknown to the Logistic Service Provider.

Optimizing - The Logistic Service Provider aims at improving and achieving better results.

With these four categories a two-by-two matrix can be constructed with the approach (internal or external) on the Y-axis and the X-axis whether the knowledge and skills already exist for improving the present situation (optimizing) or not (innovating). After categorising the approaches mentioned by the Logistic Service Providers in the lean and green award scheme the result as shown in figure 1 was achieved.

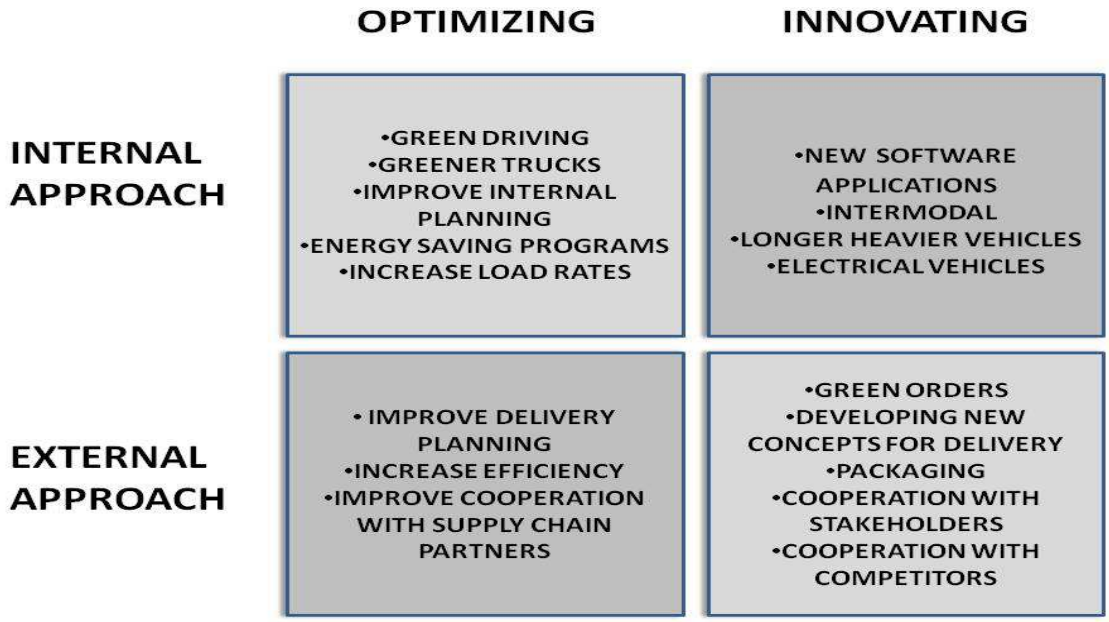

Fig. 1. Sustainability activity matrix
Rys. 1. Macierz działań zrównoważonego rozwoju

This model could be made three dimensional by including an extra level with the aspects Structural and Incidental:

Structural - The chosen method will be used for a long time and could be used for any situation.

Incidental - The chosen method will be used just once.

This additional level could give a better insight into the question whether the Logistic Service Provider can use the experiences gained to improve other (similar) situations at a later date. It is our intention to interview the participants of the lean and green award scheme for the purpose of understanding where long term/multi applicable measures will differ from short time/one time measures.

When studying the intentions of the 60 Logistic Service Providers participating in the lean and green award scheme, it was found that most measures for improvement are sought within the own company. For example 58 (97%) participators use measures of an internal optimizing character and 29

(48%) mention measures of an internal innovative character. External measures are less popular. 22 (38%) intend to improve efficiency in cooperation programs. 8 (13%) Logistic Service Providers mention cooperation with shippers. These programs include ideas like:

- Awareness programs like informing shippers of the CO_2 footprint of their shipments;
- Discussing delivery time schedules;
- Bundling deliveries to avoid empty hauls.

14 (23%) Logistic Service Providers mention cooperation with other Logistic Service Providers by sharing delivery routes. 5 (8%) Logistic Service Providers mention separate programs for both shippers and competitors. No further details are given.

The remaining 5 (8%) Logistic Service Providers take the whole value chain into perspective. They specifically mention that they want to include all partners in the value chain in their new programs.

It can be concluded that most companies hope to find improvement inside their own company and seem less willing to include partners. Logistic Service Providers also seem to be reluctant to turn to fellow Logistic Service Providers for cooperation. Perhaps cooperation with fellow Logistic Service Providers is not always easy. For instance, a project in Leiden (the Netherlands) to build a central warehouse for city distribution failed due to the unwillingness of the Logistic Service Providers involved to work with competitors (Quak, 2008).

This reluctance for cooperation with shippers is also shown by the web survey. Here 23 (56%) of the respondents state that shippers will not make any concessions if this includes changing the time schedule of deliveries or the use of alternative modes of transportation. According to 31 (76%) of the respondents, the shipper will not make any concession on delivery speed. Apparently, Logistic Service Providers feel that sustainability on its own merit is not a decisive factor for shippers to choose for a specific Logistic Service Provider. The main selection criteria for shippers of transport services are definitely price and reliability. This could indicate that Logistics Service Providers have to come up with new ideas of how to make transportation more sustainable if they want to keep the interest of shippers.

The web survey also provides an interesting view on the ideas of cooperation amongst Logistic Service Providers. Asked if they would be willing to share rides with competitors, 27 (66%) of the respondents answered yes. A smaller group of 18 participants (44%) thinks that their competitors will be willing to cooperate with them. These figures could indicate that there is potential for cooperation between competitors in the transport sector. When split up into the function of the respondent, a difference between these two groups becomes apparent: 13 of the 14 general managers (93%) say they are willing to combine rides with competitors against 6 of the 14 (43%) respondents working on an operational level. Asked if competitors would be willing to cooperate with them to improve sustainability, 8 of the 14 general managers (57%) say yes as opposed to 4 of the 14 (29%) respondents working on an operational level. Apparently top management has a more positive view on cooperation with competitors than those working on an operational level.

CONCLUSIONS

Sustainability has definitely become an integral part of the mission and vision of the leading Dutch transport sector. But shippers do not treat sustainability on an equal footing as classic aspects like reliability and price. These two aspects still dominate the choice for a particular Logistic Service Provider.

Trying to search for ways of improving sustainability, (Dutch) Logistic Service Providers look primarily for schemes which increase efficiency of existing (internal) programs and therefore having the potential of lowering costs. Schemes which include outsiders are less popular, but there is a willingness for cooperation with fellow Logistic Service Providers in order to reduce kilometers transported by combining hauls. Logistic Service Providers seem reluctantly willing to include

customers in environmental programs, but the main underlying goal remains improving efficiency. None of these actions are tested on actual fulfillment, therefore further research is needed to investigate what the real actions of Logistic Service Providers are to promote sustainability and how these actions relate to Service Level Agreements and relationships with customers.

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USŁUGODAWCY LOGISTYCZNI A ZRÓWNAŻONA DYSTRYBUCJA

STRESZCZENIE. **Wstęp:** Niezawodność oferowanych usług dostawczych przy niskich kosztach to główny cel, do którego dążą dostawcy usług logistycznych (Christopher, 2005). Jest to również główne przesłanie holenderskich dostawców usług logistycznych, jednak coraz częściej przywiązują oni większą wagę do zrównoważonego rozwoju swojej działalności. 88% z grupy dostawców usług logistycznych, objętych tymi badaniami, uznało zrównoważony rozwój za jeden ze swoich celów korporacyjnych. Firmy logistyczne wypracowały różne strategie zrównoważonego rozwoju. W pracy przedstawiono wyniki badań na temat integracji zrównoważonego rozwoju w strategię firmy w holenderskich firmach logistycznych, jak i aspekty ich praktycznego zastosowania.
Metody: W trakcie badań zastosowano różne metody, między innymi analizę oświadczeń dotyczących zrównoważonego rozwoju na stronach internetowych firm oraz wyniki ankiety przeprowadzonej przez Internet. Badaniem objęto 50 największych firm logistycznych działających w Holandii i 60 firm, które rywalizowały o nagrodę "Lean and Green" reklamowaną w Holandii. Ponadto, ankieta internetowa została wypełniona przez 41 firm, należących do sieci naszej uczelni.
Wyniki: Badania wykazały, że zrównoważony rozwój jest postrzegany przez firmy logistyczne jako integralna część strategii ich przedsiębiorstwa. W przeciwieństwie do tych przedsiębiorstw, odbiorcy ich usług, w wyborze usług logistycznych kierowali się głównie klasycznymi aspektami, takimi jak niezawodność i stabilność cen, natomiast fakt przyjęcia jako strategii firmy zrównoważonego rozwoju odgrywał przy tym wyborze mniejszą rolę.
Wnioski: Próbując znaleźć sposoby szerszego wdrożenia rozwoju zrównoważonego, holenderscy usługodawcy logistyczni zwracają uwagę przede wszystkim na rozwiązania zwiększające ich efektywność jak i ich potencjał redukcji kosztów. Realizowane są przede wszystkim rozwiązania wymagające mniejszego zaangażowania klienta, choć jednocześnie istnieje chęć współpracy z innymi firmami logistycznymi w celu zmniejszenia kilometrów realizowanego transportu. Jeszcze mniej wydają się dostawcy usług logistycznych być skłonni do włączenia klientów do swoich programów ochrony środowiska. Planuje się dalsze badania w tym obszarze.

Słowa kluczowe: dostwca usług logistycznych, rozwój zrównoważony, strategia.

LOGISTIKDIENSTLEISTER UND NACHHALTIGE DISTRIBUTION

ZUSAMMENFASSUNG. Einleitung: Das Hauptziel von Logistikdienstleistern ist es, Lieferzuverlässigkeit zu niedrigen Preisen zu bieten (Christopher, 2005). Auch bei den niederländischen Logistikdienstleistern rangieren beide Aspekte ganz oben, aber mehr und mehr berücksichtigen sie einen weiteren Gesichtspunkt: Nachhaltigkeit. 88 % der untersuchten Logistikdienstleister hat Nachhaltigkeit in die Unternehmensziele integriert. Die Logistikunternehmen haben verschiedene Strategien entwickelt, um Nachhaltigkeit praktisch umzusetzen. Dieser Artikel zeigt die Resultate einer Untersuchung zur Integration von Nachhaltigkeit in die Unternehmensstrategie bei niederländischen Logistikunternehmen sowie Aspekte ihrer praktischen Umsetzung.
Methoden: Zur Untersuchung wurden verschiedene Methoden angewendet, worunter die Analyse der Aussagen zur Nachhaltigkeit auf den Websites der Unternehmen und eine Befragung per Internet. Einbezogen wurden die 50 größten Logistikunternehmen, die in den Niederlanden tätig sind, und 60 Unternehmen, die sich um den Award "Lean and Green" in den Niederlanden beworben haben. Daneben wurde die Internetbefragung durch 41 Unternehmen beantwortet, die zum Netzwerk unserer Hochschule gehören.
Ergebnisse: Die Untersuchung hat gezeigt, dass Nachhaltigkeit von den Logistikunternehmen als ein integraler Bestandteil der Unternehmensstrategie behandelt wird. Dagegen orientieren sich Verlader bei der Wahl des Logistikdienstleister vor allem auf die klassischen Aspekte wie Zuverlässigkeit und Preis und spielt Nachhaltigkeit hierbei weniger eine Rolle.
Fazit: Bei dem Versuch, Wege zur Verbesserung der Nachhaltigkeit zu finden, schauen niederländische Logistikdienstleister in erster Linie nach Lösungen, die die Effizienz und damit das Kostensenkungspotential erhöhen. Lösungen mit Einbeziehung der Auftraggeber werden weniger realisiert, wobei es aber eine Bereitschaft zur Zusammenarbeit mit anderen Logistikunternehmen gibt, um durch die Kombination von Transporten Kilometer zu reduzieren. Noch weniger scheinen Logistikdienstleister bereit zu sein, Kunden in ihre Umweltprogramme einzubeziehen. Weitere Untersuchungen zu diesem Thema sind geplant.

Codewörter: Logistikdienstleister, Nachhaltigkeit, Strategie

Professor Stef Weijers
HAN University of Applied Sciences, Hogeschool van Arnhem en Nijmegen
Kapittelweg 33
6503 Nijmegen, The Netherlands
phone: +31(0)2691705
e-mail: HansHeinrich.Gloeckner@han.nl

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METHODS OF USING THE QUADRATIC ASSIGNMENT PROBLEM SOLUTION

Izabela Kudelska

Poznan University of Technology, Poznań, **Poland**

ABSTRACT. **Background:** Quadratic assignment problem (QAP) is one of the most interesting of combinatorial optimization. Was presented by Koopman and Beckamanna in 1957, as a mathematical model of the location of indivisible tasks. This problem belongs to the class NP-hard issues. This forces the application to the solution already approximate methods for tasks with a small size (over 30).
Even though it is much harder than other combinatorial optimization problems, it enjoys wide interest because it models the important class of decision problems.
Material and methods: The discussion was an artificial intelligence tool that allowed to solve the problem QAP, among others are: genetic algorithms, Tabu Search, Branch and Bound.
Results and conclusions: QAP did not arise directly as a model for certain actions, but he found its application in many areas. Examples of applications of the problem is: arrangement of buildings on the campus of the university, layout design of electronic components in systems with large scale integration (VLSI), design a hospital, arrangement of keys on the keyboard.

Key words: QAP, genetic algorithms, Branch and Bound, Tabu Search.

INTRODUCTION

The idea of optimum resource management is connected with determining proper relations between these resources and objectives. The optimum resource management relates with the establishing proper relations between determined resources and objectives. Occurring dependencies determine the efficiency and effectiveness and thus provide optimization. Therefore, the author presents possibilities of applying the method of Quadratic Assignment Problem (QAP).

The QAP problem is one of most interesting and most difficult problems from the area of combinatorics that appear in practice. This problem designs the issue of the allocation of the set of stores for the set of objectives, taking into account the knowledge of the size of costs of assignment and the tendency to minimize this cost. There have been many areas, in which the problem can be applied:

- ergonomics,
- architecture,
- computing science,
- logistics (distribution planning) and production.

The first chapter presents the essence of the problem of the Quadratic Assignment Problem. The author describes the mathematic model prepared by authors of the idea. Next part illustrates the

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calculative complexity of the QAP, bottom limits for costs, which constitute the basis for determining the algorithm of optimum solutions. Next, most frequent heuristics used for QAP solutions will be presented. In the summary, the author presents applications of the QAP problem.

DESCRIPTION OF THE QAP PROBLEM

Before discussing the QAP problem, the author wants to explain the question of the Problem Linear Assignment (LAP). The explanation of principal differences between these problems can help to understand better the definition and idea of QAP.

Linear Assignment Problem

The common application of LAP used by Hanan and Kurtzberg is known as assigning *n* people to *n* work. Each allocation is related to a certain cost – c_{ij}, assigning an *i* person to *j* work. The assigning of every person is made in order to assign him/her to only one workstation in a way to minimize the total of costs for each task, i.e. its total cost. The problem can be formed in a following mathematic way:

$$\min \sum_{i=1}^{n} c_{i\pi(i)} \qquad (1)$$

It is a set of permutation *1, 2, …, n* i $j=\pi(i)$ for all permutations possible $\pi=S_n$; S_n. Every set of tasks is a set of permuations for *n* numbers, and therefore it is equal *n!* we might observe that in case of high values of *n* we are not able to verify all combinations, or such verification is very difficult. For example: if we try to assign *n=10* people to 10 workstations in a way, that has been described above, then we should verify *10!* i.e. about 3.63 milion different combinations.

Quadratic Assignment Problem – Mathematic Model

Our target is a more complicated generalization of the Linear Assignment Problem. Beside the matrix of costs – like in LAP – it encloses also a matrix of distance participation. In order to maintain the cohesion, we might refer to works of Hanan and Kurtzberg [8] and their interpretations of the QAP. They used the case of allocation of offices for people. We find many mathematic definitions of the problem in the literature.

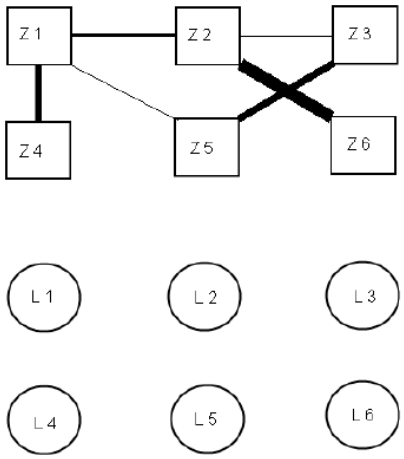
In QAP we obtain a matrix of costs $C = [c_{ij}]$, in which c_{ij} is the measure of the relation between the person *i* and the person *j*. we take under consideration *n* possible offices, to which people may be assigned. This gives us finally a so-called distance matrix $D = [d_{kl}]$, in which D_{kl} means the distance between the office *k* and the office *l*. let's assume that the *i* person is assigned to the *p(i)* office and that the *j* person is assigned to the *p(j)* office. Then, the cost related to the task is being treated as $c_{ij}d_{p(i)p(j)}$. And so the total cost of all tasks of assigning the office will be a sum of particular $c_{ij}d_{p(i)p(j)}$ in relation to all *i,j*. the optimum solution of assigning will take place only when the total cost will reach its minimum.

Similarly to the case of LAP, where there are *n!* permutations , from which one can choose the optimum assigning. However, here, the principal difference between these two problems is that in contrast with LAP, in which the assigning of *j* work to a *i* person was made independently from tasks of other workers, in QAP tasks are not independent from each other. This means that one must take under consideration the assigning for everyone, who has a non-zero relation with an individual in the study of assigning this particular person *i*.

The Quadratic Assigning Problem can be formed as follows:

There are *n* localizations and *n* tasks given. We also know a flow matrix $A = a_{ij}$, in which a_{ij} is for example a number of materials flowing from the task *i* and the task *j* during one unit of time. The cost matrix is $B = b_{ij}$, where b_{ij} is the distance between the localization *i* and the localization *j*. the cost of assigning the task $\varphi(i)$ to the localization *i*, and the task $\varphi(j)$ to the localization *j* is equal $a_{\varphi(i)\varphi(j)}b_{ij}$. the assigning of all tasks can be presented in a form of permutation *' 2 Sn.*

The figure 1 presents the problem in a graphic form. On this figure, Z1, Z2, ..., Z6 mean tasks, the flow between these tasks (matrix A) is marked by segments of different thickness – this symbolizes different flows between tasks. The problem concerns placing tasks Z1,Z2,..., Z6 in proper localizations in a way to minimize the total cost of assignment $a_{\varphi(i)\varphi(j)}b_{ij}$.



Source: Burkard, Dell'Amico, Martello, 2008

Fig. 1. Quadratic Assignment Problem
Rys. 1. Kwadratowy Problem Przydziału

The research in the literature of the problem shows that there are many mathematical definitions of the issue mentioned before. The author presents also the definition created by Koopman and Beckmann in 1957.

Koopman – Beckmann assumed that there are following matrixes:

A = (a_{ik}) – in which a_{ik} means the flow between the task *i* and the task *k*;
B = (b_{jl}) – in which b_{jl} is the distance between the localization *j* and the localization *l*;
C = (c_{ij}) – in which c_{ij} is the cost of placing the task *i* in the localization *j*;

Then, the problem has the form as presented in the figure 1 and in the formula (2)

$$\min_{\varphi \in S_n} \left(\sum_{i=1}^{n} \sum_{k=1}^{n} a_{ik} b_{\varphi(1)\varphi(k)} + \sum_{i=1}^{n} c_{i\varphi(i)} \right) \qquad (2)$$

In which S_n is the permutation of natural numbers 1, 2, 3, …, n.

The product $a_{ik}\, b_{\varphi(i)\varphi(k)}$ is the cost of combining the task *i* with the localization $\varphi(i)$, and the task *k* with the localization $\varphi(k)$. Each element from the set of conditions $c_{i\varphi(i)} + \Sigma^{n}_{k=1} a_{ik}\, b_{\varphi(i)\varphi(k)}$ is a total cost of assigning the task *i* to the localization$\varphi(i)$, and every task *k* to following remaining localization$\varphi(1),\varphi(2), ..., \varphi(n)$. The problem described this way, along with set matrixes *A,B,C* that we write *QAP*(*A,B,C*). if the problem has a non-linear character (without the known matrix *C*), we write it in a form *QAP*(*A,B*)[1].

The problem has been applied in the issue of assigning economic activities to the localization, taking under consideration the quadratic quality indicator. It remains until today its main application.

It has become popular because it generates many problems from the area of combinatorics, which can be faced in problems of the real practice.

HEURISTICS AND ACCURATE METHODS

In Linear Assignment Problems it is applied among other the Hungarian Algorithm. The cost matrix encloses in its columns tasks, in its rows - means that are in hand. Each cell refers to a cost of assigning means to a determined task. A cell in the first row and first column is the cost of assigning the first asset to the first task. This method fulfills its objective accurately for Linear Assignment Problems. However, assignment problems with square cost coefficient is a completely other problem. Accurate methods are not applied in cases bigger than 25 because of their big computational complexity. In such cases, when a big project is studied, it is enough to obtain an approximate solution; then it is possible to apply heuristic methods, which the author will present in the following part of the elaboration.

From all accurate methods, best results for difficult problems come from the Branch and Bound algorithm.

The exceptional difficulty of QAP has caused the development of heuristic methods of research. Genetic Algorithm, Tabu Search, Simulated annealing, and other specialistic methods, have been applied for solving QAP. The efficiency of various heuristics differs from each other with certain features, characteristic for every individual method. [P.Ji, 2006, p.108]

Branch and Bound

The algorithm is basing its action on the division of the issue on many smaller and less complicated ones. It is possible thanks to the search tree structure. Each branch of such tree represents a "sub-issue" that occurred in result of a division of an issue from a higher level. On the consecutive level of the tree incurred branches are being compared. This allows rejecting the worse branches, which results minimizing the amount of following sub-issues for studying. It is very important because the necessity of verifying all possible solutions doesn't make sense from the practical point of view, if the number of solutions is bigger than 25. The method is frequently used for small and medium problems.

The method of isolated assignment is the simplest and the most frequently applied method (Gilmore, Lawler). It is based on putting not-assigned objects to next locations. Thanks to such proceedings, one is creating an issue, which is the sub-problem of the issue of the higher level.

It is not the only method possible to find in the literature. Gavett and Plyter suggested an algorithm for pairs assignment. It is based on assigning a pair of tasks to a pair of localizations. Mirchandani and Obata present another approach; they propose a relative positioning algorithm. The idea of Roucairol is another solution; he named his algorithm Polytomic branching. The next step is to choose the best path for further search, which is being found by finding the lower limit. The GLB technique (Gilmore-Lawler bound) is very popular; its main advantage is that it's calculative side is not complicated.

One knows trials of upgrading the division and limitation method made by applying techniques for finding bottom limits. Hahn, Grant, and Hall presented a technique called Dual Procedure (DP).

Genetic Algorithm

Starting from the sixties of the 20th century, numerous scientific centers formed all sorts of schools promoting methodologies and algorithms of heuristic searching developed by oneself; methodologies, which were often inspired by mechanisms observed in the natural evolution. In the beginning of the

nineties, representatives of all these schools met on a conference and they agreed that they shared the same object of the interest, which were evolulutionary computation. Since then, there has been accepted to name all originally developed methods and their further alterations, which ofter result from hybridization, with the name of "evolutionary algorithms". Primitive divisions didn't disappear entirely and until today disputes and controversies continue between representatives of various directions. The group of evolutionary algorithms encloses particularly genetic algorithms and evolutionary strategies. Some authors also add to this group the method called dispersed searching, although this heuristic differs creatively from previous in a quite significant way [Grygiel, 2011] [Łęski, 2008].

The genetic algorithm has been presented for the first time in 1975 by Holland. Its characteristic is that the algorithm has a binar representation of individuals and recombination with use of the single-point crossing, the mutation of bits of representatives and the reproduction with use of the roulette method (proportional) [Łęski, 2008].

The primary version of the genetic algorithm is currently called elementary, canonical, or simple genetic algorithm [Grygiel, 2011, Rutkowska and others, 1997].

The essence of action of genetic algorithms consists in searching the space of solutions for the problem, in order to find best solutions (taking into account a determined criterion). The algorithm operates on a certain population of individuals, i.e. solutions. This allows to search the space of solutions from different points of view in the same time. The essential genetic algorithm is made by following steps [Tate, 1995, Rutkowska and others, 1997, Łęski, 2008]:

- The imitation i. e. choice of the initial population of chromosomes,
- Evaluation of the range of adaptation of chromosomes to the population,
- Verification of retention conditions,
- Selection of chromosomes,
- Application of genetic operators,
- Formation of the new population,
- Modelling of the "best" chromosome.

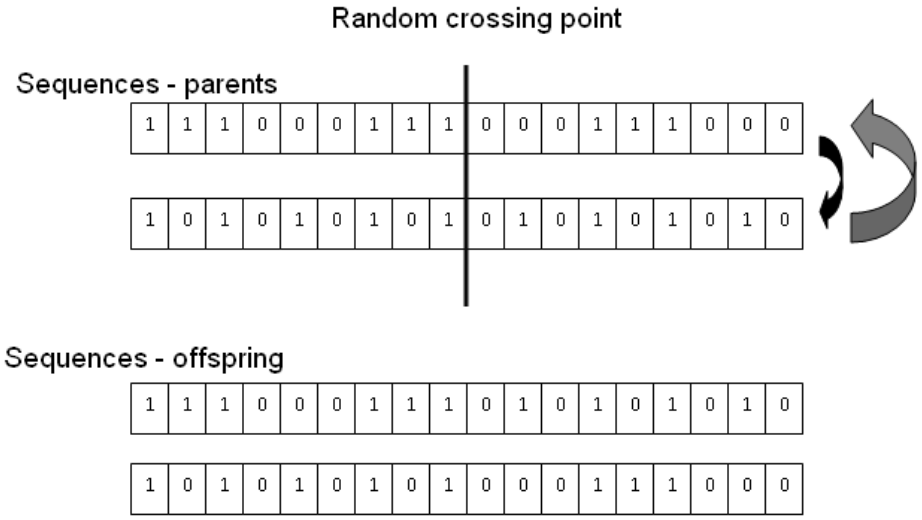
In the beginning of the work with use of the genetic algorithm there always must be created an initial population of code sequences - the first generation, which can be presented in form of the following formula (formula 3):

$$P(a) = \{x_1^a, x_2^a, \ldots, x_b^a\} \qquad (3)$$

The set of these sequences can be made in an absolutely random way; however its formation can also be based on certain rules. A set of coded sequences allows to calculate a suitable set of values for functions of objective in the same time. Classical genetic algorithms work with coded sequences written in form of chains of zeros and ones; however it is possible to write a coded sequence with use of a bigger number of letters of the alphabet. Still, the most important thing is to have the possibility of decode essential information from such sequence [Knosala 2002]. Detailed information on the process of coding can be found in the following positions: [Sarker and others 2002, Anderson 2002, Rutkowska and others 1996].

Each sequence of codes is a properly coded data concerning the required value of variables, for which the value of variables should reach the extreme value. Usually, just before the formation of the first generation, one introduces parameters for genetic algorithm work into the program: number of generations, probability of mutation and crossing. After creating the first generation, each coded sequence must be calculated with use of the function of the objective prepared for this sequence. Then, after determining values of all sequences, the draw (selection) to so-called intermediary generation,

takes place. The generation has the same size, i.e. the same number of sequences, as the first generation; however it doesn't have to be always this way. Sequences evaluated as "better" have more chances for entering into the determined generation and being copied into it. The chromosomes selection is about choosing on basis of calculated values of functions of chromosomes adjustment, which of them will participate in the formation of the next generation representatives. There are many methods of selection. The most popular is the so-called roulette method. When the intermediary generation is already formed, sequences of this generation are being subjected to the operation of crossing. In the simplest case it concern a random selection of a pair of sequences, a random selection of the crossing point inside sequences and exchange of places of fragments of sequences (figure 2) [Knosala 2002, Goldberg 1995, Rutkowska and others 1997].



Source: Personal elaboration based on [Knosala, 2002, p. 401]

Fig. 2. Sequence crossing operation
Rys. 2. Operacja krzyżowania ciągów

The literature describes many various crossing operators, which function in different ways. More information on the subject can be found in following positions: [Goldberg 1995, Michalewicz 1996, Sarker and others 2002, Rutkowska and others 1997]. However, the main goal is always to exchange information between sequences in a way to use best characteristics of parent sequences in order to form even better sequences - children [Knosala 2002, Rutkowska and others 1997, Michalewicz 1996].

After having formed the required number of children, the mutation is made. It concerns a random exchange of representation bits with small probability. Similarly to the reproduction, the mutation operates on individual parental representative. And similarly to the case of crossing, there are many types of mutation operators. However, the objective of applying the operator is always the same: to introduce the modification into sequences in order to cause the initiation of searching the space of solutions with use of the genetic algorithm in new areas, that haven't been studies yet [Knosala 2002]

Apart from two principal genetic operators, there are also a big number of other operators, for example compression [Michalewicz 1996, Goldberg 1995, Knosala 2002].

When all necessary operations on coded sequences are made, the newly formed set of sequences creates an absolutely new generation. The work of the algorithm can be finished, when the mean of the function of the objective next generations do not differ from each other [Knosala 2002].

Because of the essence of its functioning, each genetic algorithm for every individual problem must enclose following elements [Michalewicz 1996, Arabas 2001, Cytowski 1996]:

- Principal representation of potential solutions of the problem,
- Method of creating the initial population of potential solutions,
- Function of evaluation, which has the role of the environment and it assesses solutions,
- Principal operators that affect the composition of the children-population,
- Values of different parameters used in the genetic algorithm (the size of the population of the probability of using genetic operators)

The basic difference between genetic algorithms and other techniques lays in the view on the process of evolution. Genetic algorithms focus on the evolution of individual units, while other techniques stress the importance of the population's evolution out.

Simple genetic algorithms don't provide solution to certain sort of problems. This involves among others the constant length of the DNA chain. Therefore, there have been introduced an extension of the genetic algorithm, which was named ESGA.

Genetic algorithms have both strong and weak sides. Their advantages are as follows [Haupt 2004]:

- they optimize with constant and discrete variables,
- they do not require derivative of the information,
- they simultaneously search a big sample,
- they handle a big number of variables,
- they optimize composite variables,
- they provide a list of optimum variables instead of individual solutions.

From the other side, their disadvantages are:

- lack of sensible criteria of stoppage,
- calculative complexity,
- we are never certain whether the solution we found is optimal.

Simulated annealing

The simulated annealing is another method for optimization. It was presented by N. Metropolis (co-originator of MANIAC and MANIAC II computers and one of authors of Monte Carlo methods) and others in 1953 and remained later by S. Kirkpatrick and others - in 1983. The method develops iterative methods, which were based on continuous upgrading the existing solution, until it reached the moment, when the solution could not be improved anymore [Łęski 2008].

The idea of the simulated annealing method comes from the statistical physics. It is based on the analogy the behaviour of materials, which are processes with a temperature that falls with a determined tempo. If freezing out is slow, the material aims at reducing its state of energy. However, if the freezing is fast, the material transfers into an amorphous structure, with energy state that is higher than previously. In other words: molecules of a liquid move freely in a high temperature. However, when the temperature falls, molecules begin to move the more and more slowly, and gradually they form an ordered structure - a crystal. This state is characterized with a minimum level of energy. Slow cooling down the system is the necessary condition for forming the cristalic liquid; otherwise molecules of the substance will not find the optimum localization and they will form themselves in a more chaotic structure [Metropolis and others 1953, Kirkpatrick and others 1983, Łęski 2008]

The basic formula used in termodynamics for describing the phenomenon presented above, which has been transferred to the described algorithm is as follows (formula 4):

$$P(E) \approx e^{\left(\frac{-E}{kT}\right)} \qquad (4)$$

where:

k is the Boltzman constant.

The minimized function of the criterion is an analogy of the state of energy of the material.

Physics quantity of the temperature is being replaced by a so-called *pseudotemperature*. In the simulated annealing, in the situation, when the material is being cooled down, its energy is generally reduced; however its temporal increase is accepted in order to leave the local minimum [Łęski 2008].

The method can be presented in a following way [Łęski 2008]:

1. We choose the initial value θ and the initial pseudotemperature T;
2. We choose Δθ on basis of the probability distribution given by a so-called *generation g function* (Δθ, T);
3. We calculate ΔJ = J(θ + Δθ) – J θ;
4. We accept θ ← θ + Δθ with the probability given by a so-called *acceptation* α *function* (ΔJ, T);
5. If there were made the assumed number of iterations for the temperature T, then we reduce the pseudotemperature T ← λT, where λ ∈ (0, 1);
6. If conditions of the alloy are not fulfilled, then we pass to 2); otherwise - stop.

The operation from the step 5, which is supposed to reduce the pseudotemperature, is called the *annealing schedule*.

The parameter of the algorithm which is affecting the probability of worse choice of the answer is the parameter transferred directly from thermodynamic basics of the algorithm, i.e. the temperature. In the beginning of the operation, the temperature is high, thanks to this fact the algorithm can change the solution configuration very often, choosing worse solutions frequently. Along with next iterations of the algorithm the temperature is dropping and better solutions are selected more and more often. In the end of the algorithm work the temperature is so low that the probability of making the worse choice is nearly equal none. Then, the algorithm behaves in the same way as a typical iterative algorithm and it tries to improve the solution to the maximum.

There is a type of Boltzman machine – called the Cauchy machine or, in other words, the algorithm of fast simulated annealing, in which the function of the generation is determined as (formula 5) [Szu and others 1987]:

$$g(\Delta\theta, T) = \frac{T}{(\|\Delta\theta\|^2 + T^2)^{\frac{p+1}{2}}} \qquad (5)$$

The literature presents it also as a so – called very fast simulated annealing.

In many practical situations the application of simulated annealing is not possible because of the computational effort related to the required annealing schedule. It is possible to present it in other words: in order to obtain the global minimum, it is necessary to reduce the pseudotemperature very slowly.

Tabu Search

The Tabu Search Method has been accepted by Glover and Hansen to be an efficient technique for solving composite problems of optimization. Just like genetic algorithms, the determined method has the ability to lead the method to the local searching, in order to avoid the weak local optimum.

The process of searching the space of solutions is being coordinated with strategies based on mechanisms of the memory, which characterize the TS algorithm.

Principal elements of the Tabu Search are [Bożejko and others 2010]:

- The environment - the sub-set of acceptable solutions;
- The motion - the function that transforms one solution into another;
- The Tabu List - the list that contains attributes of a certain number of solutions in question.

The main idea of the Tabu Search is to use the memory and remember solutions ore movements (changes). Along the course of search, it gathers information on researched space. Local choices depend on information gathered during the entire search. Basing on information recorded in the memory it forms limitations that protect the algorithm from coming back to areas of the space that have been already searched. These limitations depend from following aspects:

- The frequency of recording determined data,
- The timeliness of data recorded in the memory,
- The impact of determined data on the quality of results obtained in the method.

In its following interactions, the algorithm searches the nearest area around the solution that has been found - in order to determine the new localization of the current solution. Therefore, it has to be defined the relation of the neighborhood for all elements of the determined space, in which we search solutions.

The memory structure stores information concerning all realized transformations. It might contain also other information, like for example: concerning the frequency of these transitions in time that has passed after the realization of one of these transitions. There are two types of memory in TS algorithms: the sort-term memory (The short-term memory is being exploited in every iteration and it serves to remember solutions that have been visited lately; its main task is to prevent choosing the movement operator that might lead to the formation of a loop in the algorithm and blocking it in a very small space of research [Glover, Laguna]) and the long-term memory (It stores information on the course of the process of searching, it allows to remember best solutions from searched areas of the space, instead of keeping only the best solution from the current neighborhood [Glover, Laguna]). Each of them is used by strategies, which are characteristic for them. Effects of their functioning can be seen in the form of the modification of the neighborhood N(x) for the current solution x. The modified neighborhood N*(x) is the result of storing information concerning the process of searching that already took place [Glover, Laguna, Witczak 2010]

The Tabu Search Algorithm realizes fully the process of searching in the area of the nearest neighborhood of the current solution. The present solution is being replaced by a best solution in the neighborhood, even if this may cause the decrease of the level of quality. The process of searching uses the system of limitations put on the set remaining the part of the

neighborhood. It is supposed to prevent the occurrence of the possibility of forming a loop in the algorithm and returning to the same, narrow areas of solutions. Solutions which earlier were accepted as current answers are being removed from the defined neighborhood. This way, a so-called tabu set is being created. Limitations used in the Tabu Search Method have the form of an absolute interdiction or certain restrictions.
The author present below an exemplary procedure of the Tabu Search [Komosiński 2010]:

The Tabu Search Procedure:

```
begin
    INITIATE (zstart, xbest, T)
    x := xstart
    repeat
        GENERATE (V⊂N(x))
        SELECT (x') // best f in V + aspiration
        UPDATE TABU_LIST(T)
        if f(x') ≤ f (xbest) then xbest := x'
        x := x'
    until STOP CONDITION
end
```

It has been accepted to use following symbols:
T – tabu set,
V – list of candidates,
N(x) – neighbourhood,
f(x') – movement quality,
x – initial solutions,
xbest – accepting the solution x the be the best solution,

In the presented procedure we deal with the selection of the initial solution x, and next - with accepting it to be the best solution. In the set of candidates from the neighborhood we choose the best one, taking into account the tabu information. Then, we update the structure of the memory.

Methods presented in this chapter have many various types of the extension and alterations, which could constitute a subject of individual chapters. Presented information concerning heuristics is only very general and it is described in order to bring the problem closer to the reader. However, those, who are interested in the question, are invited by the author to check the literature and websites enumerated in the references.

SUMMARY

The QAP issue can be used in multiple real situations. One of first examples of its application was placing buildings in the university campus. This application has been described with details by J. W. Dickey and J. W. Hopkins. It has been named "campus planning model" and it was presented in the work Campus building arrangement using 8 TOPAZ in the year 1972. Its aim was to reduce the distance between buildings.

Next similar applications were: park planning (J. Bos Enviromental Management 1993), and the project of a hospital (Elshafei 1977). From the today's point of view, this problem can only be called historical. At present we use QAP for absolutely different and more complicated problems.

Issues from the reality, just like other methods of solving problems, also evolved. The problem of placing buildings in a campus has been replaced by the problem of placing keys on the keyboard or on the steering panel. The minimization of distance between most frequently used keys is the objective - this results with shorter time needed for writing a text. The problem has been presented in a model by M. A. Pollatschek, N. Gershoni and Y. T. Radday in their work Angewandte Informatik, presented in 1976. There are various similar evolutions of this problem, for example: localization of indicators on the steering board. In such case, the minimization encloses the distance between the most important and mutually related indicators.

Also the turbine runner problem has a very interesting application. Balancing the turbine of the engine is nature of this problem. Blades of the jet engine have different mass, these differences occur in the stage of production. The centre of gravity must agree with the pivot of the turbine. J. Mosevich used the QAP problem for this case and he has presented it in his work Balancong.

The QAP problem is still very difficult. Further progress and development in these areas will certainly lead to solutions for even more complex cases. Today, the majority of best solutions for large authorities in QAPLIB is obtained through metaheuristics.

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METODY WYKORZYSTYWANIA ROZWIĄZANIA QUADRATIC ASSIGNMENT PROBLEM

STRESZCZENIE. **Wstęp:** Kwadratowy Problem Przydziału (QAP) jest jednym z najciekawszych zagadnień optymalizacji kombinatorycznej. Został przedstawiony przez Koopmana i Beckamanna w roku 1957, jako matematyczny model lokalizacji niepodzielnych zadań. Problem ten należy do klasy zagadnień NP.-trudnych. Wymusza to stosowanie do jego rozwiązania metod przybliżonych już dla zadań o niewielkim rozmiarze (powyżej 30).
Mimo że jest ono znacznie trudniejsze niż inne zagadnienia optymalizacji kombinatorycznej, to cieszy się powszechnym zainteresowaniem, ponieważ modeluje ważną klasę problemów decyzyjnych.
Metody: Dyskusji poddano narzędzia sztucznej inteligencji, które pozwoliły rozwiązać problem QAP, między innymi są to: algorytmy genetyczne, Tabu Search, Branch and Bound
Wyniki i wnioski: Sam problem bezpośrednio nie powstał jako model pewnych działań, jednak znalazł on swoje zastosowanie w wielu dziedzinach. Przykładowymi zastosowaniami problemu jest: rozmieszczenie budynków na kampusie uczelnianym, projektowanie rozmieszczenia elementów elektronicznych w układach o wielkiej skali integracji (VLSI), projekt szpitala, rozmieszczenie klawiszy na klawiaturze.

Słowa kluczowe: QAP, problem kwadratowego przydziału, algorytm podziału i ograniczeń, algorytmy genetyczne, symulowane wyżarzanie, algorytm Tabu Search

QUADRATIC ASSIGNMENT PROBLEM (QAP) UND DESSEN ANWENDUNGSLÖSUNGEN

ZUSAMMENFASSUNG. Einleitung: Quadratic Assignment Problem (QAP) ist eine der interessantesten Fragen der kombinatorischen Optimierung. Dies wurde von Koopman und Beckamanna im Jahre 1957 als ein mathematisches Modell des Standortes der unteilbaren Aufgaben vorgestellt. Dieses Problem gehört zur Klasse der NP-schwierigen Fragen. Dies zwingt zur Anwendung einer auf das Näherungsverfahren für Aufgaben mit einer geringeren Größe (über 30) gestützten Lösung.
Obwohl die Lösung viel komplizierter als andere kombinatorische Optimierungslösungen ist, genießt sie ein großes Interesse, weil sie die wichtigste Klasse von Entscheidungsproblemen zu modellieren vermag.
Methoden: Die betreffenden Diskussionen konzentrierten sich auf den Werkzeugen künstlicher Intelligenz, die das QSP-Problem zu lösen erlauben. Dazu gehören unter anderem: genetische Algorithmen, Tabu Search, Branch and Bound.
Ergebnisse und Schlussfolgerungen: Die betreffende Lösung ist nicht als Modell für alle Tätigkeiten anzusehen, es findet jedoch seine Anwendung in vielen Bereichen. Beispiele für die Lösungsanwendungen sind brauchbare Werkzeuge für: eine optimale Anordnung von Gebäuden auf dem Universität-Campus, ein effizientes Entwerfen der Anordnung von elektronischen Komponenten innerhalb der Systeme mit hohem Integrationsgrad (VLSI), eine anwendungsfreundliche Anordnung der Tasten auf der Computer-Tastatur.

Codewörter: Quadratic Assignment Problem, Branch and Bound-Algorithmus, genetische Algorithmen, Simulated Annealing, Tabu Search-Algorithmus.

Izabela Kudelska
Institute of Engineering Management
Poznan University of Technology
Strzelecka 11 St, 60-966 Poznan, Poland
e-mail: izabela.kudelska@put.poznan.pl

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PRACTICE OF BUILDING PRODUCTION PLANNING SYSTEM OF COMPANY WITH A WIDE RANGE OF PRODUCTS - CASE STUDY

Łukasz Hadaś, Piotr Cyplik

Poznan University of Technology, Poznan, **Poland**

ABSTRACT. Background: The complexity of the manufacturing environments of today's mechanical engineering companies and the number of both internal and external restrictions affecting to need of building tailored production planning and control systems. This statement is particularly important in conditions of companies with a wide range of products and different customer service strategies (different locations of the logistics decoupling point otherwise called "order penetration point"). Streams of materials in these conditions require different management what is the main reason for carrying out research in business conditions by the authors.
Material and methods: The research was carried out in industrial engineering in complex environmental conditions of production. This was a specializing in technology, multi-departments environment, with multiple streams of values and a wide range of products (about 500 items). The work was carried out under the transformation of the production system from the "push" logic of flow to "pull" logic of flow and building a dedicated system based on the best practice approach.
Results: The paper describes the process of building tailored hybrid systems in the area of planning and shop flow control of production. The authors present the theoretical considerations on the issue and practical experiences. The authors present factors of selection of the transformation path and its road map. The article describes the part of the authors' own experience in the work on the methodology of transformation of Polish companies in the running business condition.
Conclusions: Establishing the methodology of transformation of the production system is not a simple task. This paper presents only selected aspects of complex decision-making process. However, the authors presented work shows the important aspect of the transformation of production systems for these organizational conditions.

Key words: production planning system rebuilding, decupling point: Make to Order (MTO), Make to Stock - Open to Buy (MTS OTB) and MTS Buffer.

INTRODUCTION

The complexity of the manufacturing environments of today's mechanical engineering companies and the number of both internal and external restrictions affecting to need of building tailored production planning and control systems. Among many known planning methods, the following should be mentioned [Encyclopedia of Production 2000, APICS 2008] the traditional Reorder Point (ROP) method, Manufacturing Resource Planning (MRP) or the Just-in-Time method with the Kanban operating tool. The MRP II system is considered an effective tool for aggregate production potential planning [Muhlemann et. al 1992, Orlicky 1975] and a source of information used in various functional areas of a company. In the flow of material streams, it works effectively as a manufacturing scheduling tool on the level of the main schedule. However, the considerable variability of schedules and wrong decisions on the volume of production batches and delivery batches affect the total level of stock and the potential is used. On the executive level, it is clearly more effective to control material stream flow using Just-in-Time [Liker 2003, Ohno 1995]. Thanks to its basic component in the area of manufacturing, the Kanban tool, work-in-progress inventory can be kept at low levels [Ohno 1995,

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Hadas and Domanski 2008] and ensures a pace of production suitable for the demand through the effective use of the pull flow logic. However, in real-life situations in industry, the effectiveness of the pull logic depends also on many factors shown in simulations [e.g. Kim et. al 2002, Huang and Kusiak 1998, Hopp and Spearman 2004].

The selection of an appropriate method for production planning and control depends on many parameters such as: the level of complication and variety of the products offered, production repeatability or market conditions, e.g. the nature and variability of demand [Hadas and Cyplik 2010, Hadas and Cyplik 2007]. Because each manufacturing environment differs much from another, there are no standard solutions that fully meet requirements on the operating level. Probably in each case of industrial practice, a process of developing tailored solutions is necessary, based on the general guidelines of established manufacturing planning and control systems. The reason for this is that the secret of the potential of manufacturing planning and control systems lies in specific solutions, usually developed or customized for the needs of the existing conditions. This is what tailored solutions are about, and what industry practitioners usually cannot adequately do.

In other words, the construction of tailored production planning and shop floor control systems is closely and directly connected to the needs of the industrial practice, identified in our consulting and research activities. We present a case study of a multi-department company with many value streams and a wide range of products manufactured in technological production structure.

CONSTRUCTION OF TAILORED PRODUCTION SYSTEM

Framework methodology for the construction of a tailored system

The purpose of the research was to search for the best solution for the manufacturing conditions under analysis. Within the research a methodology of constructing a dedicated system of planning and controlling the flow. The methodology used consists of the following sequence of operations (see the fig. 1). The first step is the analysis of the factors of choosing a system of planning and controlling the flow of production. At this stage the factors which influence the environment of a manufacturing system are defined. The next step includes independent analyses on the level of planning and the level of the flow of material streams (steps 2a and 2b). The purpose of these analyses is to select of the logic of planning as well as the logic of the flow for "the factors of choice" identified in the first step. In the next step the possibility and the operational way of integrating both layers (the planning stage and the stage of controlling the flow) should be determined. "The core of integration" which has been created constitutes the foundation of building a hybrid system.

The next fourth step is connected with using selected support tools. They support the realization of functions from the level of planning and the level of the flow. It is a level of so called horizontal integration, which is process integration in the chain of planning and the chain of a physical flow. In the fifth step the final structure of the model of an identified hybrid model is created.

The further developments of the model - the concept of a dedicated system are connected with the stage of its verification during the implementation and operational functioning.

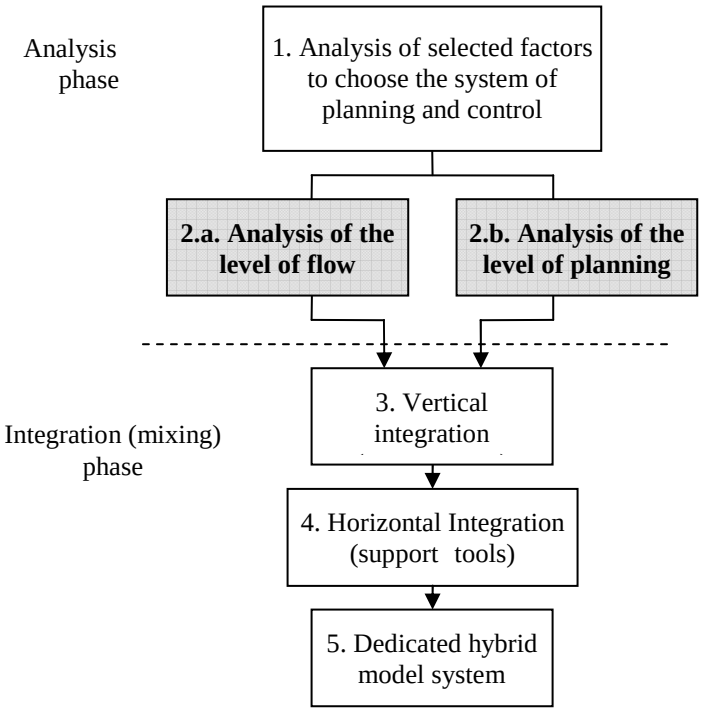


Fig. 1. Framework methodology of constructing a dedicated system of planning and shop floor control of production
Rys. 1. Ramowa metodologia konstruowania dedykowanego systemu panowania i sterowania przepływem produkcji

Description of the manufacturing environment - the place of the research

The work on the development of the tailored production planning and shop floor control system started with a thorough identification of the existing practices in the company. The discussed company's functioning can be described as traditional, with a hierarchical and centralized planning structure supported by an MRPII/ERP system. On the level of long-term planning (1 year), annual sales plans/forecasts are drafted to verify revenue and costs and to roughly balance the demand for output capacity in terms of machines and staff. On the level of medium-term planning (1-2 months), sales plans and confirmed orders are used to develop production and supply plans. In the short term, production is ordered to start in the foundry (the department beginning the production process). Orders are pushed along further departments (the push flow logic) all the way to the Assembly Department (where the final product is prepared to put on the market) or the processing department (orders for a partner in the supply chain). The planning of machine duties is tentative and the assignment of tasks to individual workstations is planned according to their technological profile.

In our analysis of the production planning and control system, we identified the following issues:

- on the long- and medium-term level:
  - low level of plan integration, both vertically (Management Board-Managers) and horizontally (supplies-production),
  - low level of the implementation of MRPII/ERP (marked C according to the ABCD Checklist),
  - low planning discipline (no clear process owner);
- on the short-term and running control level:

- numerous conflicts about resources,
- chaotic, spaghetti-like flow for the Processing Department,
- large batches,
- variability of production priorities.

In conclusion, the production system displayed significant instability in the duration of the production lead time. The variations in the production lead time were directly related with high (and expensive) level of work in progress both on the shop floor (in the process) and in inter-department storehouses. Under these circumstances, it was difficult to ensure a high logistics service level. The level of service essential for the Management Board from the perspective of the credibility of the supply chain was achieved at the cost of high levels of stock and expensive interventions in production plans (overtime work, priority changes, short batches).

A tailored planning system - framework transformation path

The changing of the company's production planning system took place in the following sequence:

- analysis of the possibility of shaping diagnosed organisational conditions,
- formulation of planning principles based on the Best Practice analysis,
- transformation of the planning system and physical flow based on the Lean production model,
- framework concept for system integration and its implementation.

In the first step, we identified the organisational situation of the company and discussed which of them could actually be changed. What turned out to be particularly important here were long-term customer relations and market characteristics (e.g. the occurrence of the end-of-the-month syndrome and its effect on the method of planning). In the next step we formulated the principles of planning for the company by reviewing Best Practices in production logistics and supply chain management. The key conclusions here are the following:

- the pull logic in planning allows for better control of flow in the links of the process,
- information on demand should be shared along the entire chain of the process, the moment something pertinent happens at any of its links,
- the location of the decoupling point should be specified based on market requirements (Customer Tolerance Lead Time and demand characteristics).

At a further remove, these were used as the leading principles for the construction of the tailored planning system. The basic direction of the transformation included the modification of the MRPII planning logic (so far operating unsatisfactorily) and the push flow logic (see fig. 2.). On the diagnostic stage, it was established that the MRPII computer system operates on a low implementation level (class C according to the ABCD Checklist), a decision was made to use the existing application for handling orders and planning demand for components, or to function according to the MRP logic.

The balancing of potential in a long-term perspective was entrusted to integrate planning in the form of Sales and Operation Planning. S&OP took over the role of MRPII, supporting decisions on such areas as liquidity, human and machine resources balancing and supply function planning. On the executive level, the main aim was to increase the flow intensity by the practical implementation of the flow and pull lean production steps.

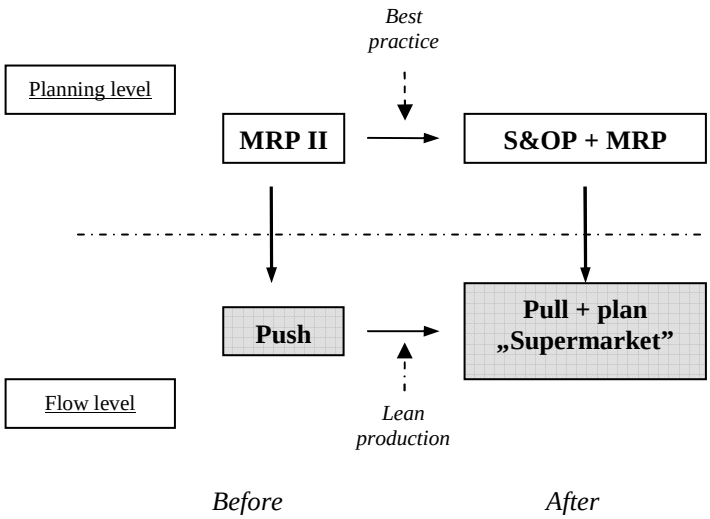


Fig. 2. The direction of transformation of the production planning system
Rys. 2. Przyjęty kierunek transformacji systemu planowania produkcji

Implementation in running business conditions - specific modification of solution

On the level of planning, the activities started with the modification of the existing MRPII planning logic in the ERP system. The principles for the construction of an S&OP integrated plan were developed. The S&OP team members were selected as well as information input and output, manner of information processing and the procedure for information approval and distribution. Based on such market conditions as:

- the volume and regularity of demand for a given group,
- key accounts (long-term contracts),
- the accuracy of forecasts or conditions for the maintenance of emergency stock,
- and the policy of product range development,

all 500 items in the sales plans were divided. The following categories were distinguished: Engineering to Order (ETO), Assembly to Order (ATO), Make to Stock - Open to Buy (MTS OTB) and MTS Buffer. The categories were located in the S&OP based on contracts and forecasts (production capacity reservation). The ready S&OP model was then embedded in the existing ERP system. The implementation process was finished by developing procedures for the planning of volume and monitoring of monthly buffers for MTS OTB and MTS Buffer, the development of a seasonal stock taken into consideration.

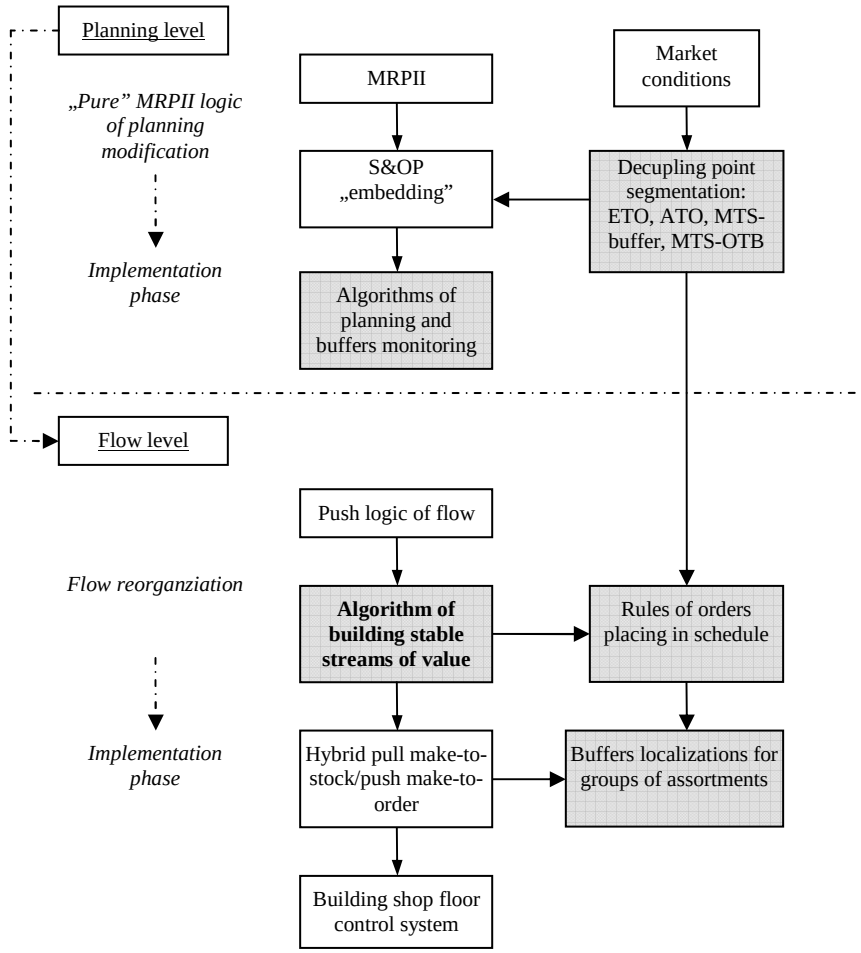
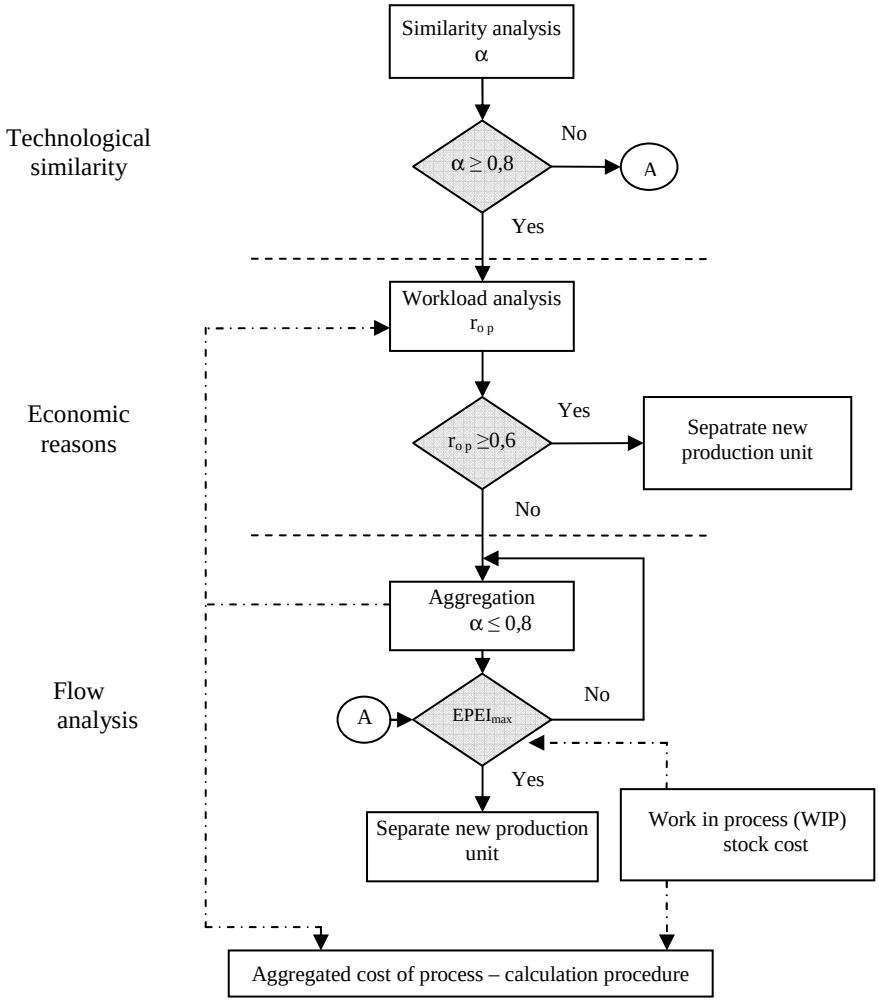


Fig. 3. The process of the transformation - sequence and critical decision
Rys. 3. Proces transformacji - sekwencja oraz krytyczne decyzje

On the level of flow, the reorganization started with the transformation of the push logic of flow into a flow initiated by demand of links down the stream of value. The framework methodology of the activities involved: the identification of value streams, creation of continuous flow and the introduction of principles for the initiation of pull flow. The reorganization was conducted using an original algorithm for establishing production units for the benefit of stable value streams (see Figure 4.). In the design of the algorithm, we considered the existing organisation of the Processing Department: the spaghetti-type flow, the range of products (500-700 items in the sales plan) and the volume and repeatability of orders. The analysis of technological similarity [Domanski and Hadas 2008] and the volume of works showed that it is impossible to build stable streams of value in line with the Lean philosophy.



α (alfa) – similarity coefficient
r_{op} – average load for each group of machines
$EPEI_{max}$ – every part every interval (maximum value)

Fig. 4. Manufacturing unit separation algorithm for building stable streams of value
Rys. 4. Algorytm wydzielania jednostek produkcyjnych w procesie budowy stabilnych strumieni wartości

It was here that the decision essential from the point of view of the future planning system was made. A system based on the Pull Make to Stock logic was selected instead of one based on the Pull Make to Order logic. The establishment of production units was essential to facilitate planning sequence and the control of the production cycle. It was decided to establish production units (see Fig. 4.) with the maximal possible duties (economical reasons) without a dramatic effect on the duration of the production lead time (analysis of aggregated EPEI). This was necessary to maintain an acceptable level of inter-departments buffers in the production process.

In the next step, market conditions contained in the ETO, MTS-buffer etc. categories were "crashed against" the developed organisation of material stream flow. The outcome is a mixture of the Pull Make-to-Stock/Push Make-to-Order systems. Then, the location of buffers was defined for each product group and specific procedures for production flow control were developed.

The final form of the planning and shop flow control system

The final form of the planning and shop flow control system is the result of the initial concept (transformation according to the Lean philosophy) having been significantly modified in consequence of encountered restrictions, however without losing the purpose of the transformation.

On the level of planning, the system transformed from a classic hierarchical planning in line with the MRPII logic to an S&OP model with MRP algorithm material planning. The model covered 18 months with a one-month planning accuracy. The system became the basis for liquidity analysis and long-term balancing. What changed on the level of operational planning and flow control were information feeding and the sequence of initiating tasks. Order execution priorities were redefined for product groups. On the executive level, logic of buffer renewal was introduced in 1-2 week cycles (depending on product group) as well as the principles for the optimization of retooling sequences in the event of non-rhythmic production. As mentioned above, here the system took on the form Pull Make-to-Stock/Push Make-to-Order. However, for product groups covered by the Pull Make-to-Stock solution, different mechanisms of initiating tasks were adopted. For the MTS-buffer category, this was the classic buffer penetration mechanism. It needs to be noted that in the Assembly Department, the buffer penetration mechanism was physically implemented by means of a supermarket and in Processing Departments by means of control of work-in-progress stock. The MTS-OTB category featured a "plan like supermarket" mechanism; in this mechanism, the collection from buffer in a period of one week is at the same time the weekly task for the preceding link (which does not wait for actual physical collection). This solution allowed for reducing the level of inventory at inter-departments work-in-progress buffers and for optimizing the sequence of works within a weekly task. Both issues are important as, if successful, they contribute to the aim of shortening and stabilizing lead time. In a situation when it is impossible to build a one-piece flow-type, this is the alternative way to achieve the aim.

The construction of a tailored solution with such varied solutions raises many questions concerning how reasonable it is to apply many practices and to modify them under the specific circumstances. Some issues worth mentioning here are the unorthodox character of the principle of production leveling or the need to monitor the lengthening the production cycle depending on machine duties. During the transformation, we identified the influence of establishing production units (for highly variable works) on the production cycle and the buffers controlling the pull mechanism.

CONCLUSION AND FUTURE RESEARCH

In any case, the development and implementation of a hybrid planning and shop flow control system is not an easy task. An operation on the living organism of a manufacturing company always involves many issues which cannot be predicted at the conceptual stage. The designing of the development path for a company and, what follows, the direction of its transformation, turn out to be a task that practically can only be done in a tentative manner, i.e. on the level of aims, framework solutions and measurement methods. The practice of implementing at a very early stage of preliminary calculations verifies the applicability of individual solutions or the classic sequence described in the literature of the subject. It is necessary to mark out your own, flexible path for transformation. In the discussed case the idea for the construction of a MRP/JIT hybrid system evolved from the classic Lean path to a fully tailored way of implementation. The final solution itself also took on the form of quite a specific hybrid, which, however, turned out to be the most reasonable from the point of view of the existing and forecast (for a perspective of 3 years) internal or market restrictions.

In conclusion, it should be noted that the final system is not static. It will evolve as a consequence of both continued B+R activities within the company and the changeability of the market environment. Currently, work is in progress on the definition of the audit cycle for critical aspects of the functioning of the planning and control system. Both time and merits-based range of the audit will be specified. The purpose of this cyclical schedule for monitoring the system is to prevent the effect of inert drifting, typical of many transformations.

The research work is aimed at creating a general methodology for the selection, implementation and evolutional shaping of the planning and shop flow control system. This methodology should limit the probability of taking the wrong way in the transformation, increase the effectiveness of implementation and overcame the inertia to the existing system (based on the measurement of the

"hard" parameters). The practice of enterprise transformation shows that there is a need for such methodology as much of the work done ended in failure. The main causes of this failure are the following: selection of a wrong way of transformation, wrong selection and modification of tools on the operational level and the inertia of the system once implemented.

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PRAKTYKA BUDOWY SYSTEMU PLANOWANIA PRODUKCJI PRZEDSIĘBIORSTWA O SZEROKIM ASORTYMENCIE PRODUKOWANYCH WYROBÓW - STUDIUM PRZYPADKU

STRESZCZENIE. **Wstęp**: Złożoność środowiska produkcyjnego dzisiejszych przedsiębiorstw z branży budowy maszyn oraz istniejąca liczba wewnętrznych i zewnętrznych ograniczeń funkcjonowania wpływa na potrzebę budowy dedykowanych systemów planowania przepływu produkcji. Stwierdzenie to jest szczególnie ważne w warunkach firm z szerokim asortymencie produkowanych wyrobów oraz różnych strategiach obsługi klienta (różnych lokalizacjach logistycznego punktu rozdziału). Strumienie materiałowe w takich warunkach wymagają odmiennego sposobu zarządzania, co jest głównym powodem prowadzenia badań przez autorów w tym zakresie.

Metody: Badania przeprowadzono w przedsiębiorstwie budowy maszyn o złożonej wielowydziałowej strukturze produkcyjnej. Celem prac było usprawnienie przepływu produkcji w warunkach szerokiej gamy produktów (ok. 500 pozycji) tworzącej kilkadziesiąt strumieni wartości oraz różnych wymagań rynkowych co do czasu i poziomu obsługi klienta w odniesieniu do poszczególnych grup asortymentowych.

Wyniki: W artykule opisano proces budowy dedykowanego systemu zarządzania przepływem produkcji. Autorzy przedstawiają krótkie teoretyczne rozważania na temat problemu oraz zdobyte doświadczenia praktyczne. Autorzy przedstawiają czynniki wyboru ścieżki transformacji systemu planowania produkcji, na podstawie diagnozy stanu obecnego, jej ramowy algorytm oraz wybrany aspekt wydzielania strumieni wartości o rożnych strategiach obsługi klienta (różnych lokalizacjach logistycznego punktu rozdziału).

Wnioski: Wypracowanie metodyki transformacji systemu produkcyjnego nie jest zadaniem prostym. Niniejszy artykuł przedstawia tylko wybrane aspekty złożonego procesu decyzyjnego jaki towarzyszy pracom nad transformacją systemu zarządzania przepływem produkcji. Niemniej autorzy artykułu kreślą obszar ich dalszych badań inspirowanych potrzebą praktyki przemysłowej.

Słowa kluczowe: Rekonfiguracja systemu produkcyjnego, logistyczny punkt rozdziału: Make to Order (MTO), Make to Stock - Open to Buy (MTS OTB) and MTS Buffer.

PRAKTISCHER ANSATZ ZUM AUFBAU EINES SYSTEMS FÜR PRODUKTIONSPLANUNG IM UNTERNEHMEN MIT EINEM BREITEM SORTIMENT VON HERGESTELLTEN ERZEUGNISSEN

ZUSAMMENFASSUNG. Einleitung: Komplexität des Produktionsumfeldes in heutigen Maschinenbauunternehmen sowie Bestehen von inneren und äußeren Funktionseinschränkungen beeinflussen heutzutage die Notwendigkeit des Aufbaus von detektierten Planungssystemen innerhalb der Fertigungsströme. Diese Feststellung ist besonders wichtig für die Firmen mit einem breiten Sortiment von hergestellten Erzeugnissen und den verschiedenen Kundenservice-Strategien (mit verschiedenen Standorten des logistischen Verteilungspunktes). Gerade in solchen Bedingungen bedürfen die betreffenden Materialflüsse eines anderen Managements, was als Hauptursache der von den Autoren in diesem Bereich betriebenen Forschungen anzusehen ist.
Methoden: Die einschlägigen Forschungen wurden im einem Maschinenbauunternehmen von einer Mehrbereich-Produktionsstruktur durchgeführt. Das Ziel der Arbeit war es, den Produktionsfluss bei einer reichen Produktpalette (ca. 500 Positionen), die mehrere Wertschöpfungsströme bei unterschiedlichen Marktanforderungen bezügl. Zeit und Kundenservice-Niveau angesichts der einzelnen Sortimentsgruppen bilden, zu vervollkommnen.
Ergebnisse: Im Artikel wurde der Prozess des Aufbaus des detektierten Produktionsfluss-Managementsystems dargestellt. Die Autoren setzen sich theoretisch mit diesem Problem kurz auseinander und stellen die in der Wirtschaftspraxis gewonnenen Erfahrungen vor. Sie zeigen aufgrund der Diagnose des gegenwärtigen Zustandes Faktoren für die Auswahl des Transformationspfades für die Produktionsplanung und dessen Rahmen-Algorithmus sowie den ausgewählten Aspekt für die Abgrenzung der Wertschöpfungsströme mit verschiedenartigen Kundenservice-Strategien (mit verschiedenen Standorten des logistischen Verteilungspunktes) auf.
Fazit: Die Ausarbeitung einer Umsetzungsmethodik für Produktionssysteme stellt eine anspruchsvolle Aufgabe dar. Der vorliegende Artikel setzt sich lediglich mit ausgewählten Aspekten des Entscheidungsprozesses, der die Unternehmungen bei der Transformation des Managementsystem des Produktionsflusses begleiten, auseinander. Gleichwohl zeichnen die Autoren hiermit den Bereich der weiteren betreffenden, seitens der Industriepraxis inspirierten Forschungen ab.

Codewörter: Rekonfiguration des Produktionssystems, logististischer Verteilungspunkt: Make to Order (MTO), Make to Stock - Open to Buy (MTS OTB) and MTS Buffer.

Łukasz Hadaś, Ph.D. Eng.
Faculty of Engineering Management
Poznan University of Technology
e-mail: lukasz.hadas@put.poznan.pl
Piotr Cyplik, Ph.D. Eng.
Faculty of Engineering Management
Poznan University of Technology
e-mail: piotr.cyplik@put.poznan.pl

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THE INFLUENCE OF LOGISTICS POTENTIALS ON BUSINESS MANAGEMENT

Rafał Matwiejczuk

Opole University, Opole, **Poland**

ABSTRACT. Background: Logistics is more and more often perceived as an integrated potential of changes in a business management system. Among the particular potentials, the key importance is assigned to logistics resources, capabilities, and particularly competences.
Methods: The article points at exploitation of possibilities of logistics potentials in achieving desired changes in business management and reaching desired market and economic effects by a company. Except for literature studies, empirical research has been conducted in 111 companies operating in Poland.
Results and conclusions: Research results have shown several symptoms of logistics influence on business management system. The significance of logistics potentials in business management system capacity development has been partially confirmed. Due to logistics potentials, the company can be more effective and efficient in reaching expected market and economic outcomes.

Key words: logistics, potentials, competences, management, effects.

INTRODUCTION

Companies are constantly searching for new solutions enabling them to get competitive advantage. Getting such advantage often requires changes in business management systems and processes. Among the concepts which have been recently developed, an important role in starting the desired changes in business management is assigned to Competence-Based Management (CBM) widely described in the literature [Enders 2004; Heene, Martens, and Sanchez 2008; Javidan 1998; Ljungquist 2007; Ljungquist 2008; Martens, Heene, and Sanchez 2008; Prahalad and Hamel 1990; Sanchez 2008; Sanchez and Heene 2004; Sanchez and Heene 2005; Sanchez and Heene 2010a; Sanchez and Heene 2010b; Srivastava 2005]. CBM concept is often related to two other similar concepts - Resource-Based View [Barney 1991; Barney and Arikan 2001; Barney and Clark 2007; Chmielewski and Paladino 2007; Grant 1991; Newbert 2007] and Dynamic Capabilities Concept [Eisenhardt and Martin 2000; Helfat et al. 2007; Teece, Pisano, and Shuen 1997; Teece 2009]. Resources, capabilities and competences may be considered as so called "business potentials". These potentials may create possibilities for targeting desired market and economic outcomes ("effects"), conditioning getting and maintaining competitive advantage. However, it requires appropriate changes in business management system.

Logistics and particularly logistics competences may be located among the "areas" which can significantly influence and shape the changes in business management system. Logistics competences as "change determinants" (i.e. determinants of change, factors influencing change) in business management facilitate getting planned market and economic effects more efficiently and more effectively. In the recent years logistics and supply chain competences have been the subject of many

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research projects. Among them the most important and significant are: research carried out at Michigan State University (USA) with Council of Logistics Management (at present: Council of Supply Chain Management Professionals) [The GLRT at Michigan State University 1995; 21st Century Logistics: Making Supply Chain Integration A Reality 1999], research of European Logistics Association with cooperation of A.T. Kearney [ELA and A.T. Kearney 1999], as well as research of such consulting companies as Computer Sciences Corporation (CSC 2008).

A large number of significant research projects dealing with logistics and supply chain competences have been conducted in many countries. One of such projects is research whose major goal is to attempt to evaluate logistics and its competences influence on changes in business management area, conducted recently in Chair of Logistics and Marketing at Opole University, Poland. The aim of the article is to exploit the possibilities of logistics potentials in achieving changes in business management and, as a consequence, reaching desired market and economic effects by a company.

RESOURCES, CAPABILITIES AND COMPETENCES AS POTENTIALS OF CHANGE IN BUSINESS MANAGEMENT

Business potentials and their influence on changes in business management - basic assumptions

A natural way of company behaviour is aspiration to reach a market success. One of the most superior symptoms of such success is company competitive advantage. Superior indicators of market success are desired market and economic outcomes. Trying to achieve competitive advantage and market success companies are supposed to create and employ a large number of changes in their management systems and processes. The reality of these changes depends on so called "business potentials". A general framework of the study, involving relationships among potentials, changes in management system and success symptoms is presented in figure 1.

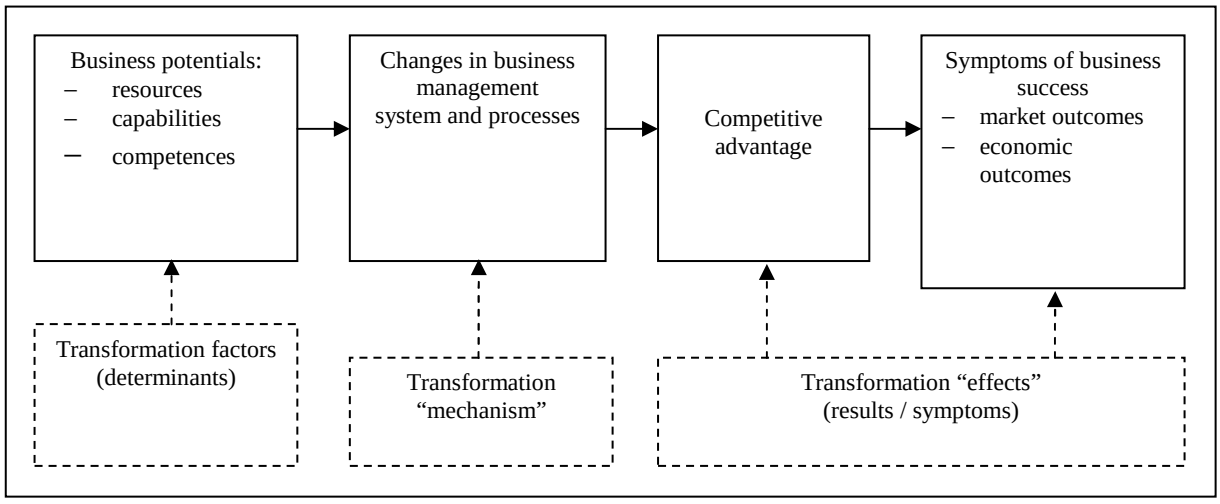


Fig. 1. A general framework of the study
Rys. 1. Ogólny schemat pracy

In general, a company achieves market success when it reaches planned and desired market outcomes (for example: market share, customer satisfaction, customer loyalty) and economic outcomes (for example: profit, profitability, ROE, ROA, ROI) [Day and Wensley 1988]. Apart from outcomes ("effects"), one may distinguish so called success factors, which are potentials that determine achieving desired outcomes by a company ("effects potentials"). When a company achieves

market success it means that the company reaches desired outcomes. Therefore, sometimes the categories of "effects potentials" and "success potentials" are used interchangeably or in the form "effects and success potentials".

Gälweiler [1987] defines a strategic potential of effects (outcomes) achievement as a general structure of all product-market premises important to company success. The success is related to getting long-term profits, ensuring desired customer benefits level and obtaining other strategic business goals. Premises important to getting desired outcomes and business success are also "hidden" in specific business functions and systems. Potentials of desired outcomes defined at strategic level may be considered as a source of long-term business market success. Such potentials present particular business capabilities and company readiness to reach goals more efficiently and more effectively than its competitors. Then, the capabilities can create conditions and a "basis" for efficient and effective operations.

Göpfert [2000] claims that effects potentials may be described as company capabilities creating the possibility of competitive position improvement. These capabilities give a basis for potential competitive position improvement and - according to Göpfert - they are long-term sources of benefits. In order to "make real" the long-term competitive benefits connected with effects potentials, it is indispensable to use them consciously.

Mikus [2003] defines effects potentials as entirety of all significant premises for future execution of expected effects, related to cross-sectional areas. Apart from effects potentials, the author also distinguishes factors (determinants) of effects. The determinants are understood as particular, less aggregated, and more specified effects premises - tangible and intangible resources and competences fulfilling the role of direct premises of reaching effects.

A little different point of view is presented by Pümpin [1986]. He uses the term "success potentials". Pümpin sees success potentials not so much as capabilities and premises in important areas of business success, but as premises of strategic success position and related benefits, which derive from competition. In other words, he means conscious desire to reach conditions ensuring competitive advantage by a company, and also ensuring long-term superior performance. Pümpin endeavours in his concept to identify a company position on the market as well as a company competitive position.

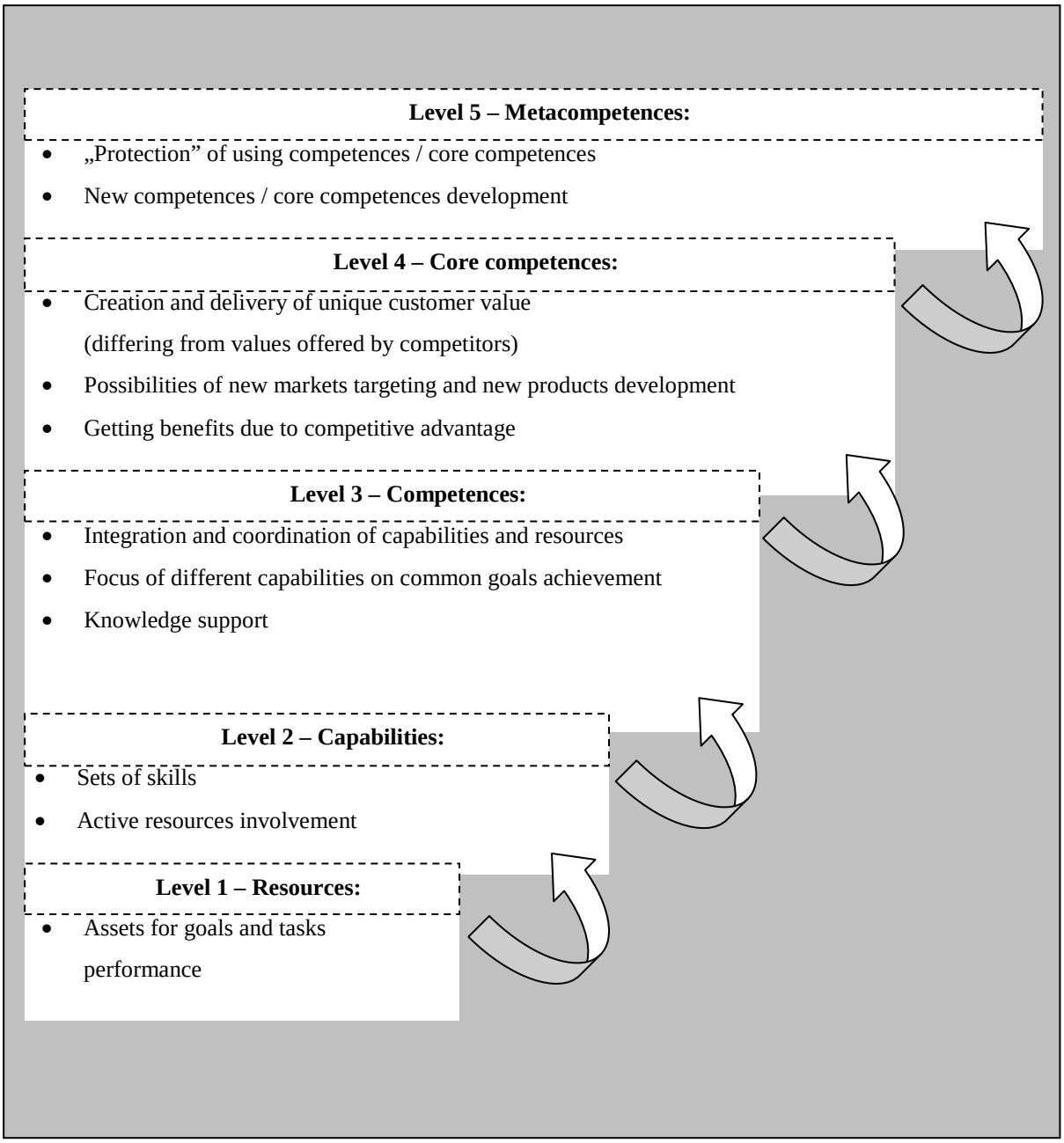
Some authors use alter interchangeable notions in relation to effects and success potentials, such as "success factors" or "benefits sources", used for example by Pfohl [1994]. In his opinion, these notions mean business capabilities for doing something better than the competitors, or maybe capabilities and resources due to which the companies have achieved competitive advantage. According to Pfohl, they are business success factors, defined on basis of comparative research.

From resources and capabilities to competences

In Resource-Based View in relation to resources two essential issues are emphasized. Firstly, attention is paid to resources strategic meaning in realization of goals facilitating competitive advantage achievement. Secondly, the necessity of business adequate capabilities of using owned resources is emphasized. Since resources value depends not only on themselves (for example their economic value or market value), but on business capabilities (sets of skills owned by a company) of using the resources in creating development strategic directions as well as implementing strategies that condition competitive advantage achievement on the market. Competitive advantage achievement which is based on resources requires, among others, defining ways and techniques of superior value creation. In this view, resources are perceived as tangible and intangible assets which are inputs in the value creation process, whose result is to realize value for a customer and value for a company [Grant 1991].

Then, it may be said that resources are fundamental "drivers" of customer created and delivered value in form of market offer (specific products and services). Due to offering the customers values that meet their expectations, a company realizes its own value in the form of sales revenue. All the more, resources are some business "values", which make it possible to use market services for getting and/or enriching benefits as to competitiveness [Mikus 2003].

Not all resources play the same role in creating business competitive advantage. Resources which are potentially sources of durable, long-term competitive advantage are often referred to as "key resources". Key resources may be discussed when they meet the following criteria: [Barney 1991]: (1) they are valuable, (2) rare, (3) imperfectly imitable and (4) they do not have substitutes.



Source: Based on Mikus 2003; Prockl 2007; Teece, Pisano, and Shuen 1997; The GLRT 1995.

Fig. 2. Hierarchy of business potentials
Rys. 2. Hierarchia potencjałów biznesowych

In the light of the above consideration it may be said that, on one hand, resources "secure" business long-term activities (including its survival). On the other hand, they determine efficient and effective goals achievement. The fundamental function of resources is to make it possible for a company to achieve such market and economic outcomes as customer satisfaction, customer loyalty, market share or profitability. When the business capabilities and competences develop, its widely understood potential of expected effects, competitive advantage and business success grows. Thus, resources may

be treated as a basis for company potential development, and simultaneously as a lowest level in the hierarchy of its potentials, indispensable for creating specific capabilities, and - in consequence - specific competences, which "span" on business resources. Resources, capabilities and competences compose a specific "business potentials hierarchy", in which the highest level is assigned to core (key) competences and so called metacompetences (see figure 2).

Considering relations between business resources and its capabilities, it may be assumed that the resources are sources ("roots") of business capabilities development. Then, business capabilities are oriented at using business resources as sources of its competitive advantage [Mikus 2003]. Capabilities may be defined as repeated patterns of actions connected with resources use in creating, production and/or offering products on the market [Daugherty et al. 2009]. Then capabilities can be referred to as "sets" of business skills in gathering, integrating and exploiting resources in order to reach by a company desired market and economic effects (outcomes) and competitive advantage as well.

The key importance in getting competitive advantage is often assigned to not so much and/or only specific business capabilities but to its competences. It may be said that business competences "emerge" out of its capabilities, creating premises for more efficient and effective commitment and exploitation of resources in expected market and economic effects execution.

Competences are sets of business capabilities ensuring coordinated resources exploitation that leads to company goals achievement [Sanchez and Heene 2004]. Competences result from resources and capabilities integration. These resources and capabilities should be committed to tasks performance in accordance with established goals. A basis for capabilities development is business resources. Yet, a basis for competences development is first of all business knowledge as a specific type of resources [Prockl 2007]. Fundamental indicators of the notion "competences" are integration and coordination. Then, business competences result from interfunctional integration and coordination of capabilities relating to specific resources and processes (sets of activities). These resources and processes may be considered in a business scope, as well as in the entire value chain scope [Javidan 1998]. Business resources and capabilities of their exploitation are often related to different functional areas within the company. Therefore, the condition for resources efficient and effective exploitation is proper integration of varied capabilities in the form of precisely defined competences (sets of competences).

Business competences are also defined as a set of capabilities that make it possible to achieve long-term and coordinated resources and skills exploitation. Such exploitation conditions and stimulates assumed business goals achievement [Sanchez 2001, Sanchez 2004]. Because of this, reaching desired market and economic effects that condition competitive advantage achievement, a key role, together with business resources and capabilities integration, is assigned to their proper coordination.

Core competences

A special type of business competences are core competences. They may be described as innovative "bundles" of knowledge, superior capabilities (sets of skills), proper technologies, information and unique operational methods. As a result of their exploitation, a product (value created and delivered to a customer) may meet a customer preferences and expectations [Boguslauskas and Kvedaravičien 2009].

Core competences are superior business potentials which ensure strategic market and economic effects achievement. These competences come into being on the verge of business resources, processes (sets of activities) and capabilities (sets of skills). Core competences make it possible to develop innovative, different from the competitors and difficult to imitate ways of behaviour leading to customer value creation. These are such types of competences which facilitate getting long-term benefits from competitive advantage (achieving and maintaining the advantage) as well as lasting superior competitive position.

Metacompetences

Apart from core competences among superior business potentials, one may also point at so called metacompetences. Mikus describes metacompetences as superior competences allowing a company to create, develop, exploit and verify already owned competences / core competences [Mikus 2003]. Metacompetences are not only on the top of resources, capabilities and competences hierarchy, but are

also connected with: (1) possibilities of long-term development of competences / core competences, (2) security and stimulation of such a development, as well as (3) development of complementary competences / core competences owned by supply chain partners. It can be stated that metacompetences are "formed mechanisms" which firstly secure present competences / core competences maintenance, and secondly make it possible for a company to develop new competences / core competences.

Apart from Mikus' suggestion of distinguishing competences, core competences and metacompetences, following Zahn, the subject literature offers other ways of competences classification and hierarchy. Bucholz and Olemotz for example distinguish two groups of competences: basic competences (involving competences oriented at whole company, specific processes carried out by a company and metacompetences as sets of learning capabilities) and core competences. In turn, Krüger and Homp present two "sections" of competences distinction: the first includes competences of the first, second and third tier, and the second comprises basic competences, metacompetences and core competences [Mikus 2003].

LOGISTICS AND ITS COMPETENCES AS CHANGES DETERMINANTS IN BUSINESS MANAGEMENT SYSTEM

Logistics potentials of business success

Recent years have seen progressing permanent growth of logistics significance as a determinant of efficiency and effectiveness increase and business success achievement. Strategic decisions in the field of logistics and supply chain management (SCM) can significantly contribute to systematic discovery and creation of new potentials of desired effects and business success [Blaik 2010]. Sennheiser and Schnetzler [2008] define logistics potentials of effects as specific capabilities and resources in logistics (relatively SCM) field, which a company is able to exploit in the long run, and/or develop further, aiming at getting lasting, significant, superior effects in relation to logistics.

Therefore, it can be said that logistics potentials of business success are long-term capabilities ensuring superior customer value creation and superior customer service. Such potentials: (1) require changes in management system and processes determining desired business effects, (2) condition achieving and maintaining competitive advantage, as well as (3) stabilize and reinforce business competitive position.

Logistics potentials of business success, as key strategic categories, apart from strategic dimension, are also characterized by normative and operational dimensions. Correlation with operational level of management reveals in practical and effective exploitation of potentials by a company. Bleicher [1995] points at connection between potentials normative and strategic dimensions, and he introduces additional category of "benefits potentials", formulating the relation "from benefits potentials to business success potentials". Strategic potentials of success are then a specific expression of normative potentials of benefits for a specific time-period of strategic planning. Possibilities of logistics potentials of business success exploitation depend on the span and range of indispensable changes in management system and processes. These changes may result from logistics and its competences.

Nature and significance of management logistics determinants

As discussed earlier in the article, permanently growing role of logistics may be a result of its crucial influence on changes in business management systems. The changes contribute to achieving greater market and economic benefits by companies. Logistics in its newest concepts is a "systemic determinant of business management" [Blaik 2010], conditioning and stimulating many crucial changes in specified management subsystems: planning, organizing, motivation and human resource management as well as controlling. The changes also involve fundamental component elements of management concept (that is: strategic analysis, goals, strategies and instruments) as well as management levels (normative, strategic and operational) (see figure 3).

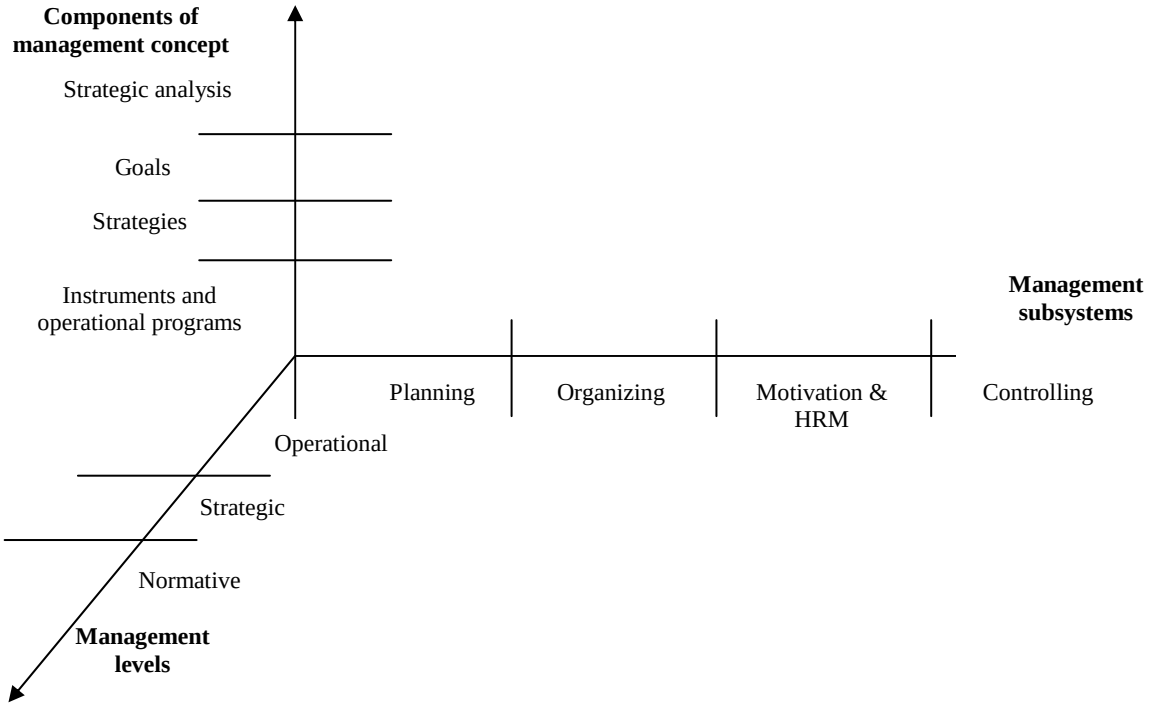


Fig. 3. Basic dimensions of business management system
Rys. 3. Podstawowe wymiary systemu zarządzania biznesowego

Logistics competences as sets of capabilities oriented at long-term and coordinated exploitation of company logistics resources and skills may be useful in execution of assumed goals and achievement of desired market and economic effects. Then, the competences create premises for changes emergence in business management system and its subsystems. Proper business competences may contribute to efficient and effective business market problems solutions as far as market challenges are concerned. The challenges involve customers' preferences and expectations changes, competitors' and market partners' ways of behaviour, technology development, ecological consciousness, etc.

Real influence on changes in management system may exert logistics determinants, seen as factors influencing the changes, developing the changes, and stimulating or limiting the scope of the changes. So, generally speaking, such determinants cause the desired changes in the business management system and its subsystems. Logistics determinants of business management are characterized by three fundamental features:

- They influence changes of forms, parameters, features and/or structure of "object" on which they have an effect (for example management system),
- They form and determine desired change directions of the object and its parameters, features and structure,
- They generate expected effects of changes (market and economic outcomes).

On one hand, logistics determinants of business management determine desired directions of changes related to business management system and its subsystems. On the other hand, they lead to achieving expected market and economic effects (outcomes) by a company. The function of management determinants is to cause such changes in business management system which lead to growth of total benefits achieved by both the customers and companies.

Logistics determinants of business management may have direct or indirect influence on changes in management system. We are speaking of direct influence when the determinant has an effect on changes in management system or any of its subsystems which directly follow the effect. For example,

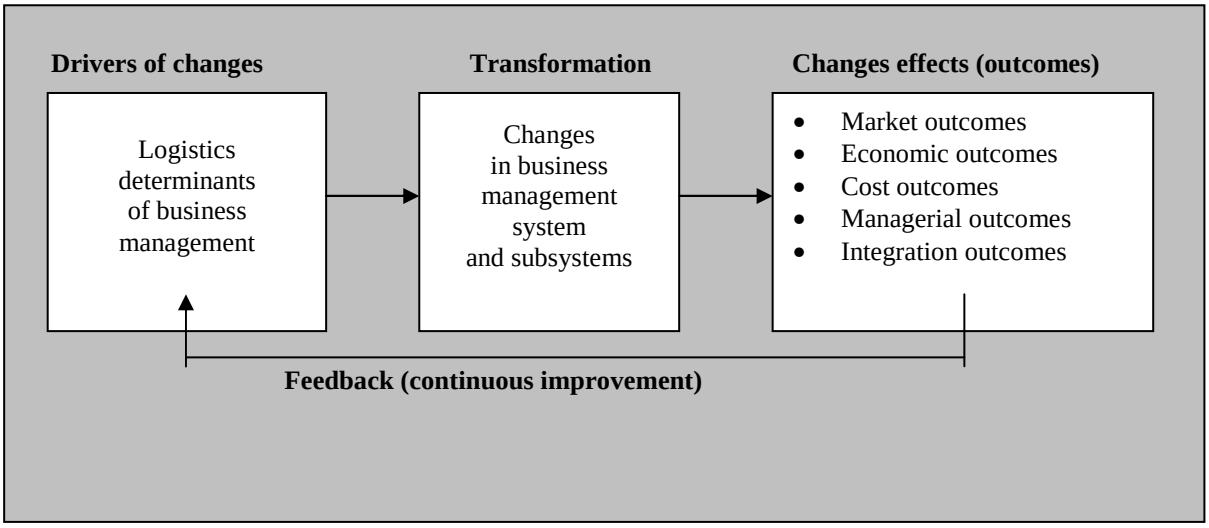
logistics planning systems development may directly influence changes in integrated planning system in a company.

Determinants which indirect influence management system cause indirect changes, related to other "objects" than management system, which occur before the proper changes concerning management system. For example, logistics can influence changes in business procurement system. Such situation may be connected with the necessity of redesigning business procurement system, which in turn can require changes in management subsystems which are responsible for processes and tasks execution in the field of business procurement system.

Changes determinants in business management system are also characterized by positive influence, which stimulates desired changes, and negative influence, which slows or reduces the changes. Speaking of logistics development, firstly the subject in question is changes determinants, which are profitable in customers' and company perspectives, which condition the growth of benefits for a customer and a company, which reinforce company competitiveness and its competitive advantage, or which strengthen business competitive position.

LOGISTICS POTENTIALS OF CHANGES IN BUSINESS MANAGEMENT IN LIGHT OF RESEARCH IN POLAND

As mentioned before, the key function of logistics determinants is to cause changes in business management system which condition achieving desired effects (outcomes) for both the customers and companies. Logistics determinants of business management are specific "drivers" of changes which occur in management system and its subsystems. As a result of the logistics determinants influence, there appears a unique transformation in management system and its subsystems. The transformation makes it possible to "go" from up-to-now solutions to solutions which condition achieving desired and more profitable effects (outcomes), connected with benefits for customers and companies. A company desire to improve achieved effects (outcomes) requires permanent improvement of logistics systems, logistics processes and logistics solutions which is seen in the feedback between achieved effects (outcomes) and "drivers" of changes in a company (see figure 4).



Source: Based on Blaik 2010, Day and Wensley 1988, Mentzer, Min, and Bobbitt 2004

Fig. 4. Logistics determinants as drivers of changes in business management
Rys. 4. Wyznaczniki logistyczne jako czynniki zmian w zarządzaniu biznesowym

The research conducted by Chair of Logistics and Marketing at Opole University, Poland has included a sample of 111 companies operating in Poland, representing five lines of business. Figure 5 presents percentage structure of companies taking part in the research, while table 1 shows percentage employment level in the researched companies.

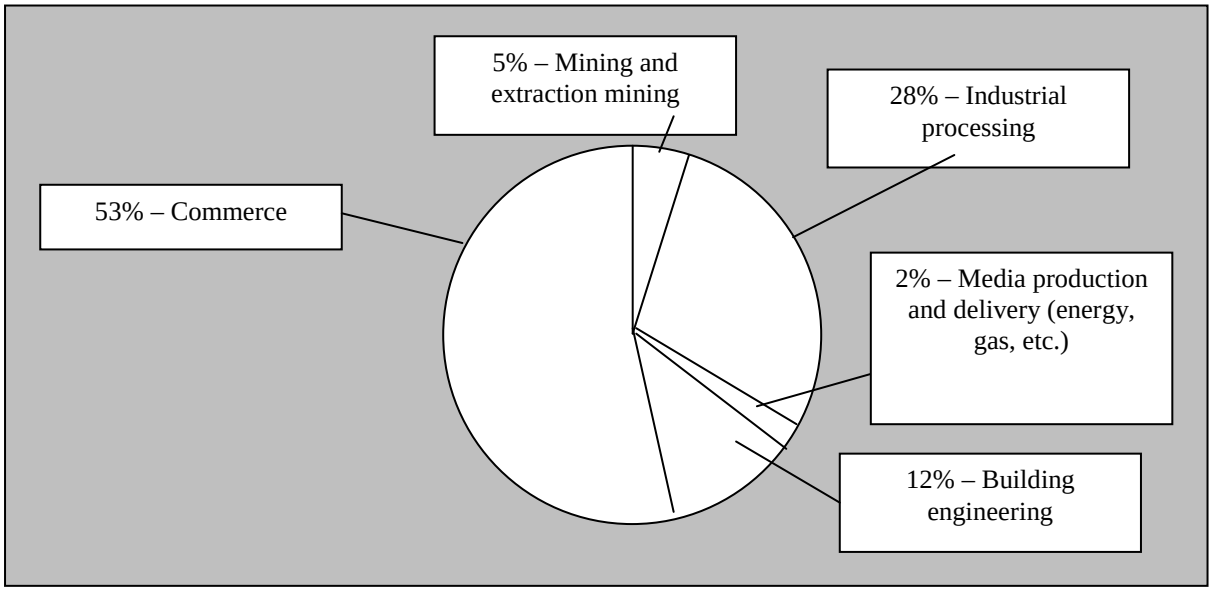


Fig. 5. Research sample lines of business structure
Rys. 5. Linie struktury biznesowej próby poddanej badaniu

Table 1. Resarch sample employment level
Tabela 1. Poziom zatrudnienia próby poddanej badaniu

Number of employed	**% share**
1-100 employed	26
101-500 employed	41
501-1000 employed	14
1001-2500 employed	10
2501-5000 employed	3
Over 5000 employed	6
Total:	100

Considering the most important factors determining logistics development, basic components of business orientation flow as well as key challenges which are encountered by contemporary companies, the research has focused first of all on:

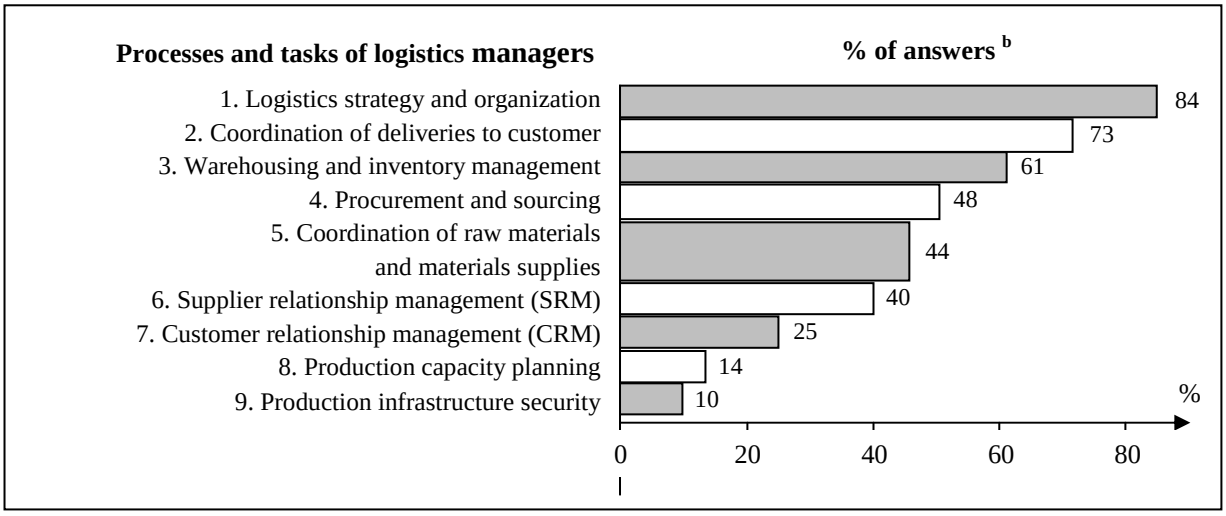
- Recognition of logistics concept implementation level (table 2),
- Recognition of tasks domain of logistics manager (figure 6),
- Determination of logistics goals influence on business goals formulation (figure 7),
- Determination of logistics strategies influence on a business strategy (figure 8).

Table 2. Four types of logistics concepts
Tabela 2. Cztery typy koncepcji logistycznych

Logistics concept	**% of answers [a]**
1st Logistics Concept: Logistics as a service function (transport, warehousing, reloading, packaging, labelling, etc.) – the least developed logistics concept	20
2nd Logistics Concept: Logistics as a function of coordination of materials, goods and information flow	32
3rd Logistics Concept: Logistics as an integrated management of materials, goods and information flow within a company	17
4th Logistics Concept: Logistics as an integrated management of materials, goods and information flow within the whole supply chain – the most developed logistics concept	31
Total:	100

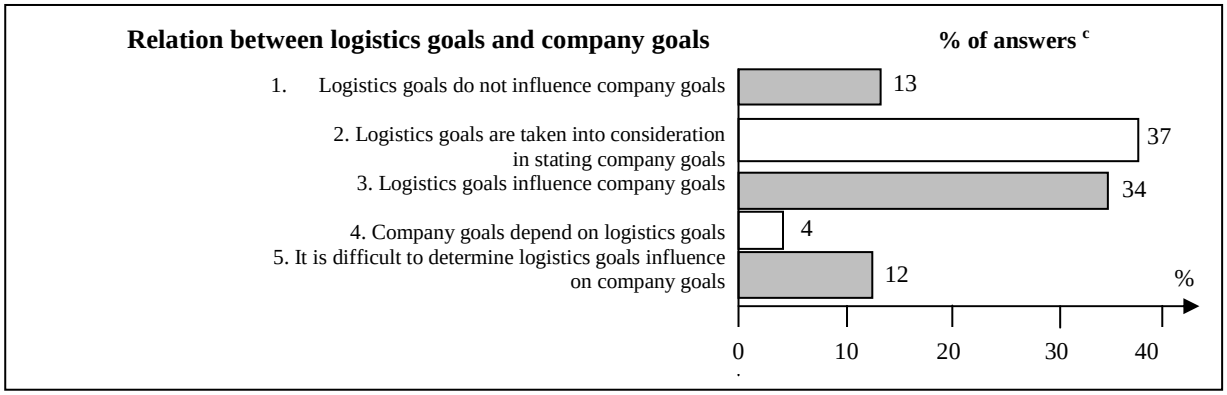
[a] single choice

Source: Logistics concepts based on Blaik 2010



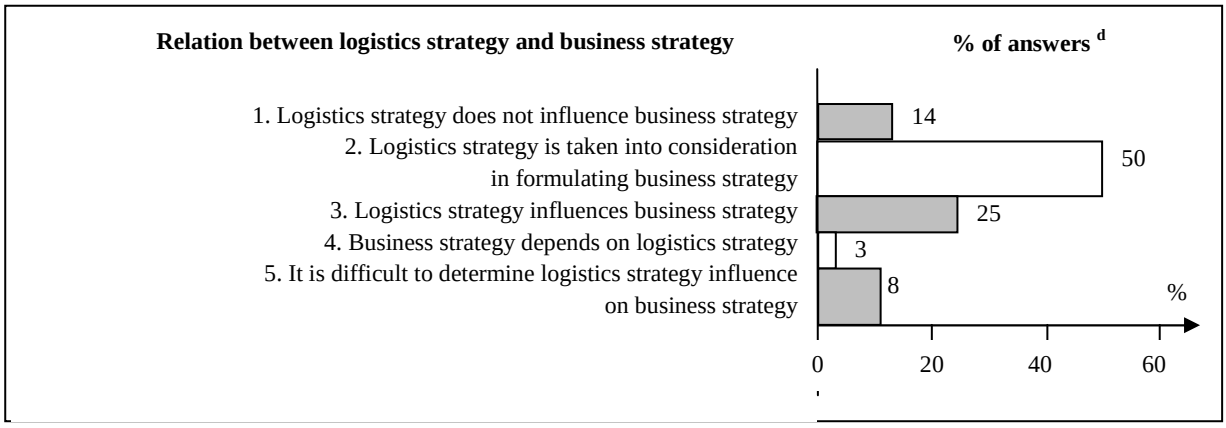
[b] multiple choice

Fig. 6. The most important tasks of logistics manager
Rys. 6. Najważniejsze zadania menadżera logistyki



[c] single choice

Fig. 7. Influence of logistics goals on company goals
Rys. 7. Wpływ celów logistycznych na cele przedsiębiorstwa



[d] single choice

Fig. 8. Influence of logistics strategy on business strategy
Rys. 8. Wpływ strategii logistycznej na strategię przedsiębiorstwa

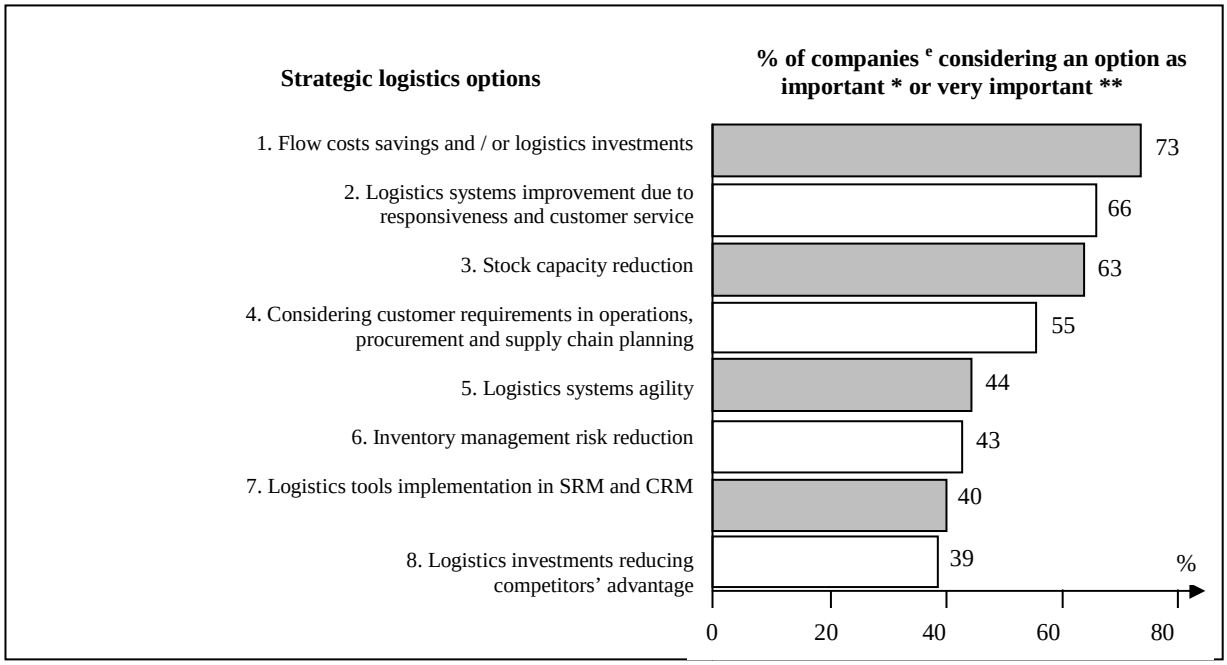
Most of the companies admit that their activity involves logistics as a function responsible for entire coordination of activities and tasks connected with materials, goods and information flow. Logistics concept understood in such a way is not, however, related to flow management. Implementation of the fourth, the most developed logistics concept, is also relatively widely declared. Logistics as a concept of flow management within the whole supply chain requires, however, more precise feedback in the course of conducted empirical research.

There are three major tasks carried out by logistics managers: participation in developing logistics strategy and logistics organizational solutions, coordination of deliveries to customers, and procedures related to warehousing and inventory management. Warehousing and inventory management are typical logistics activities, and they are independent from logistics concept implementation level in a company. Deliveries coordination suggests that at least the second logistics concept has been implemented. The interpretation of logistics strategy and organization causes serious problems as they are differently perceived and understood by managers. Therefore, this issue requires more detailed research.

Evaluating the influence of logistics goals and strategies according to company goals and strategy, logistics goals and strategies are most often taken into consideration in defining business goals and formulating business strategy. The majority of managers have admitted that logistics goals have direct influence on business goals, while logistics strategies have a direct influence on a business strategy. This issue also requires further research, and first of all the assessment of mentioned influence degree and following changes in effects achieved by a company is needed.

In order to estimate the relation between logistics strategy and business / corporate strategy, it is important to choose proper strategic option in logistics. The options are potential part of logistics strategy, as well as the determinant of reaching expected market and economic effects by a company. The research of Chair of Logistics and Marketing at Opole University, Poland, has involved eight strategic options, ranged in five-point Likert scale (figure 9).

In the opinion of 73% of surveyed companies, the most important logistics option leading to successful logistics strategy and market success is flow costs savings and / or logistics investments. It seems that these firms implement primarily cost orientation in their business management systems. 66% of surveyed companies assign importance to logistics systems improvement due to responsiveness and customer service, and 63% to stocks capacity reductions.



[e] multiple choice, * 4 points in Likert scale (from 1 to 5), ** 5 points in Likert scale (from 1 to 5)

Fig. 9. Importance of strategic options in business logistics
Rys. 9. Istotność opcji strategicznych w logistyce

In order to determine the relation between logistics manager competencies and the importance of strategic logistics options, the research has been based on chi-square (χ^2) test with V Cramer coefficient estimation (table 3).

Table 3. Relation between logistics manager competencies and the importance of strategic logistics options
Tabela 3. Zależność pomiędzy kompetencjami menadżera logistyki a znaczeniem strategicznych opcji logistycznych

Fields of logistics manager competencies	Strategic business logistics options	p-value	V Cramer [f]
Warehousing and inventory management	Stock capacity reduction	0,00003	0,4869621
Logistics strategy and organization	Flow costs savings and / or logistics investments	0,00100	0,4079953
	Stock capacity reduction	0,03245	0,3079400
Coordination of deliveries to customer	Logistics systems improvement due to responsiveness and customer service	0,00201	0,3903412
	Flow costs savings and / or logistics investments	0,00624	0,3596469
	Inventory management risk reduction	0,01748	0,3285688
Procurement and sourcing	Logistics tools implementation in SRM and CRM	0,02758	0,3135369
	Logistics systems improvement due to responsiveness and customer service	0,03145	0,3090267

[f] The table presents exclusively the relations with V Cramer ≥ 0,3. All statistics at significance level α=0,05.

CONCLUSIONS AND FURTHER RESEARCH

Implementation of logistics potentials, involving logistics resources, capabilities and competences, creates possibilities for a company to achieve desired market and economic effects. As a result, a company may offer unique customer value and get lasting and long-term competitive advantage. Logistics determinants of business management are the subject of further, more detailed research conducted in Chair of Logistics and Marketing at Opole University. The research is primarily concerned with classification and hierarchy identification of business management logistics determinant, as well as with the determinants influence on business management changes and on market and economic effects achieved by a company.

So far the research results have shown selected symptoms of logistics influence on business management system. The key role of logistics potentials (resources, capabilities and - especially - logistics competences) in business management system capacity development has been partially confirmed. Thanks to such potentials, the company can be more efficient in customer value creation, as well as in reaching expected market and economic effects (outcomes).

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WPŁYW POTENCJAŁU LOGISTYCZNEGO NA ZARZĄDZANIE BIZNESOWE

STRESZCZENIE. **Wstęp:** Coraz częściej logistyka jest postrzegana jako potencjał zmian w systemie zarządzania przedsiębiorstwem. Zasoby logistyczne, zdolności a w szczególności kompetencje to potencjały o kluczowym znaczeniu.

Metody: Praca wskazuje na wykorzystanie możliwości potencjału logistyki w osiągnięciu zamierzonych zmian w zarządzaniu przedsiębiorstwem jak również w osiągnięciu zamierzonych przez przedsiębiorstwo efektów rynkowych i ekonomicznych. Prócz przeglądu literatury, zostały przeprowadzone badania empiryczne w 111 przedsiębiorstwach działających na terenie Polski.

Wyniki i wnioski: Wyniki badań wskazują różne symptomy wpływu logistyki na system zarządzania przedsiębiorstwem. Istotność potencjału logistycznej w rozwoju zdolności systemu zarządzania przedsiębiorstwem została częściowo potwierdzona. Dzięki potencjałom logistycznym, przedsiębiorstwo może działać efektywniej i wydajniej w osiągnięciu zamierzonych celów rynkowych i ekonomicznych.

Słowa kluczowe: logistyka, potencjał, kompetencje, zarządzanie, efekty.

EINFLUSS DES LOGISTISCHEN POTENTIALS AUF BUSINESS-MANAGEMENT EINES UNTERNEHMENS

ZUSAMMENFASSUNG. Einleitung: Die Logistik wird des Öfteren als ein Potential für Veränderungen im Managementsystem eines Unternehmens angesehen. Logistische Bestände, Fähigkeiten und insbesondere Kompetenzen beinhalten Potentiale mit schlüsselmäßiger Bedeutung.
Methoden: Die Arbeit weist auf die Möglichkeit der Inanspruchnahme des logistischen Potentials bei Erzielung der angestrebten Veränderung im Managementsystems eines Unternehmens sowie bei Wahrnehmung der vom Unternehmen angestrebten wirtschaftlichen und -Markteffekte hin. Außer der Literaturübersicht wurden empirische Untersuchungen in 111 in Polen tätigen Unternehmen durchgeführt.

Ergebnisse und Fazit: Die Forschungsergebnisse zeigen unterschiedliche Anzeichen der Beeinflussung des Managementsystems eines Unternehmens seitens der Logistik auf. Die Bedeutung des logistischen Potentials bei der Entwicklung der Werkzeuge eines Managementsystems im Unternehmen wurde teilweise bestätigt. Dank der logistischen Potentiale kann das Unternehmen bei der Erzielung der angestrebten wirtschaftlichen und -Marktziele effektiver und leistungsfähiger betätigt werden.

Codewörter: Logistik, Potenzial, Kompetenzen, Management, Effekte.

Rafał Matwiejczuk, PhD, Eng.
Chair of Logistics and Marketing
Faculty of Economics
Opole University, Poland
46a Ozimska St., 45-058 Opole, Poland
tel. +48 77 40 16 900, 40 16 880, 40 16 898
fax +48 77 40 16 901
e-mail: rmatwiejczuk@uni.opole.pl

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EVALUATION OF URBAN FREIGHT TRANSPORT MANAGEMENT MEASURES

Daniel Kaszubowski

Gdańsk University of Technology, Gdańsk, **Poland**

ABSTRACT. Background: Problems with urban freight traffic in downtown areas emerge in parallel with the growth of motorization and changes in consumption patterns. Supply chains become more and more dependent on small and frequent deliveries. It is a problem common for most modern cities and one that requires tailor-made solutions which meet local requirements and can be extended, if necessary.
Methods: An extensive literature review was conducted to obtain a comprehensive overview of existing urban freight related problems and possible solutions. The specificity of the problem required a broad approach including an analysis of many case studies from European cities and gathering the theoretical background. On this basis a general set of freight related measures was selected for evaluation. Because of the complexity of both the problem and its solutions an adequate method of evaluation was needed. The method had to be flexible and offer an understandable and manageable structure. The analytic network process (ANP) was selected for this task. It is a multi-criteria decision making method used in complex decisions, which can measure tangible and intangible factors. The author's aim was to build a sufficiently detailed model that ensures reliable results and accomplishes the goals of the main actors and of sustainable city transport policy.
Results and Conclusions: The analysis showed that given the current state of development of urban freight traffic in Gdansk, the situation can be rationalised with regulatory measures. Only well balanced and carefully implemented measures have the potential to rationalize urban freight transport without disturbing the city's economic growth. They have to be prepared in advance on the basis of a continuous analysis of the urban transport system. It is important to involve all actors in the development of more advanced measures in a bottom-up planning process. Otherwise, the risk is that overly complicated solutions without a practical justification will produce counterproductive results.

Key words: urban freight traffic, urban logistics, city transport policy, multicriteria decision making, analytic network process.

INTRODUCTION

Urban freight policy is, or should be, an integral part of urban transport and economic development policy. There are several reasons why public policies in specific fields are needed. They are made when problems arise, challenges occur, objectives have to be set and verified or guidelines are needed. In most cases it is a combination of these factors [Visser, Binsbergen, Nemoto 1999]. Typically, a well-designed urban freight policy makes a rational use of available tools and measures. Freight traffic is a basic requirement for every economic activity within the city. Any changes to how it operates require careful thinking not to disrupt local business but still provide the intended long-term modifications in delivery patterns and traffic conditions.

The aim of this paper is to evaluate the feasibility of diversified measures regarding urban freight transport rationalization. While this is a theoretical paper, the models are firmly based on a critical evaluation of existing examples confronted with local conditions. Gdansk city centre was selected as the implementation area for the analysis. It has a high concentration of businesses, retail shops, services and administrative functions. This was to ensure the practical relevance of the decision factors

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included in the model. Despite that, a certain level of generalization is still possible, because many cities share the same problems and will soon have to decide which measures to adopt. Conducted with the SuperDecisions ANP application, the simulation is intended to prioritise measures rather than select the best option and exclude all the others. The main question is not to find the best solution, but to verify which measure is the most feasible under specific circumstances and limitations. The prioritization helps to understand the distance between the best and the next alternative and gives an overview of future possibilities.

GOALS OF URBAN FREIGHT POLICY

Urban freight transport policy has three main elements: transport chains, different actors and the city's business activity, and how it interrelates with other policy fields such as infrastructure, land use planning, economic development, accessibility and environmental problems [Brown, Piotrowska, Woodburn and Allen 2007]. Moreover, urban freight is part of freight transport in general, and its logistic chains and interconnections expand over a larger area than a single city. Therefore, it is difficult to design an effective urban freight policy without affecting the interurban part of goods flow. [Stratec 2005]. Account must be taken of the general situation on the freight operators market, its development, saturation and competitiveness. All this will determine the feasibility of solutions based on voluntary cooperation. An urban logistic system should be considered with three main pillars in mind [Tanguchi, Thomson, Yamada, 2004]:

- mobility,
- sustainability,
- liveability.

Mobility is considered as a basic requirement for transporting goods within the city as well as into and from urban areas. In terms of connectivity, reliability and safety it requires a well planned transport infrastructure. Reducing traffic congestion and providing a reasonable road capacity, especially through capacity optimization methods, is an important goal for urban traffic management. Sustainability is well recognized because people show a growing concern for environmental issues including air pollution, noise, vibration and visual intrusion. Large freight vehicles or multiple uncoordinated deliveries by smaller trucks are often the source of negative effects. Reducing the negative impacts of transport activity is an important goal of a freight transport policy. Liveability is a complex issue related to the role of the city as a social and economic phenomenon. Residents want to benefit from the proximity and abundance of different services, shopping and delivery possibilities. They are also concerned about general living conditions, traffic safety and real property value, which may be hampered by commercial vehicles operations. The above mentioned pillars provide a strategic basis for planning urban freight transport systems in the form of guiding principles. They may be supported by some specific goals [Tanguchi, et. al, 2004]:

- market competitiveness,
- efficiency of all involved actors,
- environmental awareness,
- congestion alleviation,
- security,
- safety,
- energy conservation.

Each goal is connected with one or more actors or stakeholders directly or indirectly involved or influenced by urban goods transport. This illustrates its complexity with multiple goals that may be conflicting. To add to the actor level complexity and number of goals, there is also a number of

different principal urban logistic chains where a common characteristics can be identified [Dablanc 2011]:

- independent retailers and local convenience stores - the sector may account for 30 - 40 percent of all daily deliveries in a city, depending on its structure, size and market profile; local stores are supplied three to ten times a week, when 7 - 8 may be the average [Bertens 2011],
- chain retailing and commercial centers - large retailing brands with subsidiaries expand on the urban market at the expense of independent local stores; this changes the delivery pattern, from numerous small shipments to less frequent deliveries with a larger number of consolidated deliveries and better load factor of vehicles,
- parcel and express services (less than a truck load) are one of the fastest growing group among urban transport operators; they utilize vans or small to medium sized trucks and the deliveries depart from cross-docking terminals located in the inner suburbs and preferably close to ring roads; deliveries are well consolidated within specified delivery areas,
- building sites are a strategic segment in urban freight management because of significant tonnage they generate; building site supply is inefficient because of the number of building contractors on each site, multiple suppliers and poorly planned delivery schedules; deliveries are usually carried by larger trucks than in other examples, causing several problems with congestion, damage to the roads, noise and traffic safety.

OVERVIEW OF THE CURRENT FREIGHT TRAFFIC STRUCTURE IN GDANSK AND TRAFFIC MANAGEMENT MEASURES WITHIN THE DOWNTOWN AREA

Providing a comprehensive picture of urban freight traffic requires data from two sources. First, urban traffic surveys covering the structure of all vehicle flows, number of trips, source and destination patterns, etc. The second source should be a detailed delivery profile survey, examining the number of daily deliveries to different types of businesses, types of cargo and delivery vehicles within a precisely specified area, for example a business district or city center. The combination of two sources gives practical knowledge about urban freight development [Kaszubowski 2011]. The latter survey method is rarely used due to its cost, complexity and a high level of voluntary participation required from both the businesses and delivery companies. In Gdańsk the most recent traffic survey was conducted in 2009. Its results regarding freight vehicles are as follows [KBR 2009]:

- 80 000 trips were made by all types of freight vehicles,
- 80% of freight vehicles were up to 3.5t,
- total share of freight traffic within the city limits was 10%,
- average number of trips per vehicle was 2.15,
- most of the trips (55 000) were made within city borders,
- 60% of trips were made by empty vehicles, while 75% of the rest were loaded up to 30% of capacity,
- average declared travel time for all trips was 45 minutes, and 25 minutes within the city limits,
- average number of trips of empty vehicles was 1.2, for vehicles with foodstuffs 0.22, construction materials 0.19 and other goods 0.32.

When compared with a 1990 general traffic survey [KBR 1990] the results show a significant increase in urban freight traffic. In 1990 40 500 freight vehicles were counted with an average of 2.23 trips per vehicle. The slight decrease in trips per vehicle is outweighed by total trips which doubled. Because urban deliveries are bound to cause problems in areas where transport demand is the highest, downtown Gdańsk was selected as a test site for the proposed measures. The size is about 1.8 sq. km,

with about 12 000 inhabitants and 16 000 jobs in retail, services, etc. Currently, it has a designated limited traffic zone (30km/h) and a pay and display parking zone. There are no specific measures for freight vehicles. Local shopkeepers and business owners can apply to the urban roads authority for a loading bay for their purposes. Permits are granted if there are several potential users in close vicinity. The maximum time of delivery is 30 minutes. When the loading bay is within the parking zone, delivery vehicles still have to pay for parking.

FREIGHT MANAGEMENT MEASURES SELECTED FOR ANP MODELLING

There are a number of different strategies or measures that may be applied in urban freight policy and planning [Visser, et al. 1999]:

- parking and loading strategies: utilization of different types of facilities for parking, loading and unloading, kerb-side, off-street facilities and truck parking facilities, often as part of a wider freight policy [TfL 2009],
- dedicated logistics routes or road network strategies: specific routes may be nominated for truck use; routes may be dedicated to specific classes of vehicles only to prevent entry into restricted areas;
- licensing and regulations: a wide array of measures may be considered, i.e.: allocation of kerb space, loading time restrictions, truck access control, truck route regulations, permits for entering certain areas and vehicle regulations (size, emission, noise standards)
- pricing strategies: road pricing or access/parking charges allow the market and cost calculations to solve traffic congestion,
- city terminals or urban freight consolidation centers: transfer and consolidation facilities are located outside urban areas which helps to optimise truck movement; sometimes additional inner-city transfer points are created,
- voluntary cooperation of transport and logistics operators for coordinated deliveries or terminal operations,
- location and zoning: incentives to concentrate facilities generating transport near freight infrastructure and facilities,
- ITS technology used for city logistics, both as a solution for vehicles and infrastructure-related systems [Kaszubowski, Oskarbski 2011].

Table 1. Complexity of urban freight transport policy measures
Tabela 1. Stopień złożoności narzędzi zarządzania transportem ładunków w miastach

Basic regulatory measures	**Intermediate** market-driven initiatives, public sector facilitates and sometimes subsidies the initiatives	**Advanced** full public involvement, alternations to the supply chain supported by additional measures, constant financing, additional regulatory measures required
parking and loading strategies dedicated logistic routes licensing and regulations pricing strategies	freight operators voluntrary cooperation	urban consolidation centre (UCC) based on the public – private partnership
Supporting measures		
ITS road traffic management systems, zoning strategies,		

The policy measures described above should be structured according to their level of complexity (Table 1). They may be discussed as standalone solutions or, preferably, as part of a wider strategy addressing problems identified within the city's transport system. It is also important to note the distinction between measures which concern freight vehicle traffic and those altering the supply chain

performance. Some of them are regulatory in nature while others involve the cooperation of different actors [Marcucci, Danielis, 2008]. Finally, there are measures playing a supporting role. There are spatial strategies designed to concentrate freight-related activities or road traffic management systems (ITS).

Four measures were selected for the evaluation of the most feasible urban freight transport management solution in the Gdańsk city center:

1. continuation of the current traffic policy,
2. regulatory scenario: mix of access restrictions, weight restrictions and loading time restrictions,
3. voluntary cooperation of freight operators,
4. urban consolidation centre (UCC).

The Tristar ITS road management system was selected as the possible supporting measure due to its advanced implementation stage. All of the proposed measures have been discussed and described in many publications and analyses. However, some of the solutions, i.e. voluntary cooperation and urban consolidation centers vary in terms of how they are implemented. It must be clarified at this point which concrete option is being considered to avoid confusion and unclear conclusions derived from the ANP model.

Regulatory measures are the most common actions to solve basic problems of freight traffic in urban areas. Access restrictions according to weight, time windows and loading zones followed by parking restrictions represent the typical set of regulations [Duin, Muňuzuri, 2006 s. 343]. Such measures are often introduced "automatically" - without previous analysis or without the knowledge of the area's delivery structure. But if well planned and managed, the measures can offer practical tools for urban traffic management and create a basis for further developments. This can be observed for example in London, where the Traffic for London authority (TfL) introduced several additional measures to unlock the potential of existing regulations within the London Freight Plan [Tf, 2007].

Voluntary cooperation of freight operators may be considered as a method of improving the effectiveness of logistic operations. It was introduced in Kassel in 1994 as an initiative of private companies. Several other cities followed suit (i.e. Freiburg, Essen) with their own alterations of the scheme. The idea in Kassel was to consolidate goods and have a single neutral carrier make the deliveries. The intended traffic reduction and vehicle utilization rates were achieved leading to a 60% reduction in inner city mileage and a 100% increase in vehicle saturation by volume [Kohler, 2003, 321-333]. However, the project collapsed due to high costs of transshipment operations and fleet maintenance. Keywords for this alternative are: private initiative and kick-off financing, and public involvement (direct subsidy) if possible.

The urban consolidation center is described as a logistics facility that is situated in close proximity to the city center (in most cases) or to a specific site (e.g. shopping center), from which consolidated deliveries are carried within the area [Browne, 2005]. To provide a clear distinction from the voluntary cooperation model (initiated by the private sector) it was assumed that UCC in this case will be a public initiative as part of an active urban freight policy. It requires stable financing from the public sector and a clear long term policy orientation. There are examples [Duin 2010] of consolidation centers initiated in this way (Leiden - Netherlands, Malaga - Spain) indicating the critical factors to be considered, besides the necessary financial involvement. There may be opposition both from retailers and freight operators claiming that the municipality is aiming to create a monopoly in the urban freight market. Moreover, when other measures provide an acceptable level of delivery service for retailers, a UCC is likely to be considered a nuisance. The keywords for this measure are: direct public involvement, public-private partnership, dedicated facility and regulatory measures.

DESCRIPTION OF THE ANALYTIC NETWORK PROCESS METHOD (ANP)

The analytic network process (ANP) is a multicriteria theory of measurement used to derive relative priority scales of absolute numbers from individual judgments or from actual measurements normalized to a relative form [Saaty 2009]. It may be applied as a decision making framework for political, social and economic problems. It includes all the factors and criteria, tangible and intangible, which are important to understand the problem. Judgments represent the relative influence of one of two elements over the other in a pairwise comparison process on a third element in a system, with respect to an underlying control criterion. In the ANP dominance or influence are central concepts. A decision maker or a group of decision makers use the fundamental scale of absolute numbers (1 - 9) to make a comparison [Saaty 2006] as shown in Table 2.

Table 2. ANP fundamental scale of comparisons
Tabela 2. Fundamentalna skala porównań w metodzie ANP

Intensity of importance	Definition	Explanation
1	equal importance	two activities contribute equally to the objective
2	weak importance	
3	moderate importance	experience and judgments slightly favor one activity over another
4	moderate plus	
5	strong importance	experience and judgments strongly favor one activity over another
6	strong plus	
7	very strong or demonstrated importance	an activity is favored very strongly over another, its dominance is demonstrated by practical examples
8	very, very strong	
9	extreme importance	the evidence favoring one activity over another is of the highest possibile level

In order that all influences would be meaningful to synthesize it is essential to take the same criterion to all the comparisons. Such a criterion is called a control criterion. It is an important way for focusing thinking to answer the question of dominance among selected factors. Control criteria are utilized to cover both favourable and unfavorable concerns which must be considered to achieve rationality of decision. They are grouped into benefits, opportunities, costs and risks [Saaty, Vargas 2006]. Benefits are favourable sure concerns and unfavorable ones are costs. The uncertain concerns of a decision which are positive are the opportunities connected with the decision. The last group, risk, covers all the negative factors the decision can entail. These four groups of concerns are referred to as the BOCR merits. ANP models generally have three layers, also presented in Figure 1:

Top layer - a single network that includes benefits, opportunities, costs and risk nodes (BOCR nodes) and the strategic criteria used to evaluate their importance for the decision. Strategic criteria are the optional element of the model. If they are not included, BOCR control networks are rated with respect to their influence on the decision; this approach is used in the presented paper.

Control criteria network - each of the BOCR with a subnet containing its control criteria.

Decision networks - the alternatives to the decision appear in a cluster in each decision subnet, with all connections between control criteria.

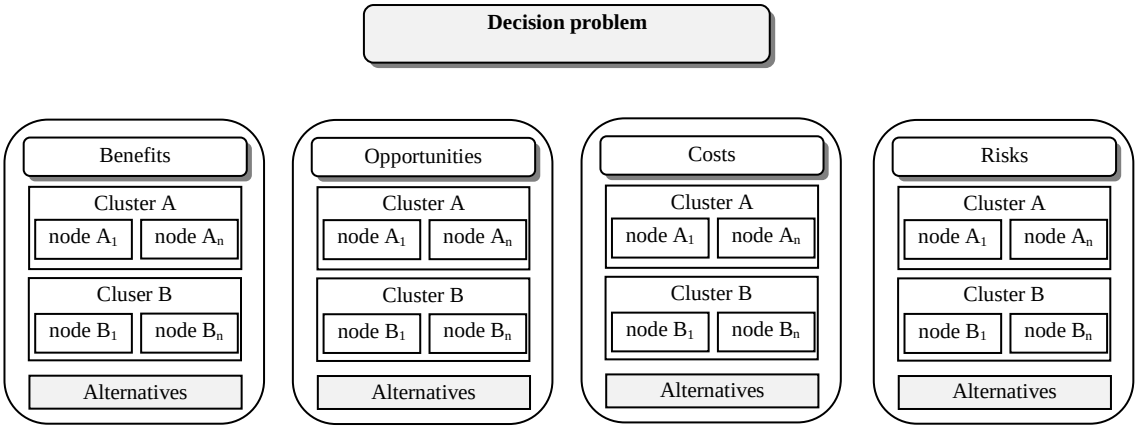

Fig. 1. General framework of the ANP method model
Rys. 1. Bazowa struktura modelu w metodzie ANP

There are several decision situations to which the analytic network process method can be applied [Forman, Gass 2001]:

- choice: the selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved,
- ranking: putting a set of alternatives from the most to the least desirable,
- prioritization: determining the relative merit of a set of alternatives, as opposed to selecting a single one or merely ranking them,
- resource allocation: apportioning resources among a set of alternatives,
- benchmarking: comparing the processes in one's own organization with those of other best-of-breed organizations,
- quality management: dealing with the multidimensional aspects of quality and quality improvement.

In this paper the prioritization approach was selected as the most feasible. When prioritizing alternatives, the order, intervals, and ratios of the resulting priorities are of interest, in addition to knowing which alternative has the highest priority. This is important because in the presented model all alternatives may be rational under favourable conditions and they have the potential to supplement each other when properly executed.

ANP MODEL AND RESULTS

The criteria used to evaluate selected alternatives are derived from the main goals of urban freight traffic policy. They are directed at providing consistency between all involved stakeholders' objectives. At the same time criteria must reflect general long-term policy objectives. Criteria were clustered within each BOCR (benefits, opportunities, costs and risks) control network. Clustering similar criteria is a practical method to make the analysis manageable. It also gives an opportunity to check whether the first assumptions were appropriate by confronting different clusters. The number of decision criteria is intentionally limited not to blur the whole picture by implementing a large number of irrelevant factors.

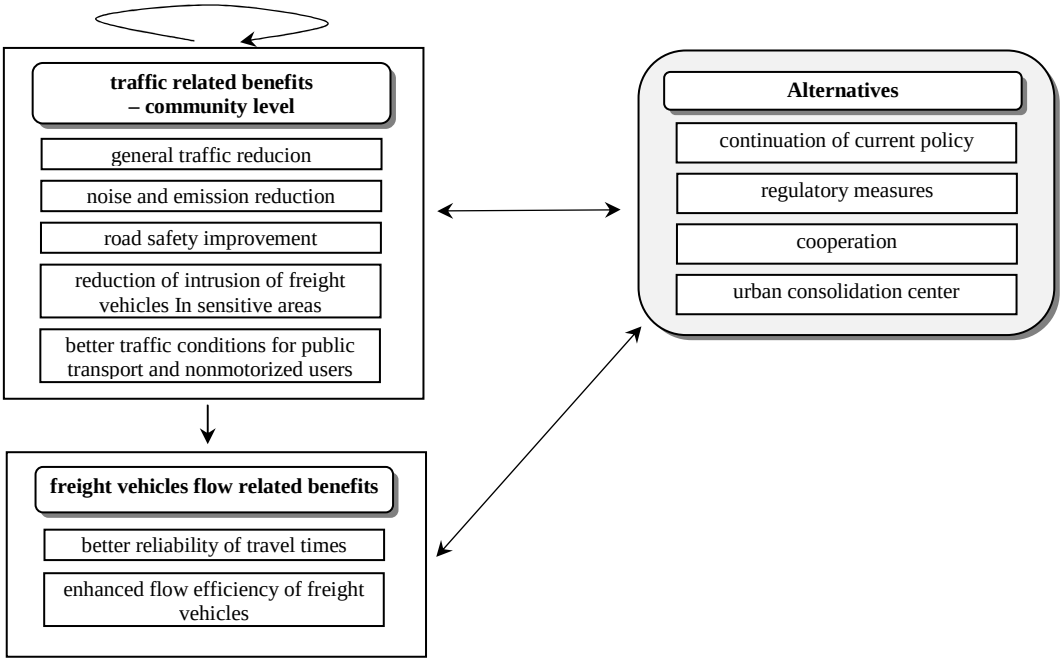

Fig. 2. Benefits subnet
Rys. 2. Sieć korzyści

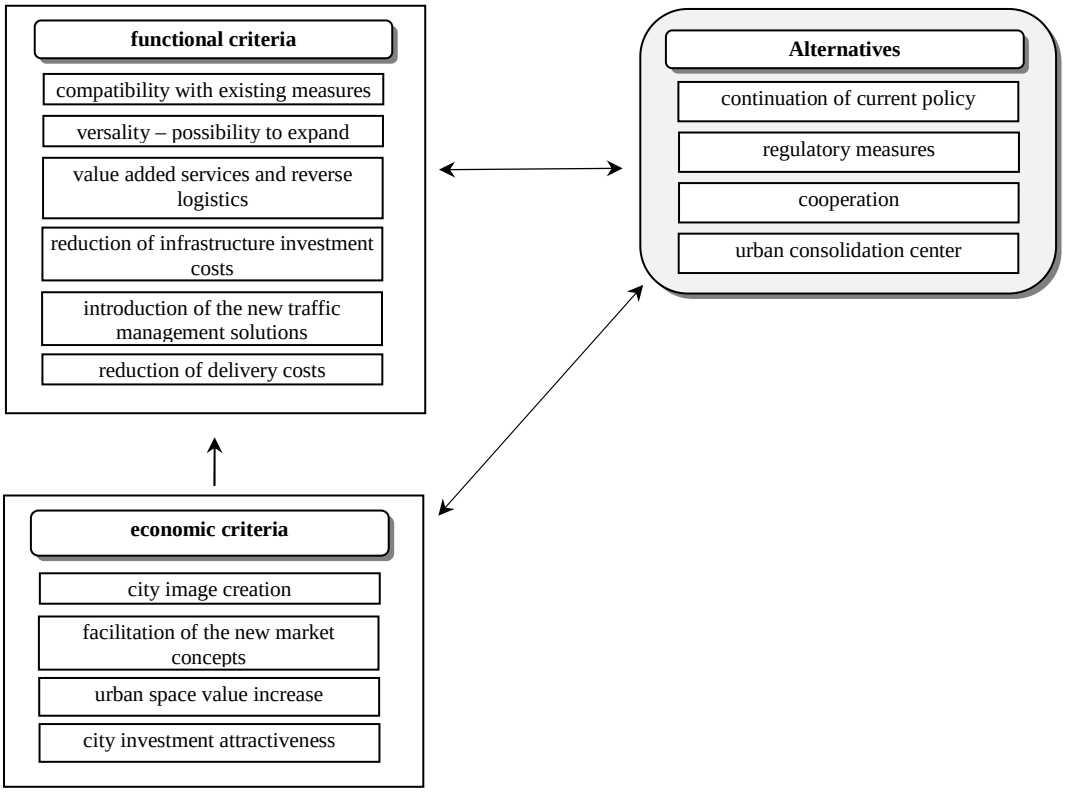

Fig. 3. Opportunities subnet
Rys. 3. Sieć szans

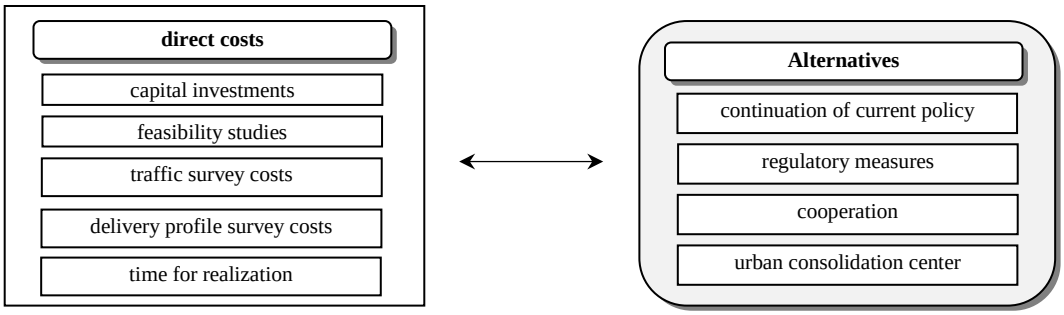

Fig. 4. Costs subnet
Rys. 4. Sieć kosztów

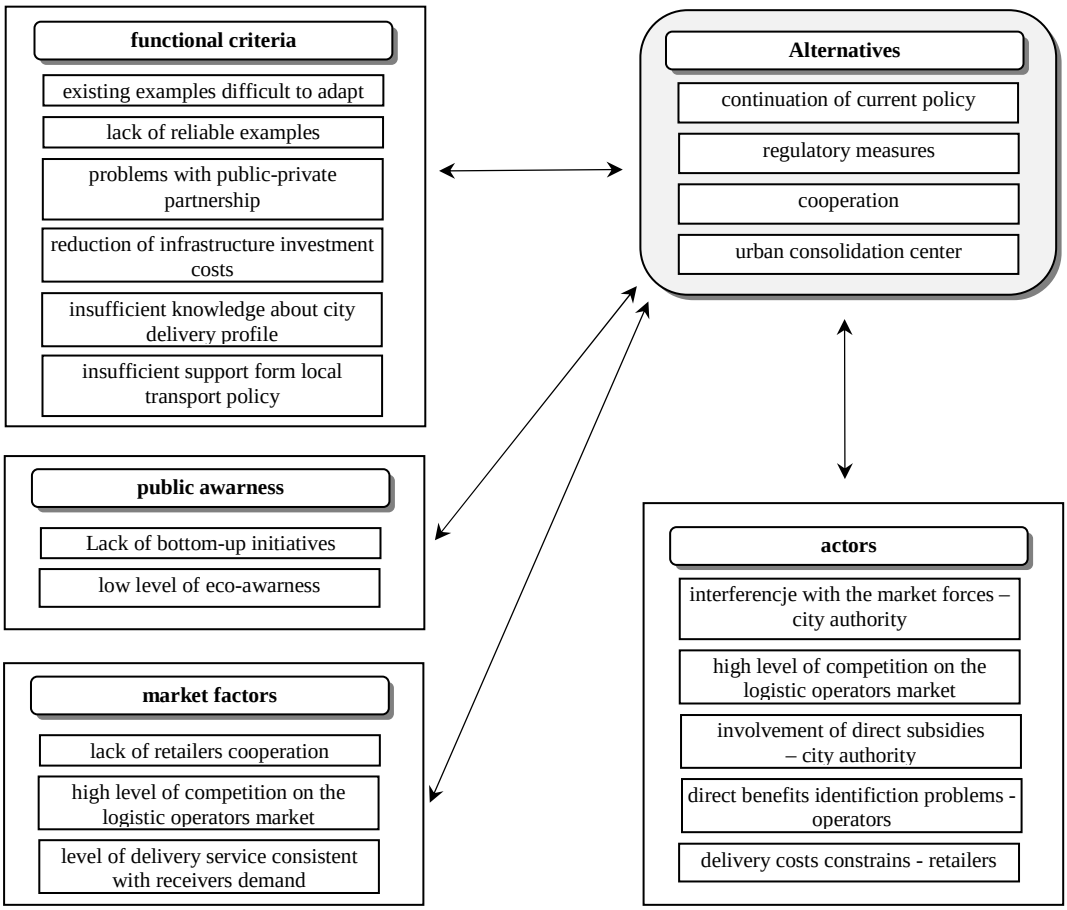

Fig. 5. Risk subnet
Rys. 5. Sieć ryzyka

Due to editorial limitations only the final output of the model will be presented and discussed. According to the structure of the ANP model the top level network was evaluated first. It was achieved by setting the priorities for each of the benefits, costs and opportunities control networks. This provides the necessary balance between all control criteria networks and clusters within them with regards to the nature of the problem analysed. Because the model concerns a policy which influences many areas of the city's economic and social system it has to incorporate a balanced approach. It is reflected directly by accepted priorities:

- benefits 0,15
- opportunities 0,25
- costs 0,20
- risks 0,40

The benefits control network priority is low at 0.15. It is difficult to evaluate the direct benefits for many directly involved actors and indirectly influenced sectors. Accepting the strategic approach, some direct benefits in a longer planning perspective should be considered as opportunities. The main possible positive effects of the measures are within the opportunities control network. They reflect both far-reaching economic benefits and functional opportunities such as the possibility to expand or increase versatility. This control network has the priority of 0.25. However, this is noticeably less than the risks priority set to 0.40. A careful consideration of a wide array of diversified factors must be performed each time. It is difficult to transfer existing good practices because of local differentiation. Experience from many urban freight traffic solutions reveals that measures plausible from the operational perspective are sensitive to unexpected conditions, unique to the implementation area. Thus the priority for risks control network is set at the high value of 0.40.

After performing pairwise comparisons within each BOCR control network, involving clusters and nodes, the final model was obtained as a set of priorities. The first value is the normalized value (all priorities divided by the priority of the best alternative), while the latter value in brackets is a standard priority:

1. regulatory scenario 1,000000, (0.354384)
2. current traffic policy 0.717577, (0.254298)
3. cooperation scenario 0.667857, (0.236678)
4. urban consolidation center 0.436366, (0.154641)

As stated before, the prioritization approach was accepted to determine the relative merit of a set of alternatives. All alternatives included into the ANP model are supplementary to some extent. Some of them may be considered as a favourable precondition for achieving measures of a higher level of complexity. This is the case in the regulatory scenario and the current traffic management policy. The possibility to implement restrictions (weight, time, etc.) depends on the existing inner city traffic regulations and effective enforcement. Regulatory measures influencing freight vehicles complement regulations already in place in sensitive areas. If properly managed, they allow a seamless introduction and positive feedback from involved actors - retailers, transport companies and the community. This is reflected by the highest ranking of the regulatory scenario among other alternatives. The current traffic policy was regarded as a continuation of different measures, for example speed limits, restricted parking zones etc., and ITS road management systems covering arterial roads and other roads if needed. The relatively high ranking of this measure, scoring 0.71 of the best alternative, confirms the link between them. In practical terms, standard measures may be followed by more detailed regulatory solutions when applicable. The strong dominance of these two alternatives seems rational from the perspective of market development, existing examples and traffic conditions. Because they are traffic-related measures, they may be a step forward towards more complex solutions such as operator cooperation or an urban consolidation center. Cooperation and UCC differ in character because they focus mainly on logistic chain efficiency. While they follow similar objectives, they differ in the implementation methods and level of interference with existing delivery patterns. Both require a well developed cooperation between operators, significant pressure on the quality of deliveries and, in the case of UCC, on direct involvement of city authorities. Especially the UCC concept requires a high level of public involvement. To implement the consolidated deliveries scheme with a UCC as a central point, strict traffic regulations are important as a factor influencing both freight demand and supply. Direct subsidies are required in most cases, not only in the initial phase, but most likely during the whole period of operation. All of these factors make such initiatives very demanding and vulnerable to unexpected circumstances. This limitation is reflected with lower priorities derived from the model for

voluntary cooperation and UCC, 0.66 and 0.43 respectively. In other words, UCC is about 2.5 times less plausible than the regulatory scenario within existing and predicted conditions.

CONCLUSIONS

The evaluation of freight management measures carried out with the analytic network process (ANP) method provided some important findings. If well structured, this method can serve as a useful management tool for decision-makers seeking support with complex problems. The analysis can be performed for different levels of detail regarding the decision criteria or alternatives to be verified. It provides an opportunity to include and rationalize many opinions from experts, stakeholders, businesses and decision-makers. The ANP follows a natural process of comparing alternatives in accordance with the influencing factors. It can guide this process through a flexible structure of the model and achieve understandable results in the form of priorities.

The results achieved with the model and studies of literature reveal a growing importance of dedicated freight-related measures within urban transport policy. Freight traffic produces increasing pressures on urban transport systems and the city itself. As a consequence, the negative side-effects of transport are likely to exceed public acceptance and the capacity of the transport system. A rational evaluation is essential as a prerequisite for a successful introduction of optimal measures. Pursuing idealistic objectives is out of the question. Solutions should be tailor-made to existing problems, but with an option to expand if required. The ANP model showed that regulatory measures are the most feasible measure, as exemplified in the current policy profile and experiences from other cities. The final form of this measure should be developed with a detailed technical analysis covering both economic and traffic flow related aspects because different combinations of the practical tools are possible.

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OCENA WSKAŹNIKÓW ZARZĄDZANIA TRANSPORTEM MIEJSKIM

STRESZCZENIE. **Wstęp**: Problemy funkcjonowania przewozów ładunków w centrach miast stają się coraz wyraźniejsze wraz ze wzrostem poziomu motoryzacji oraz zmianami w strukturze popytu. W rezultacie łańcuchy dostaw stają się coraz bardziej uzależnione od częstych dostaw małych partii zróżnicowanych ładunków. Jest to typowy problem w większości współczesnych miast, którego rozwiązanie wymaga precyzyjnie dopasowanych narzędzi.

Metody: W celu uzyskania kompleksowej charakterystyki problemów związanych z transportem ładunków w miastach oraz ich możliwych rozwiązań dokonano analizy istniejących doświadczeń w tym zakresie. Specyfika poruszanej problematyki wymagała szerokiego podejścia badawczego. Obejmowało ono zarówno analizę szeregu przykładów i doświadczeń z miast europejskich, jak również weryfikację uwarunkowań teoretycznych. Na tej podstawie opracowano zbiór najczęściej występujących metod usprawnienia systemu transportu ładunków, który następnie poddano weryfikacji. W tym celu konieczne było zastosowanie metody analitycznej odzwierciedlającej złożoność badanego problemu. Musiała ona zapewniać elastyczność związaną z koniecznością uwzględnienia wielu zróżnicowanych kryteriów, przy zachowaniu jednocześnie przejrzystej struktury modelu. Do tego celu została wybrana metoda analitycznego procesu sieciowego (ANP - analytic network process). Jest to metoda wielokryterialnego wspomagania procesu decyzyjnego stosowana w złożonych problemach decyzyjnych, umożliwiająca relatywną ocenę zarówno wymiernych jak i niewymiernych czynników. Założeniem autora było stworzenie modelu zachowującego racjonalny poziom szczegółowości odzwierciedlający wszystkie najważniejsze kryteria decyzyjne oraz interesy zaangażowanych podmiotów.

Wyniki i Wnioski: Przeprowadzona analiza wykazała, że w obecnej sytuacji optymalnym rozwiązaniem w Gdańsku może być wdrożenie rozwiązań o charakterze regulacyjnym. Odzwierciedla to przekonanie, że jedynie wyważone i przemyślane rozwiązania mogą przyczynić się do usprawnienia systemu transportu ładunków bez narażania na szwank lokalnej gospodarki. Ich wdrożenie powinno być wynikiem regularnie prowadzonych analiz funkcjonowania miejskiego systemu transportowego. Natomiast wdrożenie narzędzi o bardziej złożonym charakterze jest uzależnione od zaangażowania wszystkich zainteresowanych podmiotów w formie planowania oddolnego. W innym przypadku, forsowanie nadmiernie skomplikowanych rozwiązań pozbawionych praktycznego uzasadnienia spowoduje efekty odwrotne do zamierzonych..

Słowa kluczowe: transport ładunków w miastach, logistyka miejska, miejska polityka transportowa, analityczny proces sieciowy ANP.

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KENNZIFFER-BEWERTUNG IM STÄDTISCHEN TRANSPORT-MANAGEMENT

ZUSAMMENFASSUNG. Einleitung: Die Probleme mit der Warentransport-Logistik in den Stadtzentren werden mit der Entwicklung des Verkehrs und der Struktur der Nachfrage immer deutlicher. Im Endeffekt werden die Logistikketten immer stärker abhängig von häufigeren Lieferungen der kleineren Chargen, die aus differenzierten Waren bestehen. Es ist ein typisches Problem für moderne Städte, das nur mit präzise angepassten Instrumenten gelöst werden kann.
Methoden: Zwecks Aufnahme der komplexen Charakteristik der Probleme, die mit der Warenlogistik in den Städten verbunden sind und in Bezug auf die Entwicklung von möglichen Lösungen, wurden die in diesem Bereich schon vorhandenen Erfahrungen analysiert. Der spezifische Charakter der untersuchten Problematik verlangte eine breite Palette von Instrumenten der Forschungsmethodik: sie umfasste sowohl die Analyse von zahlreichen Beispielen und Erfahrungen der europäischen Städte, als auch die Verifizierung der theoretischen Voraussetzungen. Auf diesem Grund ist eine Sammlung der am häufigsten vorkommenden Methoden der Steigerung der Leistungsfähigkeit der Logistikkette entwickelt worden, die dann nachträglich auch verifiziert wurde. Für diesen Zweck war es nötig, ein analytisches Verfahren zu verwenden, das die Komplexität des untersuchten Problems widerspiegeln könnte. Diese Methode musste Flexibilität gewährleisten, die mit der Notwendigkeit der Berücksichtigung von vielen unterschiedlichen Kriterien verbunden war, bei gleichzeitiger Beibehaltung einer transparenten Struktur des Modells. Zu diesem Zweck wurde die Methode des Analytischen Netzwerkprozesses (ANP) in Anspruch genommen. Es ist eine Methode zur Lösung von mehrkriteriellen Entscheidungsproblemen, die bei komplexen Entscheidungsproblemen verwendet wird und die eine relative Bewertung sowohl der messbaren, als auch nicht messbaren Faktoren ermöglicht. Die Voraussetzung des Autors war, ein Modell zu entwickeln, in dem ein rationelles Niveau der Ausführlichkeit beibehalten wird und welches alle wichtigen Entscheidungskriterien und Interessen der betroffenen Akteure widerspiegelt.
Schlussfolgerungen: Die durchgeführte Analyse hat gezeigt, dass in der heutigen Situation die optimale Lösung für Danzig (Gdańsk) wäre, Lösungen vom Regulierungscharakter einzuführen. Es widerspiegelt die Überzeugung, dass nur ausgeglichene und durchdachte Lösungen dazu beitragen können, dass die City-Logistik leistungsfähiger wird, ohne die lokale Wirtschaft zu verletzen. Die Einführung dieser Lösungen sollte das Ergebnis der regelmäßig durchgeführten Analysen des städtischen Transportsystems sein. Was den Einsatz der Instrumente, die einen mehr komplexen Charakter haben, anbetrifft, dann ist er vom Engagement aller interessierten Akteure in die Planung "von unten" abhängig. In anderem Fall wird das Forcieren von übermäßig komplizierten Lösungen, die keine praktische Begründung haben, zu einem ganz anderen Ergebnis führen, als das beabsichtigte.

Codewörter: städtischen Transportsystem, City-Logistik, Methode des Analytischen Netzwerkprozessen ANP

Daniel Kaszubowski
Gdansk University of Technology
Faculty of Civil and Environmental Engineering
Highway Engineering
ul. Narutowicza 11/12
80-233 Gdańsk
phone: 692-478-220
e-mail: daniel.kaszubowski@pg.gda.pl

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AUTOMATION OF THE LOGISTICS CHAIN IN THE FORM OF AN INNOVATIVE CONCEPT CONTAINER TRANSPORT SYSTEM FOR LUGGAGE HANDLING AT AIRPORTS

Bernd Hentschel[1], Gerhard Richtsteig[2], Karol Górski[3]

[1)] BERLINOXX Projektzentrum Logistiknetzwerke Berlin, **Germany**, [2)] Richtsteig Anlagentechnik GmbH & Co. KG, Eisenhüttenstadt, **Germany,** [3)] Institute of Logistics and Warehousing,Poznan, **Poland**

ABSTRACT. Background: The transport of luggage units between the check-in terminal and airplanes is realized by the use of very simple transport solutions and manual reloading of the luggage. The luggage trolleys are used for the transport purposes, which are hitched to the mover and moved directly to the surroundings of the airplane. The loading and unloading of luggage is performed manually. Regarding actual safety requirements there was a need to create a new transport system, working in a closed cycle and based on the device for automatic loading and unloading of luggage units.
Methods: Various potential variants of the device were generated based on results of analytical researches by the use of the morphological schema. The detail evaluation and the optimization of individual variants allow to prepare the concept of the complex method to solve problems of the reliable transport of luggage units within an airport.
Results: The closed transport system was created as a result of the innovative project. The main element of this system is a container trolley, which is equipped in five storage layers. By the use of the special mover and gravitational forces, luggage units can be transported and placed inside this trolley as well as being loaded and unloaded. This solution enables to move 200 pieces of luggage in one transport cycle from the check-in terminal to the hatchway of the airplane.

Key words: automation, supply chain, innovative transport system, container trolley, logistics, luggage handling, transport space between chek-in terminal and the airplane, airports.

ASSUMPTIONS OF THE CONCEPT AND PRESENTATION OF TRANSPORT SYSTEMS OPERATING IN THIS AREA

The unsatisfactory state of systems of luggage transport at airports (from the check-in point until placing them in the luggage holds of an airplane) operating at present in this area was the starting point for the development of this concept.

The present situation can be described as follows:

- The luggage, labelled with the destination address, is taken over at the exit of the terminal usually by two persons of the ground staff (truck driver and ground worker), who manually arrange the luggage on luggage trolleys. This operation is performed in rather chaotic ways, resulting in the mutual pressure of individual units of luggage, and which in turn can cause the potential damages.
- This transport process is usually supported by wheel sets, which consists of 4-5 trucks, all connected with the front mover. When the loading space is fulfilled up to maximum, the whole sets are transported from terminals to waiting airplanes (within terminals or internal taxing areas).

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- After reaching the airplane luggage hutch area, the luggage units are manually located (or rather thrown) on the conveyor belt. Then they are moved by the conveyor to the airplane hutch and placed within cargo space of the airplane. Usually this operation is conducted by two persons of the ground staff (driver and manual worker).
- Developments trends, observed currently in this field, aim to the change of characteristics of the physical load performed by workers employed in this area and lead to create and develop concepts of high mechanized luggage handling systems, operating within airport areas.
- Concepts of the use of luggage containers are one of postulated variants in this area. The use of luggage containers are expected to be implemented within big airports, where luggage units are reloaded within loading spaces of very big transport airplanes and warehouses used as the pre-storage of the luggage prior to the departure or in the buffer zones.
- The concepts proposed by innovation departments of companies "Lödige Industries" (www.loedige.com) and Projektlogistik GmbH (www.projektlogistik-gmbh.com) are ones of already introduced to the practice in this field. The company group Grenzebach (together with its departments "Airport" www.grenzebach.com) is another leading competitor in this field.

  Lödige company developed and implemented the concept of LSYS Putter, intended for mechanical loading and unloading of luggage containers, along with the function of taking the luggage units on conveyor belts.

Fig. 1. Solution LSYS Putter by Lödige company
Rys. 1. Rozwiązanie LSYS Putter firmy Lödige

Projektlogistik company developed the concept based on the solution called "Zero-G-Loader". This solution is concentrated on the loading and unloading of individual transport trolleys.

Fig. 2. The mechanized transport trolley. This solution was developed only until the prototype stage.
Rys. 2. Zmechanizowany wózek transportowy. Rozwiązanie to nie wyszło poza fazę wykonania prototypu doświadczalnego.

– Grenzebach company specializes in the field of loading and unloading of luggage containers. It prefers the simple, uncomplicated spilling of containers onto operating surfaces of conveyors.

The Danish company PowerStow A/S (www.powerstow.com) should be placed among the leading dynamic operators and specialists in the field of luggage handling within airports, thanks to its innovative solution of luggage units transport automation, called RampSnake. The RampSnake solution creates the essential coupling point with already existing solutions, which are used in the area of transport support of airports, especially within InterAirport in Monachium. This feature makes this solution an important and significant one.

Fig. 3.RampSnake in use (in coupling point: airplane and roll conveyor)
Rys. 3. RampSnake w użyciu (w punkcie sprzężenia: samolot w kontakcie operacyjnym z przenośnikiem rolkowym)

Other leading producers of this type of solutions operate on American market, among others: JBT AeroTech Corporation, Ground Support Servie Cart Corporation, Spokane Industries and others. JBT company already introduced the RampSnake solution to the practice as an effective transport system. It should be stated, that main selected solutions (expect this of Projektlogistik GmbH) were already patented.

Based on the pre-researches, conducted in the cooperation with specialists from selected airports (mainly Schönefeld as well as Tegel), it was concluded, that the desired solution should fulfill the following conditions:

- The possibility of the mechanical acceptance of luggage units at the exit of the check-in terminal without the physical handling by ground staff.
- The possibility of the luggage inspection with respect to its destination (there is a requirement of no mistakes with respect to the assignment of luggage units to their final destination). The external control at the end point of the conveyor at the exit from the terminal building is the preferred one.
- The possibility of the transport of the whole luggage (all luggage units) in one transfer operation between the terminal and the loading space of the airplane.
- The possibility of mechanical/automatic transfer of luggage units from transport trolleys to the device of Rampsnake type or of other type of the luggage transport device under condition that

the physical work of the ground staff will be eliminated or highly limited or the ergonomics of this work will be significantly improved.

The above-mentioned criteria determine the success of the research works concerning the devices for mechanical/automatic transport of luggage units and they are an indispensable part of innovations in this field, especially under condition of existing competition.

THE PATENT EXAMINATION

The patent examination was conducted by the use of DepatisNET system. This analysis was focus on the following expressions:

- Baggagehandling AND Systeme
- Handling AND Freight AND Container
- Front AND Loading AND Baggage
- Transportation AND Baggage
- Transportation AND Luggage
- Baggage AND Security
- Airport AND Transportation
- Ground AND Transportation AND System
- Container AND System AND Airport
- Airport AND Container
- Airport AND Baggage

No patent rights similar to devices of this project were found during the patent examination. Regardless of that, it was recommended to obtain the opinion of the patent attorney, who will determine the patent rights and conduct necessary additional analysis.

To protect the patent rights, the application was sent on 8th Sept. 2011 to the Office for Patent Protection Kietzmann, Vosseberg, with request to set the patent rights for above-mentioned prototype and its protection as an utility model. The protection of the utility model was legally set on 29th Sept. 2011 and registered under the No 20 2011 105 486.5. The patent application concerning the luggage units transport system in airports was registered under No 10 2011 112 898.8 in German Office of Patents and Utility Models on 29th Sept. 2011 and at present waits for the final decision.

THE GEOMETRY OF LUGGAGE UNITS AND THE KIND OF BUILDING MATERIAL

The following conclusions can be provided based on the analysis of the geometry of luggage units:

- The transported luggage units are of various geometry as well as of various hardness of building material, therefore they have various durability.
- The maximal weight of the transported suitcase is usually app. 20 kg, but there are many situations that there are suitcases of higher weight up to 30 kg (passenders usually accept such situations and without problems pay the additional manipulation charges).
- The relations of dimensions (length x width x height) range from minimal dimensions 20 x 20 x 20 cm up to size level of 70 x 28 60 cm for big suitcases in form of hard cuboids or soft travel bags.

- The hardness and the kind of building materials of luggage units range from textile bags (susceptible to crashing) to suitcases made of the leather or its imitations (partially susceptible to crashing), travel and sport bags (susceptible to crashing) and suitcases and other units made of inflexible materials (metal, plastics - not susceptible to crashing).
- There is a problem of various types of safety belts (of various clamp strength) individually applied in case of almost all types of luggage units. Especially the belts of loose clamp strength can cause problems during the implementation of the automation of the transport within airports (falling off such belts can cause very danger situation of hooking, catching, etc.).

LOGISTIC PROCESSES OCCURRING IN THE TRANSPORT AREA BETWEEN THE TERMINAL BUILDING AND THE AIRPLANE, PERFORMED BY THE SET OF TRANSPORT TROLLEYS

The following conditions must be fulfil by all devices of the airport transport system operating between the starting point of the transfer of the luggage unit from the belt conveyor, located in airport terminal to the final point within the luggage space of the airplane:

- The possibility of the reliable and collision-free coupling of elements of mobile transport system with the internal belt conveyor at the point of its exit from the wall of the airport terminal.
- The possibility of the immediate inspection of luggage units with respect to their assignment to the final destinations (the inspection of individual luggage units or in future, remote verification of the given destination by the use of the radio-frequency identification system (RFID) together with the return of the incorrectly assigned luggage units by the transfer of such units from external zone onto the elements on the transport system, operating between the airplane and the terminal (such kind of the inspection was not possible so far in presently used transport systems)).
- After the verification of the assignment of the luggage unit to the given destination, there is a possibility to transfer standing suitcases and bags onto the devices of the internal transport system and to assign them the location within the internal waiting interoperetional zone.
- The determined number of luggage units can be transported depending on the given system. The required transport efficiency of individual systems are presented below (based on data of Frankfurt (Main) airport:

  The typical types of airplanes with the manual loading of the luggage:

  B737 version 300 - 800

  B757 version 200 + 300

  A319, A320/A321 (partially manual loading, depending on airlines)

  TU154, ATR42 + 72 Cargo

  The share of airplanes with the manual loading of the luggage in total number of loadings is about 30% (B737, B757, A319) or even 40%, taking into consideration such types of airplanes like MD80, Embraer, etc.

  The average quantity of luggage units is:

  B738 = approx. 160 pieces

  B752 = approx. 180 pieces

  B753 = approx. 200 pieces.

  The ULD type devices are used in case of bigger types of airplanes (B747, A340 and bigger).

The decrease of transport cycles between the terminal and the airplane is the preferable goal in this case.

- The possibility of trolley transport (by the use of a mover of with the own drive) within the surroundings of a hatchway of the airplane, where the belt conveyors or RampSnake type devices are used. It allows the reliable coupling of distant points of both systems and the mechanical transfer of luggage units on the conveyor belt. There is no need for another verification of suitcases in respect of their proper destination. The driver of the transport set is the last control instance to exclude possible mistakes.
- The possibility of the extension of elements of each system as well as to repeat the transport operations.

THE PRESENTATION OF VARIANTS BY THE USE OF THE MORPHOLOGICAL SCHEMA

The morphological schema was created at the stage of study researches to describe the specific requirements of individual solutions of the transport between the terminal building and the storage spaces of the airplane. It allows to identify individual, technically workable variants of handling and transport devices.

The description of components of this schema is presented in the table 1, where six basic variants of the solution are distinguished. It was created based on consultations with specialists, who work at the airport Schönefeld as well as on the specialist knowledge, provided by the international company Vanderlande Industries. The prepared internal evaluation matrix allows the evaluation of factors with respect to their importance and significance. Based on it, two variants of the significant importance for proposed solutions were selected.

Table 1. The morphological schema of variants' description
Tabela 1. Morfologiczny schemat dla opisu wariantów

Function	**Solution 1**	**Solution 2**	**Solution 3**	**Solution 4**	**Solution 5**	**Solution 6**
Acceptance from conveyor belt and transfer to con- tainer trolley F1	transfer directly on the roller- band device	manual handling	separate extendable device	direct transfer by the gravity usage	external manipulator at the access belt	
internal transport solution in con- tainer trolley F2	driven conveyor belt	roller band	friction band with side drive	roller band with side unloading	manual handling by ground staff	free running roller cart
storage in con- tainer trolley F3 (horizontally)	single deck	multiple deck of fix height	multiple deck of various height			
identification of luggage at the transfer point	label scanning at reloading point	RFID- identification	manual inspection by ground staff			
unloading of luggage on the external conveyor belt F5	direct transfer on transport conveyor, driven by motor	manual handling	extendable allocating device driven by motor	external manipulator on conveyor belt	free-running roller cart	
drive type F6	external towing vehicle	own petrol motor	own battery motor			
construction type of airport con- tainer trolley F7	connected individual trailers	flexible "Snake" construction	solid construction			

Variant 1: F1/L1 - F2/L2 -F3/L3 - F4/L1 - F5/L1 - F6/L3 - F7/L2
Variant 2: F1/L4 - F2/L2 - F3 /L3 -F4/L2 -F5/L1 - F6/L3 - F7/L2
Variant 3: F1/L1 - F2/L3 - F3/L2 - F4/L1 - F5/L1 - F6/L3 - F7/L2
Variant 4: F1/L1 - F2/L3 - F3/L2 - F4/L2 - F5/L1 - F6/L3 - F7/L2
Variant 5: F1/L4 - F2/L6 - F3/L3 - F4/L1 - F5/L5 - F6/L3 - F7/L3
Variant 6: F1/L4 - F2/L6 - F3/L3 - F4/L1 - F5/L5 - F6/L3 - F7/L3 - preferable target variant

The two from above-mentioned variants were selected and put to the further analysis, i.e.:

Morphological variant 1 ——————————

Morphological variant 6 - - - - - - - - - - - - - - - - - -

AT the beginning, the morphological schema included also the variant, represented by the conveyor, equipped in transport band using the static friction. The development of this variant was not continued due to the technical problems in the concept phase of this research. These problems were connected with the necessity of the implementation of the additional tilting device to enable positioning of units on side storage locations. The conducted researches and analysis indicated the variant 6, as the most promising one to be implemented in the form of the innovation project. This solution was also recommended by prominent experts in the field of the internal transport, i.a. Karl-Heinz Dullinger (long-term president of Vanderlande Industries) and Ing. Leichtweiß from Lödige Industries company.

Table 2. Analysis of the morphological schema of variants' description
Tabela 2. Analiza morfologicznego schematu dla opisu wariantów

Function	**Solution 1**	**Solution 2**	**Solution 3**	**Solution 4**	**Solution 5**	**Solution 6**
Acceptance from conveyor belt and transfer to container trolley F1	transfer directly on the roller-band device	manual handling	separate extendable device	direct transfer by the gravity usage	external manipulator at the access belt	
internal transport solution in container trolley F2	driven conveyor belt	roller band	friction band with side drive	roller band with side unloading	manual handling by ground staff	free running roller cart
storage in container trolley F3 (horizontally)	single deck	multiple deck of fix height	multiple deck of various height			
identification of luggage at the transfer point	label scanning	RFID-identification	manual inspection by ground staff			
unloading of luggage on the external conveyor belt F5	direct transfer on transport conveyor, driven by motor	manual handling	extendable allocating device driven by motor	external manipulator on conveyor belt	free-running roller cart	
drive type F6	external towing vehicle	own petrol motor	own battery motor			
construction type of airport container trolley F7	connected individual trailers	flexible "Snake" construction	solid construction			

Variant 1: F1/L1 - F2/L2 -F3/L3 - F4/L1 - F5/L1 - F6/L3 - F7/L2
Variant 2: F1/L4 - F2/L2 - F3 /L3 -F4/L2 -F5/L1 - F6/L3 - F7/L2
Variant 3: F1/L1 - F2/L3 - F3/L2 - F4/L1 - F5/L1 - F6/L3 - F7/L2
Variant 4: F1/L1 - F2/L3 - F3/L2 - F4/L2 - F5/L1 - F6/L3 - F7/L2
Variant 5: F1/L4 - F2/L6 - F3/L3 - F4/L1 - F5/L5 - F6/L3 - F7/L3
Variant 6: F1/L4 - F2/L6 - F3/L3 - F4/L1 - F5/L5 - F6/L3 - F7/L3 - preferable target variant

Both solutions (variants 1 and 6) will be presented below in the form of the project, but the main focus is put on the realisation of the variant 6 (in agreement with common opinion of experts in the area of the airport transport logistics from Schönefeld airport as well as of the market practice of Vanderlande Industries company).

THE CONCEPT OF THE PREFERABLE VARIANT

The project conditions for the variants, which obtained the recommendation of potential users, are presented below.

The concept of the set used for the transport of luggage units is based mainly on a set of a few trolleys or one solid construction. The maximal number of transported suitcases was evaluated on the basis of experimental researches, conducted in the airport in Frankfurt am Main. It is equal to 200 pieces and the number was taken as an assumption to create the project of the transport system for the passenger service in airports.

The transported units were assumed to be delivered in the horizontal position and of maximal dimensions equal to 70 cm x 60 cm (length x width). The designed system must be able to handle also smaller luggage units of dimensions 20 cm x 20 cm.

To support and assure the transport of max. 200 pieces of luggage in one operation cycle, the transport device was equipped in multi-level system of parallel storage areas.

Assuming, that the transport trolley is equipped in 5 storage layers and the maximum loading is 200 pieces, then 40 luggage units must be arranged on each layer. The presumed configuration of the layout of transported luggage units along three parallel lines (working version) and the length of one suitcase equal to 700 mm, determines the total length of transport device to be 9100 mm, having 13 luggage units arranged in one line and on one level (13 x 700 mm). Taking into consideration construction parts of the transport trolley, at this phase of the research, the total length of this trolley was assumed to be 10000 mm.

Both variants, intended to be realized, are presented as Attach. 1 and 2 of this paper.

THE CONSTRUCTION OF THE WHEEL SET OF SNAKE TYPE

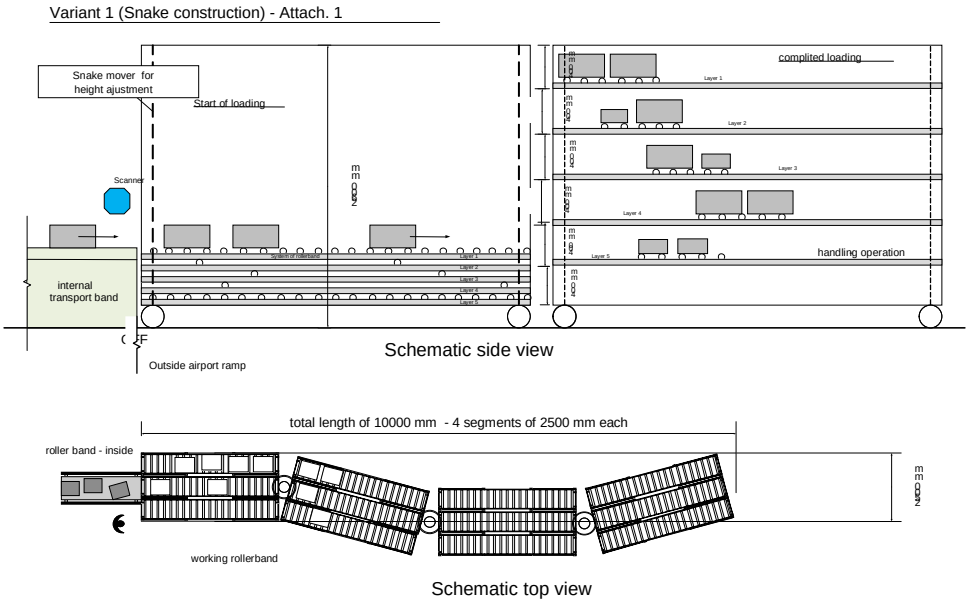

Fig. 4. The construction of multi-segment wheel set of Snake type purposed for the transport of luggage units
Rys. 4. Zasadnicza konstrukcja wieloczłonowego zestawu kołowego typu Snake przeznaczonego do transport jednostek bagażowych

The construction of wheel set of Snake type consists of four carriages, connected with each other. At the beginning of this work, the possibility of creating the one segment vehicle of flexible body was

taken into consideration. It turned out to be impossible due to technical problems. The biggest problem was the transfer of luggage units from one segment to another one in case the whole device is flexible like a snake.

The segmentation of the set into four separate carriages turned out to be not optimal because of the excessive time needed for handling operations, especially that each carriage had to be handled separately both at the terminal exit and at the hatchway of the airplane. Therefore the continuation of the work on this variant was ceased. Additionally in this solution, there was a necessity to employ two additional workers, which caused extra costs and did not fit to cost reduction condition of this project.

THE CONSTRUCTION OF ONE SEGMENT VEHICLE IN THE FORM OF TRANSPORT CONTAINER

The concept of one-segment construction in the form of transport container turned out to be the most optimal solution from the economical and technical point of view:

- It turned out, that it is possible to construct a "container trolley", equipped in three parallel storage flows, within which the luggage units move under gravitational forces over rolls till the hatchway.
- The construction of the space was adapted to dimensions and geometry of 200 suitcases (luggage load of an airplane of the average size) and equipped in five separately operating storage layers, each of them can be levelled up to the desired height by the snake device (its construction is not yet confirmed).
- The principle of operation is as follows:
  - the back of container trolley is placed up to the belt conveyor at the exit of the check-in terminal,
  - the arrangement of luggage units on the first storage level by gravitational forces until filling in the whole available space. It is available due to slopes of the surfaces inside the trolley where the units are placed.
  - the snake drive levels the storage layer in the top location of the container space,
  - all four storage layers are loaded with the luggage units. The storage layers 2-4 are also moved to the top and positioned in the transport configuration,
  - the fifth storage layer is loaded. Due to the fact, that at each level there are parallel configurated storage layers, each of them should be moved horizontally to allow the loading operation of each storage layer at each of levels. There is still no technical solution of this issue. There is still a need of further consultations with the logistics provider, responsible for luggage transport within the airport.
  - After loading all 200 suitcases (so the maximal quantity of luggage units) at the exit of check-in terminal onto all 15 storage layers, the special vehicle moves the transport container between the terminal container and the belt conveyor. The task of this conveyor is to move separate suitcases to the hatchway of the airplane.
  - At this moment, starting from the level 5, the luggage units are moved gravitationally (by the change of the rake of storage layer) on the external belt conveyor (there is still a need to conduct additional researches, due to the fact that belts and safety bands of different type, cause difficulties in free movement of units or even their blockage because of hooking).
  - After unloading, the storage layer 5 reaches its starting position (the lowest one) and is inactivated. Then, the storage layer 4 moves to the position, which enable the unloading of luggage units and the operation of unloading takes place.

– The above-mentioned operations repeat until the moment of unloading the storage layer 1, which means the return of the device to position "ready for new loading operation". There is also an assumption, that the external belt conveyor (it can be a device of RampSnake type) can change its position and take over suitcases located on the band of conveyor, which is configurated parallel.

– The operator of the transport system controls the whole time the loading and unloading processes, therefore there is no need for additional workers for reloading of the luggage on the belt conveyor within the check-in terminal or on the external belt conveyor, located within hatchways of the airplane. Therefore it was possible to resign from two additional workers in this investigated variant, especially that the trolley operator inspects all alone the whole process of loading and unloading of luggage units.

– Each phase of this process is presented at the Figures 5.1-5.3.

– The construction of the container trolley requires still the detail solution of individual parts of this system:

  – Each storage layer using the gravitational forces by the implementation of slope, must be additionally equipped in an element, located in the middle, which will compensate the differences in length of individual levels.

  – It must be the possibility to move individual storage layer vertically by the use of snake gear or other driving system.

  – It is assumed, that the scanning of luggage units will take place within the check-in terminal (it will secure the conformity of each luggage unit to its destination). The rescanning before the arrangement of luggage units in the loading space of airplanes is taken additionally into consideration, which should ensure 100% reliability of the system with respect to avoid mistakes connected with luggage of travellers.

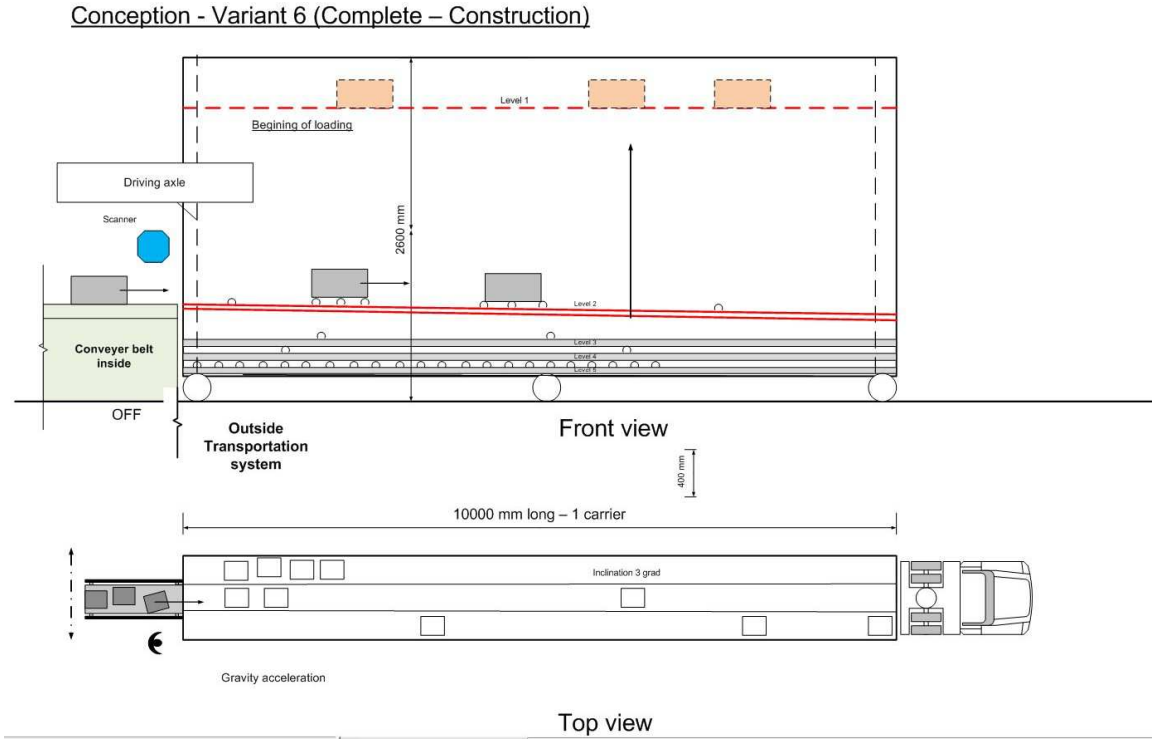

Fig. 5.1. The transport system of luggage units in airports using the container trolley - during the additional loading
Rys. 5.1. System transportu jednostek bagażowych w portach lotniczych przy pomocy wózka kontenerowego - w trakcie trwania operacji doładunku

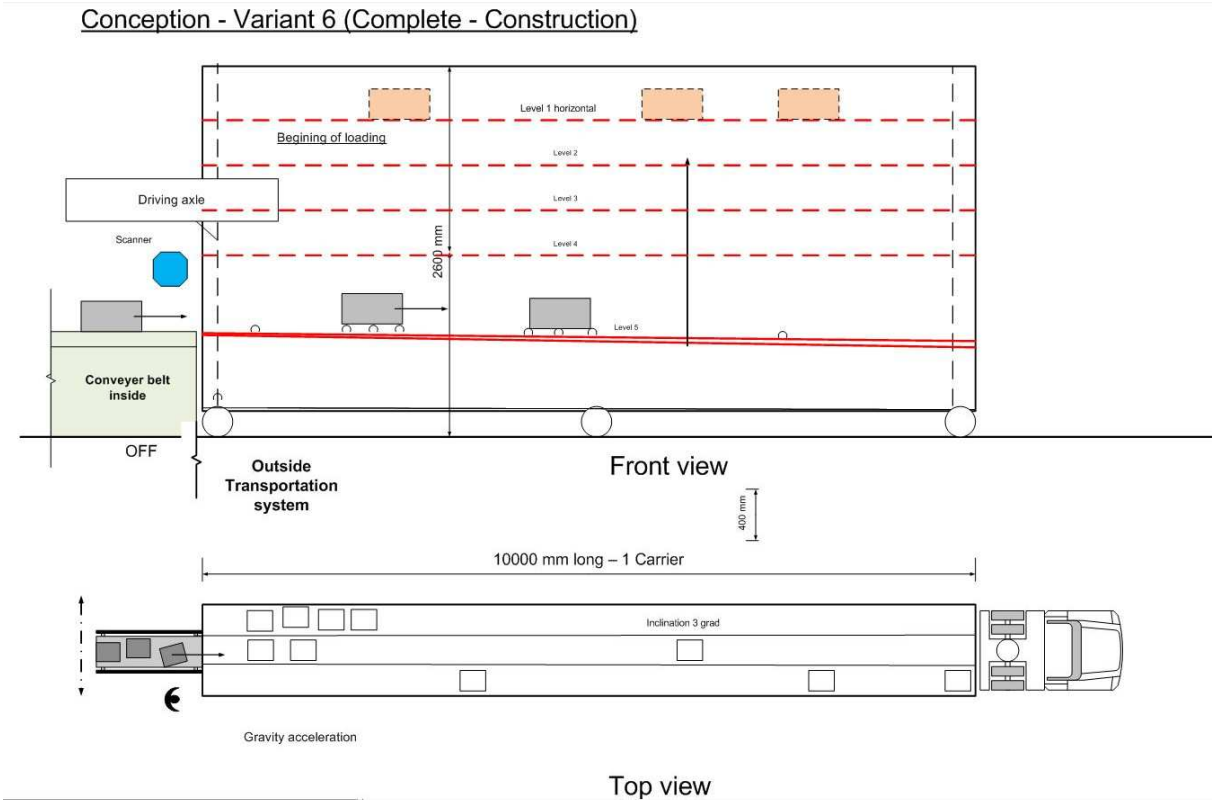

Fig. 5.2. The transport system of luggage units in airports using the container trolley - after additional loading operation

Rys. 5.2. System transportu jednostek bagażowych w portach lotniczych przy pomocy wózka kontenerowego - w stanie zakończonego doładunku

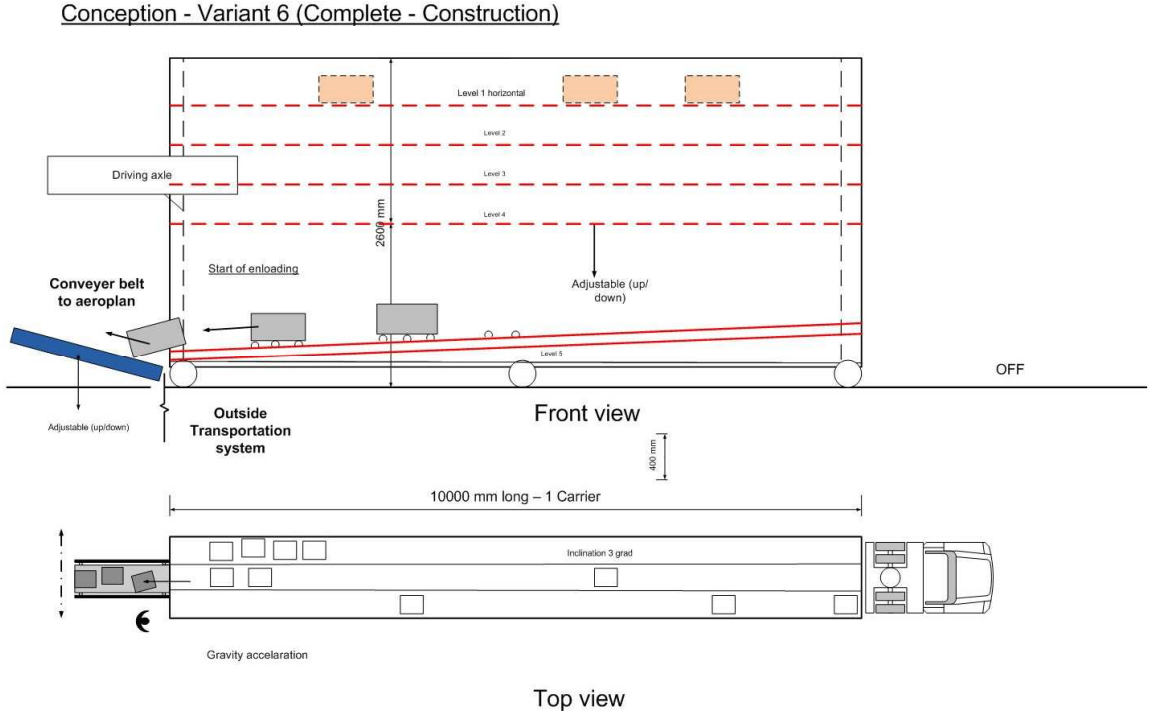

Fig. 5.3. The transport system of luggage units in airports using the container trolley - at the moment of coupling with external belt conveyor, working at the hatchway of an airplane

Rys. 5.3. System transportu jednostek bagażowych w portach lotniczych przy pomocy wózka kontenerowego - w stanie sprzężenia z zewnętrznym przenośnikiem taśmowym, obsługującym wloty do luków bagażowych samolotu

– There is still open topic of the selection of the cover of one-segment container trolley as well as its wheel construction and their integration with the undercarriage. The possibility to move separate storage layers lengthwise should be ensured to improve the construction variants of the trolley. It should be possible to extend and fold up lengthwise these layers by lifting and lowering them.

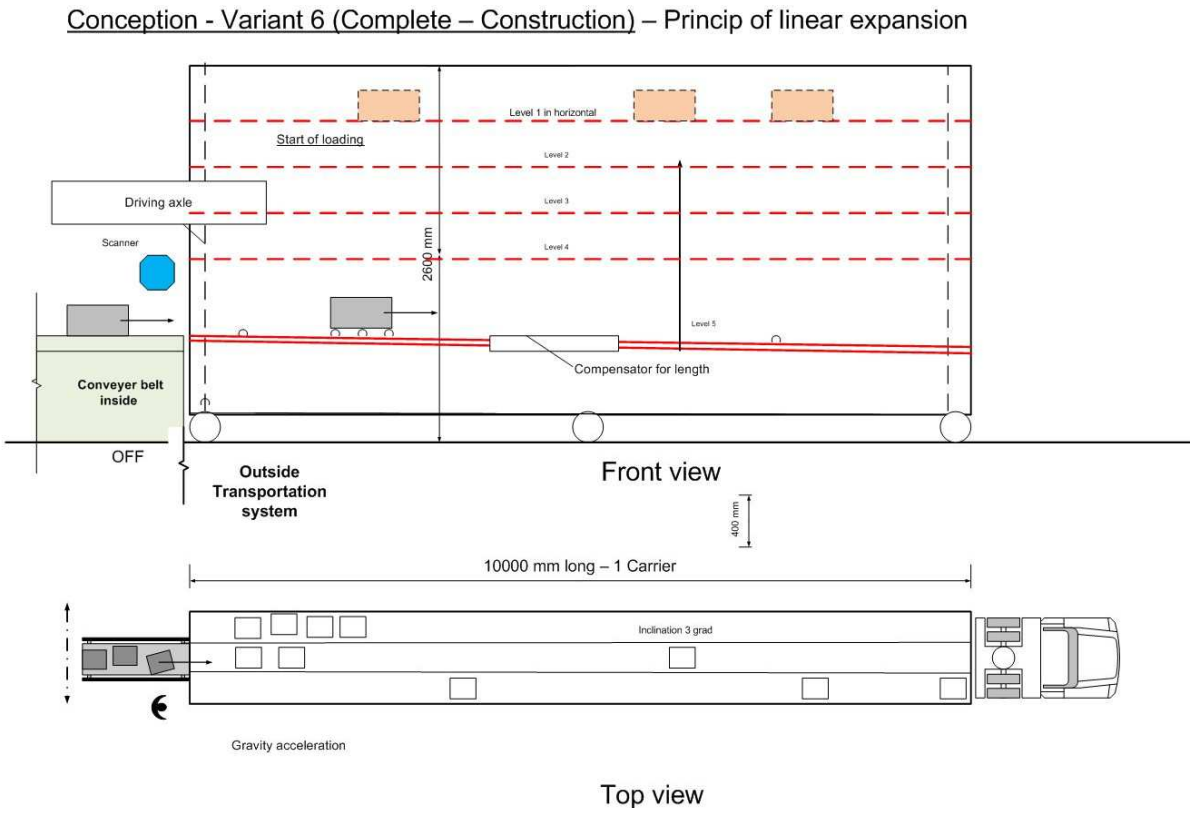

Fig. 5.4. The schema presenting the possibility to move layers horizontally
Rys. 5.4. Schemat obrazujący możliwość przesuwania poziomów w kierunku wzdłużnym

The front view schema of transport system is presented in figure 6, which allows to demonstrate the way how individual layers perform. The geometric dimensions of the system are also presented at this figure:

– the width is equal to 2700 mm together with additional size of both wheels of the trolley,
– the height is equal to 2625 mm.

This geometry allows an effective transport of max. 200 luggage units, and therefore the optimal service of airplanes of the average size.

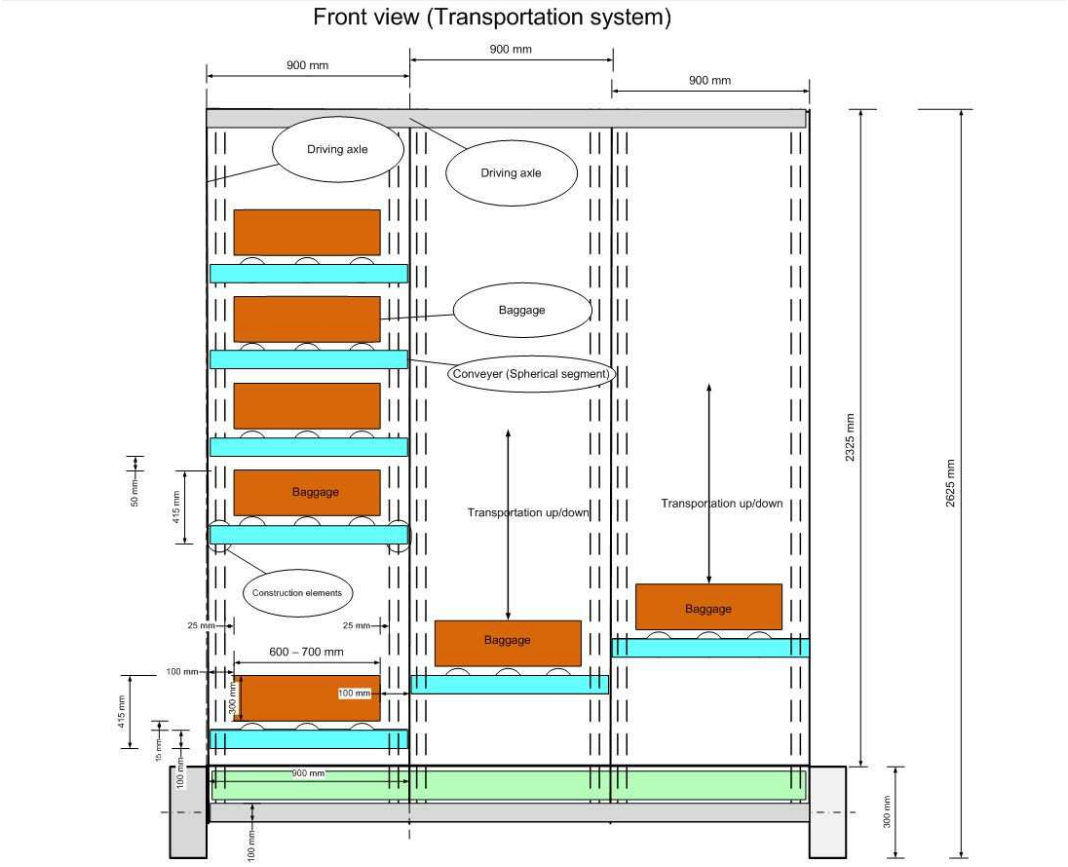

Fig. 6. The front view and the schema how three given loading spaces and storage layers operate
Rys. 6. Rzut czołowy wraz ze schematem funkcjonowania 3 poszczególnych przestrzeni ładunkowych i poziomów odkładczych

SUMMARY AND CONCLUSIONS

The potential automated solution how to create logistic processes inside the airport area, between check-in terminals and hatchways of airplanes was presented. The presented solution is a compact, uniform and complex concept, within which an attempt is made to create the possibility to transport a set of luggage units of one destination in one cycle, between check-in terminal and an airplane of an average size. It fulfils all actual safety requirements thanks to the great integration of identification systems for the luggage units with their content as well as to its closed structure. Therefore this system excludes the possibility to mistakenly change the luggage in regards to its destination, and at the same time it minimizes the risk of eventual terrorist attacks.

Based on presented system, the problem of transport logistics inside airports can be solved in a complex way. The technical solution of a proposed container trolley, which works in the form of RampSnake device, assures the reliable and collision-free transport of luggage units from the check-in terminal to the hatchways of airplanes.

The innovative input of originators of this project (Hentschel, Richtsteig) relates to the creation of sophisticated solutions of highly efficient systems of goods flow, based on automatically controlled storage fields of this trolley as well as automatic stations for picking luggage units in check-in area and transporting them to hatchways of airplanes. The innovation of this solution consists mainly of the speed of transport processes realized. The challenge of this task lies in the differentiation of the geometry of transported luggage units and the threat of their blocking during their flow within the transport system. Richtsteig company possesses all engineering competences for effective realization

of this project as well as is supported by the scientific environment. All these factors ensure the creation of such sophisticated solutions in the area of material flow systems. The internal steering system of such multilevel system cannot be an easy one, only the transfer of luggage units on transponder band manually and in automatically steering one should be considered as a very innovative challenge.

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AUTOMATYZACJA ŁAŃCUCHA LOGISTYCZNEGO W FORMIE INNOWACYJNEJ KONCEPCJI ROZWOJU SYSTEMU TRANSPORTU KONTENERÓW DO TRANSPORTU BAGAŻU W PORTACH LOTNICZYCH

STRESZCZENIE. **Wstęp:** Transport jednostek bagażowych pomiędzy budynkami terminali portów lotniczych a samolotami pasażerskimi charakteryzuje sie obecnie stosowaniem prostych rozwiązań transportowych i ręcznym przeładunkiem bagażu podróżnych. Do realizacji przedmiotowego transportu używa się wózków bagażowych, które podczepione pod ciągnik, przemieszcza się bezpośrednie w otoczenie obsługiwanego samolotu. Zarówno załadunek na wózki, jak również rozładunek w obrębie luków samolotowych odbywa się w ramach obsługi ręcznej.
Ze względu na współczesne wymogi bezpieczeństwa powstała potrzeba wygenerowania nowego, pracującego w cyklu zamkniętym systemu transportowego, opartego na automatycznym urządzeniu do za- i rozładunku jednostek bagażowych.
Metody: Na podstawie analitycznych wyników badań przy użyciu schematu morfologicznego wygenerowano szereg potencjalnych wariantów urządzenia. Ich szczegółowa ocena oraz optymalizacja poszczególnych wariantów pozwoliły na opracowanie koncepcji kompleksowego rozwiązania problemów w zakresie niezawodnego transportu jednostek bagażowych w portach lotniczych.

Wyniki: W wyniku realizacji innowacyjnego przedsięwzięcia powstał zamknięty system transportowy, którego istotę tworzy kontenerowy wózek, wyposażony w pięć poziomów odkładczych, które w oparciu o mechanizm unoszący oraz działanie siły grawitacji mogą zarówno przejmować i pozycjonować w swym wnętrzu jednostki bagażowe, jak również umożliwiać ich za- i wyładunek. Rozwiązanie w tym kształcie pozwala w ramach jednego cyklu transportowego na przemieszczenie 200 szt. bagażu z budynku terminala odpraw do luków bagażowych samolotu.

Słowa kluczowe: automatyzacja, łańcuch logistyczny, innowacyjny system transportu wewnętrznego, wózek kontenerowy, logistyka transportu bagażu, przestrzeń transportowa pomiedzy terminalem odpraw a samolotem, porty lotnicze

AUTOMATISIERUNG DER LOGISTIKKETTE FÜR DAS FLUGHAFENVORFELD IN AIRPORTS DURCH EIN INNOVATIVES FRACHTGUTTRANSPORTSYSTEM

ZUSAMMENFASSUNG. Einleitung: Gegenwärtig ist der Gepäcktransport im Bereich des Vorfeldes, somit zwischen Flughafengebäude und Flugzeug, durch eine einfache Transportlösung charakterisiert. Bevorzugt werden Einzelgepäckwagen, die von einer Zugmaschine gezogen, zum Flugzeug gefahren werden. Die Beladung der Wagen und auch die Entladung erfolgt manuell. Aus Sicherheitsgründen ist es erforderlich, eine neue, geschlossene Lösung mit automatisierter Be- und -Entladung zu entwickeln.
Methoden: Aus den analytischen Ergebnissen lassen sich über ein Morphologisches Schema unterschiedliche Varianten ermitteln.
Mittels einer Variantenbewertung und -optimierung ist eine Lösung für eine ganzheitliche Frachtgutlösung entwickelt worden.
Ergebnisse: Das Ergebnis ist ein geschlossenes Containersystem, das in fünf Ebenen über ein Hubsystem und unter Nutzung der Schwerkraft die Koffer aufnimmt und sowohl eine automatisierte Be- als auch Entladung ermöglicht. Es ist die Lösung so entwickelt worden, dass sie für 200 Gepäckstücke ausgelegt ist und somit nur einen einzigen Transport vom Flughafengebäude zum Flugzeug notwendig macht.

Codewörter: Automatisierung, Logistikkette, innovatives Frachtguttransportsystem, Containerwagen, Gepäcklogistik, Flughafenvorfeld, Airports

Prof. Dr.-Ing. habil. Bernd Hentschel
BERLINOXX Projektzentrum Logistiknetzwerke
Berlin, Germany
Dipl.-Ing. Gerhard Richtsteig
Richtsteig Anlagentechnik GmbH&Co.KG
Eisenhüttenstadt, Germany
MA. Karol Górski
Institute of Logistics and Warehousing
ul. Estkowskiego 6, 61-755 Poznan, Poland
e-mail: karol.gorski@wsl.com.pl

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AN EMPIRICAL ANALYSIS OF CONSUMER AWARENESS AND TRUST IN ORGANIC FOOD LEGISLATION IN CROATIA

Vesna Brčić-Stipčević, Kristina Petljak

Faculty of Economics and Business, Zagreb, **Croatia**

ABSTRACT. Background: The results of the research conducted in March 2009 on a representative sample of the citizens of the Republic of Croatia using a highly structured survey questionnaire in households have shown that the majority of the respondents (76.6%) are familiar with organic food. In the survey, special emphasis is put on the purchase of organic food, especially among regular buyers.
Methods: Regular buyers were asked about their familiarity with the information on the organic food declaration and their trust in the reliability of the information on the organic food declaration. Furthermore, research explored respondents' familiarity with the label organic product of Croatia according to frequency of organic food purchase. Also, research explored consumer trust in organic food monitoring and control system in Croatia.
Results and conclusions: The research gives insight into familiarity with measures for organic food consumer protection in Croatia and recommendations for organic food legislation bodies.

Key words: organic agriculture, Croatian market for organic food, organic food legislation, survey research.

INTRODUCTION

Organic agriculture was defined by the International Federation of Organic Agriculture Movements (IFOAM) as a production system that sustains the health of soils, ecosystems and people. It is a production system which relies on ecological processes, biodiversity and natural cycles adapted to local conditions, rather than the use of inputs with adverse effects [IFOAM, 2012]. Organic agriculture has developed as an answer to capital intensive agriculture and its negative ecological, social and economic consequences.

In Croatia, a legal framework for the regulation and development of organic agriculture is represented by the Act on the Organic Production of Agricultural Products and Foodstuffs (Zakon o ekološkoj proizvodnji poljoprivrednih i prehrambenih proizvoda) which was passed in 2001. This Act regulates organic production of agricultural products and foodstuffs, processing in organic agriculture, trade of organic food, unprocessed plant and animal products and products that are fully or partially composed of such products, labelling of organic products, inspection activities, certification process and incentives for organic farming. The purpose of organic agriculture is the protection of human health, nature, the environment and consumers.

An organic product is every agricultural product and foodstuff which is produced and marked in accordance with the Act on the Organic Production of Agricultural Products and Foodstuffs and the regulations based on it [Šamota et al., 2005]. The label organic product of Croatia (HRVATSKI EKO PROIZVOD) is a unique label in the Croatia which denotes that products have been produced in

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accordance with organic production standards and certified by a certification body [Krešić and Sučić, 2010]. The right to the use of the label organic product of Croatia for a period of one year is given by the Ministry of Agriculture, Fisheries and Rural Development based on the request of organic food producer and certificate. The label HRVATSKI EKO PROIZVOD (Figure 1) has been in use since 2008.

Source: Ordinance on labelling and marking of organic products, Official Gazette (Narodne novine), No. 10/07

Fig. 1. Label organic product of Croatia
Rys. 1. Chorwacka etykieta żywności organicznej

The development of organic production has also been developing organic food market. The organic food market in Croatia is still underdeveloped, but a number of organic farms have been growing rapidly [Petljak, 2011]. Consumers are becoming more concerned about their nutrition, health and food safety. Therefore, organic food has become an area of research interest for many authors.

METHODOLOGICAL APPROACH

Research instrument and data collection

The primary research was conducted in March 2009, through personal interviews in households using a highly structured questionnaire. For the purpose of this study, a nationally representative sample of 1,000 Croatian citizens older than 15 has been defined. The sources of the data for defining the framework for a sample selection were the results of the census conducted in 2001 by the Croatian Bureau of Statistics. The stratification is two-dimensional and was conducted according to two characteristics: (1) according to 6 traditional regions defined as a set of existing counties (Table 1) and (2) according to 4 settlement sizes (Table 2). Thus, a total of 24 strata were created.

Table 1. Respondents' representation by region
Tabela 1. Reprezentacja respondentów w regionie

Region	Number of respondents	% of respondents
Zagreb and surroundings	249	24.9
Northern Croatia	180	18.0
Slavonia	174	17.4
Lika, Kordun and Banovina	88	8.8
Istria, Primorje and Gorski Kotar	119	11.9
Dalmatia	190	19.0
Total	**1,000**	**100.0**

Source: primary research

Table 2. Respondents' representation by settlement size
Tabela 2. Reprezentacja respondentów według rozmiaru zasiedlenia

Settlement size	Number of respondents	% of respondents
up to 2,000 inhabitants	400	40.0
from 2,001 to 10,000 inhabitants	153	15.3
from 10,001 to 100,000 inhabitants	212	21.2
more than 100,001 inhabitants	235	23.5
Total	**1,000**	**100.0**

Source: primary research

Zagreb region and the surroundings includes Zagreb county and the City of Zagreb; Northern Croatia region includes Krapinsko-zagorska county, Varaždinska county, Koprivničko-križevačka county, Bjelovarsko-bilogorska county, Virovitičko-podravska county and Međimurska county; Slavonija region includes Požeško-slavonska county, Brodsko-posavska county, Osječko-baranjska county and Vukovarsko-srijemska county; Lika, Kordun and Banovina region includes Sisačko-moslavačka county, Karlovačka county and Ličko-senjska county; Istra, Primorje and Gorski kotar region includes Primorsko-goranska county and Istarska county, and Dalmatia region includes Zadarsko-kninska county, Šibenska county, Splitsko-dalmatinska county and Dubrovačko-neretvanska county.

To disseminate the survey and gather answers from respondents, the professional market research agency's network of field operatives was used. After all questionnaires were completed, the survey data was analyzed using the methods of descriptive and inferential statistics.

The objectives of this research were:

- to explore respondents' familiarity with organic food,
- to explore whether the respondents buy organic food and to which extent,
- to identify regular buyers of organic food, their familiarity with and trust in the information on the organic food declaration,
- to explore respondents' familiarity with the label organic product of Croatia,
- to explore respondents' familiarity with organic food monitoring and control system,
- to explore respondents' familiarity with measures for organic food consumer protection in Croatia.

Respondents' characteristics

Table 3 shows respondents' characteristics - gender, age, education level, number of household members, number of children under the age of 18, employment status, personal monthly income and monthly household income.

Table 3. Respondents' characteristics
Tabela 3. Charakterystyki respondentów

	n	***%***
Gender		
male	471	47.1
female	529	52.9
Age		
15-17	28	2.8
18-24	136	13.6
25-34	158	15.8
35-44	178	17.8
45-54	170	17.0
55-64	135	13.5
more than 65	195	19.5
Education level		
no elementary school	63	6.3
elementary school	163	16.3
high school (3 years)	196	19.6
high school (4 years)	442	44.2
college or higher education	136	13.6
Number of household members		
1 member	192	19.2
2 members	278	27.8
3 members	224	22.4
4 members	195	19.5
5 members and more	111	11.1
Number of children uder the age of 18		
children under the age of 6	127	12.7
children between 7 and 14 years	156	15.6
children between 15 and 18 years	102	10.2
no children under the age of 18	615	61.5
Employment status		
full-time employment	384	38.4
fix-term contract	53	5.3
part-time employment	25	2.5
not-registered	9	0.9
self-employment	16	1.6
unemployed	513	51.3
Personal monthly income		
less than 1,200 kn	73	7.3
1,201-2,000 kn	142	14.2
2,001-3,500 kn	215	21.5
3,501-5,500 kn	197	19.7
5,501-7,000 kn	51	5.1
7,001-9,000 kn	15	1.5
more than 9,000 kn	15	1.5
no personal monthly income	173	17.3
no answer	119	11.9
Monthly household income		
less than 1,800 kn	78	7.8
1,801-3,500 kn	169	16.9
3,501-5,500 kn	137	13.7
5,501-8,000 kn	171	17.1
8,001-11,000 kn	135	13.5
more than 11,000 kn	89	8.9
no answer	221	22.1
Total	**1,000**	**100.0**

Source: primary research

RESEARCH RESULTS ANALYSIS

Respondents' familiarity with organic food

From 1,000 research respondents, most of them (76.6%) are familiar with the definition of organic food (m=766). However, the smallest share of the respondents (11.0%) correctly defined organic food, i.e. the smallest share knows that organic food is the food which is produced using the procedures defined by the law on organic production. The most respondents (52.2%) think that organic food is the food produced without pesticides, chemical fertilizers, genetically modified organisms and other chemical additives. While 21.0% of the respondents think that organic food is the food produced on family farms using conventional agricultural techniques, 15.7% of the respondents think of organic food as the one produced without the use of genetically modified organisms. The research results show that although the respondents think that they are familiar with organic food that is not true because the smallest number of the respondents correctly define organic food.

The purchase of organic food

Half of the respondents (50.1%) said they never buy organic food. Organic food is rarely bought by 37.5% of the respondents, while 12.4% of the respondents often buy organic food. The above mentioned results are not only the specificity of the Croatian market. Similar findings about the low purchase of organic food on a regular basis have been found by Tarkiainen and Sundqvist as well [Aertsens et al., 2009]. Further analyses were conducted with the respondents who frequently buy organic food (m=95) and hereafter they are referred to as "regular buyers". The regular buyers of organic food buy it two to three times a week (32.2%) or weekly (22.3%). Less than once a month organic food is purchased by 18.8% of regular buyers, and two to three times a month by 17.2% of them. The smallest percentage of regular buyers (9.5%) buys organic food once a month. Furthermore, regular buyers often buy fresh fruit and vegetables (31.2%), bread and other bakery products (29.4%), milk and dairy products (24.0%). Other products such as honey, fresh meat and meat products, baby food are bought in smaller percentage (less than 10.0%), and the reason is their under-representation on the Croatian market [Petljak, 2010].

Regular buyers' familiarity with and trust in the information on the organic food declaration

Regular buyers of organic food were asked if they have read the information on the organic food declaration. The majority of regular buyers (66.1%) answered that they have read the information on the organic food declaration, while 33.9% of frequent buyers do not read the information on the organic food declaration. Afterwards, regular buyers were asked to answer what information there are on the organic food declaration. The distribution of responses is given in Table 4.

Table 4. Regular buyers' familiarity with the information on organic food declaration
Tabela 4. Znajomość regularnych odbiorców z informacją na deklaracji żywności organicznej

Information on declaration of organic food	**f**	**%**
Information which are prescribed by the ordinance on labelling	20	21.1
Information which are prescribed by the ordinance on labelling, the name of the control station and/or the code of the control station	15	15.8
Information which are prescribed by ordinance on labelling, the name of the control station and/or the code of the control station and the number of certificate	25	26.3
I do not know	35	36.8
Total	**95**	**100.0**

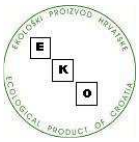
Source: primary research

The majority of regular buyers of organic food are not familiar with the information on the organic food declaration (36.8%). Furthermore, 26.3% of regular buyers answered correctly that the organic food declaration contains information which are prescribed by the ordinance on labelling, the name of the control station and/or the code of the control station and the number of certificate. Also, 21.1% of regular buyers consider that declaration contains information which is prescribed by the ordinance on labelling, and 15.8% of regular buyers consider that declaration contains information which is prescribed by the ordinance on labelling, the name of the control station and/or the code of the control station. After that, regular buyers of organic food were asked if they believed in the reliability of the information on the organic food declaration. The majority of regular buyers of organic food (73.8%) believe in the reliability of the information, while 26.2% of regular buyers do not believe in the reliability of the information on the organic food declaration.

Respondents' familiarity with the label organic product of Croatia

Respondents who are familiar with the definition of organic food (m=766) were asked about their familiarity with the label organic product of Croatia. Respondents were shown four labels (Table 5) and they were asked which of the labels the label organic product of Croatia is. Research results indicate that 43.6% of respondents are familiar with the label organic product of Croatia and 30.8% of respondents answered incorrectly. As many as 25.6% of respondents are not familiar with the label organic product of Croatia. These results indicate that further effort should be put into informing about and promoting the label organic product of Croatia.

Table 5. Respondents' familiarity with the label organic product of Croatia
Tabela 5. Znajomość respondentów na temat chorwackiej etykiety żywności organicznej

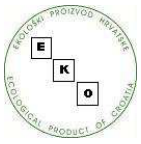
Label organic product of Croatia	**f**	**%**
	334	43.6
	46	6.0
	76	9.9
	114	14.9
I do not know	196	25.6
Total	**766**	**100.0**

Source: primary research

For further data analysis, all respondents (m=766) were divided into 3 categories: regular consumers, frequent consumers and those who do not consume organic food. Research confirmed statistically significant difference in the respondents' familiarity with the label organic product of Croatia and the frequency of purchase of organically produced food; χ^2=15.998, p <0.05 (Table 6).

The label organic product of Croatia is recognized by 43.6% of respondents. The largest percentage of respondents, who recognize the label organic product of Croatia are those who rarely buy organic food (46.9%) and the least those who buy it often (38.9%), which are indeed surprising results.

Table 6. Respondents' familiarity with the label organic product of Croatia according to the frequency of organic food purchase
Tabela 6. Znajomość odbiorców z chorwacką deklaracją żywności organicznej odnośnie częstotliwości zakupu żywności organicznej

Label organic product of Croatia	**Frequency of organic food purchase**						**Total**	
	often		**rarely**		**never**			
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**
	37	**38.9**	135	**46.8**	162	**42.3**	334	**43.6**
	11	**11.6**	18	**6.3**	17	**4.4**	46	**6.0**
	12	**12.6**	34	**11.8**	30	**7.8**	76	**9.9**
	13	**13.7**	40	**13.9**	61	**15.9**	114	**14.9**
I do not know	22	**23.2**	61	**21.2**	113	**29.5**	196	**25.6**
Total	95	**100.0**	288	**100.0**	383	**100.0**	766	**100.0**
χ^2, p	**χ^2 = 15.998; p<0.05**							

Source: primary research

Respondents' opinion about the organic food monitoring and control system

From the total number of respondents who are familiar with the definition of organic food (m=766), most of them (42.8%) are not aware of the existence of organic food monitoring and control system in Croatia. Respondents, who are familiar with the label organic product of Croatia, were asked about effectiveness of organic food monitoring and control system. As seen from Table 7, statistically significant difference is determined by respondents' opinion about the organic food monitoring and control system and frequency of organic food purchase (χ^2=20.994, p<0.01). Respondents who frequently buy organic food in the largest percentage believe that organic food monitoring and control system in Croatia is effective (48.7%) while that this system is effective believes 17.3% of respondents who do not buy organic food.

Table 7. Respondents' opinion about the effectiveness of organic food monitoring and control system according to the frequency of organic food purchase
Tabela 7. Opinia respondentów na temat efektywności systemu monitoringu i kontroli odnośnie częstotliwości zakupu żywności organicznej

Organic food monitoring and control system is effective.	**Frequency of organic food purchase**						**Total**	
	often		**rarely**		**never**			
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**
yes	18	**48.7**	32	**23.7**	28	**17.3**	78	**23.4**
no	10	**27.0**	55	**40.7**	56	**34.6**	121	**36.2**
I am not aware of existence of this system	9	**24.3**	48	**35.6**	78	**48.1**	135	**40.4**
Total	37	**100.0**	135	**100.0**	162	**100.0**	334	**100.0**
χ^2, p	**χ^2 = 20.994; p<0.01**							

Source: primary research

Respondents' familiarity with the measures for organic food consumer protection

The largest number of respondents (31.8%) believes that enhanced control of organic food producers from authorized institutions is measure for organic food consumer protection, as it is. 27.3% of respondents think that Consumer Protection Act (Zakon o zaštiti potrošača) is a measure for organic food consumer protection, while 24.3% of respondents think that the publication of the results of monitoring and control of individual organic food producers is a measure for organic food consumer protection. Finally, 15.5% of respondents are of the opinion that comparative tests for organic food are a measure for organic food consumer protection. If respondents were suspicious about the quality and freshness of organically produced food, the majority of them (25.9%) would not know who to contact for the protection of their consumer rights; 19.7% of respondents would notify sanitary inspection, 17.1% of respondents would inform the inspection and the Ministry of Agriculture, Fisheries and Rural Development, 11.8% of respondents would call the supervision station and 11.4% of respondents would call the inspection.

CONCLUSION

This paper presents the research findings based on the survey research conducted on a representative sample of respondents using a highly structured questionnaire. The first part of the paper elaborates on organic agriculture, with a special emphasis on organic food legislation in Croatia. The results of the conducted survey based on 1,000 respondents indicate that the respondents (m=766) think they are familiar with the definition of organic food, but when they were asked about the definition of organic food, the smallest percentage of the respondents (11.0%) knows that organic food is the food which is produced by using the procedures defined by the legislation on organic production. Half of the respondents (50.1%) said they never buy organic food. Organic food is rarely bought by 37.5% of the respondents, while 12.4% of the respondents often buy organic food. The majority of regular buyers (66.1%) claim that they read the information on the organic food declaration, but when asked about the information on the organic food declaration, only 26.2% of regular buyers gave the correct answer. Despite this, the majority of regular buyers of organic food (73.8%) believe in the reliability of the information on the organic food declaration. When asked about their familiarity with the label organic product of Croatia, research confirmed statistically significant difference in the familiarity of respondents with the label organic product of Croatia and the frequency of purchase (often, rarely, never) of organically produced food. In fact, the largest percentage of

respondents who recognize the label organic product of Croatia are those who rarely buy organic food and the smallest percentage are those who buy it often. Respondents who frequently buy organic food in the largest percentage believe that organic food monitoring and control system in Croatia is effective (48.7%), and those who never buy organic food in the largest percentage believe that this system is effective (17.3%). The largest number of respondents (31.8%) believes that enhanced control of organic food producers from authorized institutions protects consumers who consume organic food. The original contribution of this research is in the analysis of consumers' familiarity with organic food legislation in Croatia. Survey research results indicate the necessity for further education of consumers and informing them about organic food legislation in order to raise the awareness of organic food legislation and consumer confidence in organic food in Croatia. Above mentioned activities would certainly contribute to the further development of organic food market in Croatia. Therefore, this research provides very important implications for decision makers in Croatia, in terms of further steps needed to speed the development of organic agriculture and market for organic food in Croatia.

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EMPIRYCZNA ANALIZA ŚWIADOMOŚCI I ZAUFANIA KLIENTÓW DO USTAWODAWSTWA W ZAKRESIE ŻYWNOŚCI ORGANICZNEJ W CHORWACJI

STRESZCZENIE. **Wstęp:** Wyniki badań (z użyciem wysoko ustrukturyzowanych kwestionariuszy skierowanych do gospodarstw domowych) przeprowadzonych w marcu 2009 r. na reprezentacyjnej próbie mieszkańców Chorwacji wskazały, że większość respondentów (76,6%) jest zaznajomionych z żywnością organiczną.
Metody: W badaniach szczególny nacisk położony jest na zakup żywności organicznej, zwłaszcza przez regularnych odbiorców, którzy zostali zapytani o znajomość informacji znajdującej się w deklaracji organicznej żywności i pewność, czy jest to informacja rzetelna. Dalej badanie zgłębiło znajomość etykiety żywności organicznej odnośnie częstotliwości zakupu tej żywności. Ponadto badania opisują zaufanie konsumenta odnośnie monitorowania i systemu kontroli żywności organicznej w Chorwacji.
Wyniki i wnioski: Badanie daje wgląd w znajomość miar ochrony konsumenta żywności organicznej w Chorwacji i podaje rekomendacje dla organów legislacyjnych w zakresie żywności organicznej.

Słowa kluczowe: organiczne rolnictwo, chorwacki rynek żywności organicznej, ustawodawstwo dla żywności organicznej, badanie ankietowe.

EINE EMPIRISCHE ANALYSE DER BEWUSSTHEIT UND DES VERTRAUENS VON VERBRAUCHERN IN DIE BIO-LEBENSMITTEL ANBETREFFENDEN VORSCHRIFTEN IN KROATIEN

ZUSAMMENFASSUNG. Einleitung: Die Ergebnisse der im März 2009 an einer repräsentativen Stichprobe von Bürgern der Republik Kroatien mit Hilfe einer stark strukturierten Fragebogen-Umfrage in den Haushalten durchgeführten Forschung haben gezeigt, dass die Mehrheit der Befragten (76,6%) mit Bio-Lebensmitteln vertraut sind.
Methoden: In der Umfrage wurde besonderer Wert auf den Kauf von Bio-Lebensmitteln gesetzt, vor allem bei regelmäßigen Käufern. Die regelmäßigen Käufer wurden also nach ihrer Vertrautheit mit den auf der Deklaration befindlichen Angaben zu den Bio-Lebensmitteln sowie nach dem Vertrauen in Bezug auf die die Zuverlässigkeit der Informationen über die betreffenden Bio-Lebensmittel befragt. Im Rahmen der Forschung untersuchte man weiterhin die Vertrautheit der Befragten mit dem kroatischen Label für Bio-Produkte; diese wurde nach der Häufigkeit des Verbrauchs von Bio-Lebensmitteln beurteilt. Die Forschung ermittelte darüber hinaus das Vertrauen der Verbraucher in das Überwachungs-und Steuerungssystem für Bio-Lebensmittel in Kroatien.
Ergebnisse: Die empirischen Analysen ergaben einen Einblick in die Vertrautheit der kroatischen Bio-Lebensmittel-Verbraucher mit Maßnahmen des Verbraucher-Schutzes sowie zahlreiche Empfehlungen für die gesetzgebenden Körperschaften im Bereich der Bio-Lebensmittel.

Codewörter: Bio-Landwirtschaft, kroatischer Markt für Bio-Lebensmittel, Gesetzgebung von Bio-Lebensmitteln, Umfrageforschung.

Vesna Brčić-Stipčević, Ph. D.
Professor, Department of Trade
Faculty of Economics and Business, University of Zagreb
J. F. Kennedy Square 6, 10000 Zagreb, CROATIA
Phone: ++385 1 238 3383
Fax: ++385 1 233 5633
e-mail: vbrcic@efzg.hr

Kristina Petljak, Spec. M. Sc. Econ.
Teaching and Research Assistant, Department of Trade
Faculty of Economics and Business, University of Zagreb
J. F. Kennedy Square 6, 10000 Zagreb, CROATIA
Phone: ++385 1 238 3384
Fax: ++385 1 233 5633
e-mail: kpetljak@efzg.hr

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A PRODUCTION INVENTORY MODEL FOR AN ITEM WITH THREE PARAMETER WEIBULL DETERIORATION AND PRICE DISCOUNT

Pradhan L.M[1)], Tripathy C.K.[2)]

[1)]Silicon Institute of Technology, Sambalpur, **India**, [2)]Sambalpur University, Sambalpur, **India**

ABSTRACT. Background: Deterioration is a natural process for most of the items as such it cannot be ignored in study of inventory control and management. In recent years great deal of study is devoted in developing inventory models for deteriorating items considering various practical situations. Price discount for partially deteriorated items is considerably a new concept introduced in developing various models.
Methods: This paper deals with the development of an inventory model for Weibull deteriorating items. Here production and demand rate are considered to be constant and the holding cost per unit is assumed to be constant with respect to time. Completely deteriorated units are discarded and partially deteriorated items are allowed to carry a discount. Shortages are not allowed.
Results and conclusions: A Production Inventory model for an item with three parameter Weibull deterioration with price discount for partially deteriorated item have been proposed in this paper. Here the optimal cycle time for the model has been derived and the result is illustrated with the help of numerical example. Sensitivity analysis has been carried out to analyze the changes in the optimal solution with respect to the change in other parameters.

Key words: Production quantity model, Weibull deterioration, Price discount.

INTRODUCTION

One of the important concerns of the inventory management is to decide as to when and how much is to be ordered or manufactured so that the total cost associated with the inventory system can be kept at minimum. When the inventory is subject to significant deterioration, it becomes more important as loss due to deterioration cannot be ignored in this case. Study in this direction have resulted in continuous modification of inventory modelling for deteriorating items by including more and more practical features. The impact of product deterioration should not be neglected in the decision process of production lot size. Researchers are engaged in analyzing inventory models for deteriorating items such as volatile liquids, medicines, electronic components, fashion goods, fruits, vegetables, etc. An order level inventory model with constant deterioration was developed by Aggarwal [1978]. Earlier some researchers like Ghare [1963] considered exponentially decaying inventory for a constant demand. Optimum production planning for a deteriorating item was developed by Hwang [1986]. A production inventory model for decaying raw materials and a decaying single finished product system was developed by Raffat [1985], [1991]. Optimal pricing and lot sizing under conditions of perishability and partial backordering was studied by Misra [1975] and Abad [1996]. Goyal and Giri [2001] have also given many deteriorating inventory models. Then Economic lot scheduling problem was studied by Gary et.al [2005] and Deng et.al [2007]. Yang and Wee [2003] developed an integrated multilot-size production inventory model. Then Sugapriya and Jeyaraman [2008] studied a common production cycle time for an EPQ model of non instantaneous deteriorating items allowing price discount using permissible delay in payments. Inventory management of time dependent deteriorating with salvage value was developed by Mishra [2008]. Optimal policy for a deteriorating

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item with finite replenishment and with price dependent demand rate was studied by Sabahno [2008]. Shah and Acharya [2008] have established a model of time dependent deterioration with exponential demand. An EPQ model under stock dependent demand, Weibull distribution deterioration and shortage was developed by Roy and Choudhuri [2009]. Tripathy C.K. and Pradhan L.M., [2010] developed a Production Inventory model for Weibull deteriorating Items allowing price discount & permissible delay in payments. Tripathy C.K. and Pradhan L.M., [2011] then studied optimal Pricing & Ordering Policy for three parameter Weibull deterioration under trade credit. Tripathy C. K., and Mishra U., [2011] developed an EOQ model with time dependent Weibull deterioration and ramp type demand. Tripathy C.K.,. Pradhan L.M, and Mishra U, [2010] studied an EPQ Model for Linear deteriorating Item with Variable Holding cost. Meher M.K et.al [2012] have proposed an inventory model with Weibull deterioration rate considering delay in payment for declining market.

In the present paper a production inventory model has been developed considering three parameter Weibull deterioration with price discount for partially deteriorated items. The holding cost is assumed to be constant and shortages are not allowed for this model. In section 2 assumptions and notations required for the development of the model are given. The optimum cycle time, holding cost and total variable cost of the model is derived in the Section 3. An illustrative numerical example, a sensitivity table and conclusion are given in section 4, 5 and 6 respectively.

BASIC ASSUMPTIONS AND NOTATIONS

The following are the assumptions required for development of the model:

1. The demand rate for the product is known and finite.
2. Shortage is not allowed.
3. Planning horizon is infinite.
4. Once a unit of the product is produced, it is available to meet the demand.
5. Price discount is allowed for partially deteriorated items.
6. There is no replacement or repair for a deteriorated item.

The notations that are employed here:

p: Production rate per unit time.

d: Actual demand of the product per unit time

A: Set up cost

θ: Weibull three parameter deterioration rate (unit/unit time), $\theta = \alpha\beta(t-\gamma)^{\beta-1}$, where $0<\alpha<1$, $\beta>1$, $0<\gamma<<1$,where α is called scale parameter and β is called shape parameter and γ is called the location parameter.

h: Inventory carrying cost per unit per unit time which is constant.

k: Production cost per unit.

l: Price discount per unit cost.

T: Optimal cycle time.

T_1: Production period.

T_2: Time during which there is no production. i.e., $T_1 = T - T_2$.

$I_1(t)$: Inventory level for product during the production period, i.e. $0 \le t \le T_1$.

$I_2(t)$: Inventory level of the product during the period when there is no production i.e. $T_1 \le t \le T_2$.

$I(M)$: Maximum inventory level of the product.

$TVC(T)$: Total cost/unit time.

MATHEMATICAL MODEL

At $t=0$, the inventory level is zero. The production and supply start simultaneously and the production stops when the maximum inventory $I(M)$ is reached at time $t=T_1$. During this period of time inventory built up at a rate $p-d$ and there is no deterioration. After time T_1 , the produced units start deterioration and supply is continued at the discount rate. As the demand remains constant for the product the inventory level reduces to zero and then the production run begins. Thus the inventory level of the product at time t over the period $[0,T]$ can be represented by the following differential equations

$$\frac{dI_1(t)}{dt} = p-d \qquad 0 \le t \le T_1 \qquad (1)$$

and

$$\frac{dI_2(t)}{dt} + \theta I_2(t) = -d \qquad 0 \le t \le T_2 \qquad (2)$$

Where $\theta = \alpha\beta(t-\gamma)^{\beta-1}$, where $0<\alpha<1,\ \beta>1,\ 0<\gamma<<1$
α is called scale parameter and β is called shape parameter and γ is called the location parameter.

Here the boundary conditions are $I_1(0) = I_2(T_2) = 0$

Solving equation (1) and (2), we get

$$I_1(t) = (p-d)t \qquad , 0 \le t \le T_1 \qquad (3)$$

$$I_2(t) = d\left[T_2 - t + \frac{\alpha}{\beta+1}(T_2-\gamma)^{\beta+1} - \frac{\alpha}{\beta+1}(t-\gamma)^{\beta+1} - \alpha T_2(t-\gamma)^{\beta} + \alpha t\,(t-\gamma)^{\beta} + \alpha(t-\gamma)^{2\beta+1}\right]$$
$$, 0 \le t \le T_2 \qquad (4)$$

The **production cost** per unit time is

$$PC = pk\frac{T_1}{T} \qquad (5)$$

The **set up cost** per unit time is

$$SC = \frac{A}{T} \qquad (6)$$

The **Holding Cost** is

$$HC = \frac{1}{T}\left[\int_0^{T_1} h(t)\ I_1(t)dt + \int_0^{T_2} h(t)\ I_2(t)dt\right] = \frac{1}{T}\left[h\int_0^{T_1}(p-d)\,t\,dt\right] \quad +$$

$$h\,d\int_0^{T_2}\left[T_2 - t + \frac{\alpha}{\beta+1}(T_2-\gamma)^{\beta+1} - \frac{\alpha}{\beta+1}(t-\gamma)^{\beta+1} - \alpha T_2(t-\gamma)^{\beta} + \alpha t\,(t-\gamma)^{\beta} + \alpha\,(t-\gamma)^{2\beta+1}\right]dt$$

Integrating the above we get

$$HC = \frac{h(p-d)T_1^{\,2}}{2T} +$$

$$\frac{hd}{T}\left[\frac{T_2^2}{2} - \frac{2\alpha(T_2-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)} + \frac{\alpha T_2(T_2-\gamma)^{\beta+1}}{(\beta+1)} + \frac{\alpha(T_2-\gamma)^{2\beta+2}}{2(\beta+1)} + \frac{2\alpha(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)}\right]$$

$$+ \frac{hd}{T}\left[\frac{\alpha T_2(-\gamma)^{\beta+1}}{(\beta+1)} - \frac{\alpha(-\gamma)^{2\beta+2}}{2(\beta+1)}\right] \qquad (7)$$

Let us express T_1 and T_2 in terms of T

We know $I_1(T_1) = I_2(0)$

$$(p-d)T_1 = d\left[T_2 + \frac{\alpha}{\beta+1}(T_2-\gamma)^{\beta+1} - \frac{\alpha}{\beta+1}(-\gamma)^{\beta+1} - \alpha T_2(-\gamma)^{\beta} + \alpha(-\gamma)^{2\beta+1}\right]$$

Neglecting the terms involving second and higher power of γ as $0 < \gamma << 1$ and T_2 from the right hand side to get a suitable solution, we have

$$(p-d)T_1 = d\,T_2$$

$$(p-d)(T-T_2) = dT_2$$

$$T_2 = \frac{(p-d)}{p}T = xT \qquad \text{, where, let } x = \frac{p-d}{p} \qquad (8)$$

$$T_1 = \frac{dT}{p} \qquad (9)$$

Using these values of T_1 and T_2 in equation (7) we get

$$HC = \frac{h\,d\,xT}{2} - \frac{2\alpha\,h\,d(xT-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)T} + \frac{h\,d\,\alpha\,x(xT-\gamma)^{\beta+1}}{(\beta+1)} + \frac{h\,d\,\alpha(xT-\gamma)^{2\beta+2}}{2(\beta+1)T}$$

$$+ \frac{2\alpha\,h\,d(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)T} + \frac{h\,d\,\alpha\,x(-\gamma)^{\beta+1}}{(\beta+1)} - \frac{h\,d\,\alpha(-\gamma)^{2\beta+2}}{2(\beta+1)T} \qquad (10)$$

Deterioration cost

The number of units that deteriorate in a cycle is the difference between the maximum inventory and the number of units used to meet the demand. Hence the deterioration cost per unit time is given as $DC = \frac{k}{T}\left[I_2(0) - \int_0^{T_2} d\,d\,t\right]$

$$= \frac{k\,d}{T}\left[\frac{\alpha(T_2-\gamma)^{\beta+1}}{(\beta+1)} - \frac{\alpha(-\gamma)^{\beta+1}}{(\beta+1)} - \alpha T_2(-\gamma)^{\beta} + \alpha(-\gamma)^{2\beta+1}\right] \qquad (11)$$

Price discount

Price discount is offered as a fraction of production cost for the units in the Period $[0, T_2]$

$$PD = \frac{k\,l}{T}\int_0^{T_2} d\,dt$$

$$= \frac{k\,l\,d T_2}{T} \tag{12}$$

Therefore the **average total cost** per unit time is given by

$$TVC(T) = PC + SC + HC + PD + DC$$

$$= \frac{pkT_1}{T} + \frac{A}{T} + \frac{h\,d\,xT}{2} - \frac{2\alpha\,h\,d(xT-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)T} + \frac{h\,d\,\alpha\,x(xT-\gamma)^{\beta+1}}{(\beta+1)} + \frac{h\,d\,\alpha\,(xT-\gamma)^{2\beta+2}}{2(\beta+1)T}$$

$$+ \frac{2\alpha\,h\,d(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)T} + \frac{h\,d\,\alpha\,x(-\gamma)^{\beta+1}}{(\beta+1)} - \frac{h\,d\,\alpha\,(-\gamma)^{2\beta+2}}{2(\beta+1)T} + \frac{k\,l\,dT_2}{T}$$

$$+ \frac{k\,d}{T}\left[\frac{\alpha(T_2-\gamma)^{\beta+1}}{(\beta+1)} - \frac{\alpha(-\gamma)^{\beta+1}}{(\beta+1)} - \alpha T_2(-\gamma)^{\beta} + \alpha(-\gamma)^{2\beta+1} + \right] \tag{13}$$

Putting the values of T_2 and T_1 in terms of T from equation (8) and (9) respectively, equation (13) becomes

$$TVC(T) = k\,d + \frac{A}{T} + \frac{h\,d\,xT}{2} - \frac{2\alpha\,h\,d}{(\beta+1)(\beta+2)T}\left((xT-\gamma)^{\beta+2} - (-\gamma)^{\beta+2}\right)$$

$$+ \frac{h\,d\,\alpha}{2(\beta+1)T}\left((xT-\gamma)^{2\beta+2} - (-\gamma)^{2\beta+2}\right) + \frac{h\,d\,\alpha\,x}{(\beta+1)}\left((xT-\gamma)^{\beta+1} + (-\gamma)^{\beta+1}\right)$$

$$+ \frac{kd\,\alpha}{(\beta+1)T}\left((xT-\gamma)^{\beta+1} - (-\gamma)^{\beta+1}\right) + \frac{\alpha\,kd\,(-\gamma)^{2\beta+1}}{T} + k\,l\,d\,x - \alpha\,k\,dx(-\gamma)^{\beta} \tag{14}$$

To find the minimum total cost, we calculate the value of T from

$$\frac{d}{dT}(TVC(T)) = 0$$

$$\Rightarrow \frac{-A}{T^2} + \frac{h\,d\,x}{2} - \frac{2\alpha\,hd}{(\beta+1)(\beta+2)T^2}\left[Tx(\beta+2)(xT-\gamma)^{\beta+1} - (xT-\gamma)^{\beta+2} + (-\gamma)^{\beta+2}\right]$$

$$+ \frac{\alpha\,h\,d}{2(\beta+1)T^2}\left[Tx(2\beta+2)(xT-\gamma)^{2\beta+1} - (xT-\gamma)^{2\beta+2} + (-\gamma)^{2\beta+2}\right]$$

$$+ \frac{\alpha\,k\,d}{(\beta+1)T^2}\left[Tx(\beta+1)(xT-\gamma)^{\beta} - (xT-\gamma)^{\beta+1} + (-\gamma)^{\beta+1}\right]$$

$$+ \alpha\,h\,d\,x^2(xT-\gamma)^{\beta} - \frac{\alpha\,k\,d\,(-\gamma)^{2\beta+1}}{T^2} = 0 \tag{15}$$

The value of T calculated from (16) will minimize the TVC if

$$\frac{d^2}{dT^2}(TVC(T))>0$$

$$\Rightarrow \frac{2A}{T^3}-\frac{2\alpha h d x}{(\beta+1)T^2}\left[Tx(\beta+1)(xT-\gamma)^{\beta}-(xT-\gamma)^{\beta+1}\right]$$

$$+\frac{2\alpha h d}{(\beta+1)(\beta+2)T^4}\left[T^2x(\beta+2)(xT-\gamma)^{\beta+1}-2(xT-\gamma)^{\beta+2}T\right]+\frac{4\alpha h d(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)T^3}$$

$$+\frac{\alpha h d x}{T^2}\left[Tx(2\beta+1)(xT-\gamma)^{2\beta}-(xT-\gamma)^{2\beta+1}\right]$$

$$-\frac{\alpha h d}{2(\beta+1)T^4}\left[T^2x(2\beta+2)(xT-\gamma)^{2\beta+1}-2(xT-\gamma)^{2\beta+2}T\right]-\frac{\alpha h d(-\gamma)^{2\beta+2}}{(\beta+1)T^3}$$

$$+\frac{\alpha k d x}{T^2}\left[Tx\beta(xT-\gamma)^{\beta-1}-(xT-\gamma)^{\beta}\right]$$

$$-\frac{\alpha k d}{(\beta+1)T^4}\left[T^2x(\beta+1)(xT-\gamma)^{\beta}-2(xT-\gamma)^{\beta+1}T\right]$$

$$-\frac{2\alpha k d(-\gamma)^{\beta+1}}{(\beta+1)T^3}+\alpha h d\beta x^3(xT-\gamma)^{\beta-1}+\frac{2\alpha k d(-\gamma)^{2\beta+1}}{T^3}\ >0 \qquad (16)$$

NUMERICAL EXAMPLE

Let $A = Rs\,2000$ /set up, $p = 200$ units/unit time, $d = 50$ unit/unit time, $\alpha = 0.6$, $\beta = 10$, $\gamma = 0.4$, $k = Rs\,60$ /unit, $l = 0.05$, $h = 2$. Using equation (15), (10), (14) and (16) we get the optimum values of $T^* = 1.83038$, $HC^* = 72.1144$, $TVC^* = 4343.27$, $\frac{d^2}{dT^2}(TVC(T)) = 4776.65 > 0$ respectively.

SENSITIVITY ANALYSIS

We now perform the sensitivity analysis of the optimal solution of the model for changes in $A, \alpha, \beta, \gamma, k, p$ and d parameter values associated with the system. We change one parameter at a time keeping the other parameters unchanged for study of sensitivity analysis. The original values of all the parameters for sensitivity analysis are taken from the example given above. Sensitivity analysis is performed by changing the values of all the parameters from -50% to +50%, one by one in the model which are given in the following table 1.

Table 1. Sensitivity Analysis
Tabela 1. Analiza wrażliwości

Changing parameter	% change	Change In T*	change in HC*	change in TVC*
	-50	1.74415	66.8461	3785.18
	-40	1.76679	68.0679	3899.09
	-30	1.78593	69.1759	4011.66
	-20	1.80254	70.2063	4123.12
	-10	1.81722	71.1808	4233.62
	10	1.8423	73.0169	4452.18
A	20	1.8532	73.8963	4560.42
	30	1.86325	74.759	4668.04
	40	1.87258	75.6099	4775.11
	50	1.88127	76.4507	4881.66
	-50	2.73961	70.7141	3918.37
	-40	2.35044	71.1952	4060.01
	-30	2.13391	71.5286	4161.18
	-20	1.99599	71.7741	4237.05
	-10	1.90046	71.9636	4296.06
	10	1.77676	72.2362	4381.9
	20	1.73443	72.3382	4414.09
p	30	1.70015	72.4237	4441.32
	40	1.67183	72.497	4464.67
	50	1.64804	72.5606	4484.9
	-50	1.64423	41.0672	2898.62
	-40	1.6722	47.2891	3193.9
	-30	1.70513	53.52	3485.39
	-20	1.74256	59.7403	3773.82
	-10	1.78431	65.9401	4059.67
	10	1.88088	78.2594	4624.88
d	20	1.93604	84.3737	4904.68
	30	1.99619	90.4568	5182.82
	40	2.06173	96.5071	5459.4
	50	2.13317	102.524	5734.52
	-50	1.91322	75.8871	4296.11
	-40	1.89113	74.8473	4308.32
	-30	1.87261	73.9958	4318.75
	-20	1.85669	73.2771	4327.87
	-10	1.84276	72.658	4335.97
	10	1.81925	71.6307	4349.91
	20	1.80915	71.1957	4356.00
α	30	1.79991	70.8008	4361.63
	40	1.7914	70.4396	4366.87
	50	1.78352	70.1071	4371.76
	-50	1.81262	74.3514	4419.78
	-40	1.81706	73.5764	4395.05
	-30	1.82098	73.0561	4377.45
	-20	1.82453	72.6585	4363.39
	-10	1.82764	72.3561	4352.36
	10	1.83278	71.9177	4335.75
	20	1.8349	71.7543	4329.38
β	30	1.83678	71.6164	4323.94
	40	1.83847	71.4995	4319.23
	50	1.83997	71.3973	4315.11
	-50	1.58625	63.9971	4529.37
	-40	1.63485	65.5722	4487.27
	-30	1.68357	67.1745	4447.83
	-20	1.7324	68.8004	4410.81
	-10	1.78134	70.4479	4376.02
	10	1.87951	73.7974	4312.4
γ	20	1.92873	75.4954	4283.25
	30	1.97804	77.2068	4255.68
	40	2.02743	78.9287	4229.54
	50	2.0769	80.6587	4204.68
	-50	1.90347	78.8454	2473.8
	-40	1.88504	76.8311	3065.86
	-30	1.86892	75.2701	3386.59
	-20	1.85465	74.0176	3706.28
	-10	1.84189	72.9849	4025.12
	10	1.8199	71.366	4660.85
	20	1.81031	70.7139	4977.94
k	30	1.80148	70.1383	5294.61
	40	1.79329	69.6238	5610.92
	50	1.78567	69.1604	5926.91

From the table 1 we can conclude the following:

i. T^* is directly proportional to A, d, β, γ but inversely proportional to p, α, k.

ii. HC^* is directly proportional to A, p, d, γ but inversely proportional to α, β, k.

iii. TVC^* is directly proportional to A, d, p, α, k but inversely proportional to β, γ.

CONCLUSION

Here, a Production inventory model has been developed for an item with three parameter Weibull deterioration where the holding cost is constant per unit, per unit time. We have assumed here that the production and demand rate are constant and shortages are not allowed. Completely deteriorated items are discarded and partially deteriorated items are offered for sale with a discount meeting the demand. The optimum production cycle time, holding cost and total variable cost has been derived for the developed model. Sensitivity analysis shows how the different parameters affect the production cycle time, holding cost and total variable cost. It is clearly seen from the table that to minimise the total cost, the set up cost, production rate, demand rate, scale parameter and the production cost per unit should be minimised whereas the value of the shape parameter and location parameter should be maximised.

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MODEL ZARZĄDZANIA PRODUKCJĄ Z TRÓJPARAMETROWYM WPŁYWEM PSUCIA SIĘ PRODUKTÓW I UPUSTEM CENOWYM

STRESZCZENIE. **Wstęp:** Psucie się jest naturalnym procesem większości produktów i nie może być ignorowane przez zarządzających produkcją. W ostatnich latach opublikowano wiele prac poświęconych różnym modelom zarządzania zapasem i produkcją, uwzględniających psucie się produktów w różnych warunkach praktycznych. Upust cenowy stosowany dla częściowo zepsutych produktów jest stosunkowo nową koncepcją, wprowadzoną w wielu rozwijanych obecnie modelach.
Metody: Praca ta porusza zagadnienia związane z opracowaniem modelu dla artykułów podlegających psuciu się według modelu Weibulla. Wielkość produkcji i popytu są wielkościami stałymi, zakłada się, że koszt utrzymania jednostki towaru jest stały w czasie. Całkowicie zepsute artykuły są usuwane z zapasu, natomiast częściowo zepsute mogą być sprzedane z upustem cenowym. Nie dopuszcza się braków towarowych.
Wyniki i wnioski: Został zaproponowany model zarządzania produkcją uwzględniający trójparametrowe psucie się towaru oraz możliwość upustów cenowych dla towarów częściowo zepsutych. Ustalono optymalną długość cyklu uzupełniania. Wyniki przedstawiono za pomocą przykładu. Analiza wrażliwości została przeprowadzona w celu stworzenia optymalnego rozwiązania uwzględniającego zmiany w innych parametrach..

Słowa kluczowe: model zarządzania produkcją, proces psucia się Weibulla, upust cenowy.

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MANAGEMENT-MODELL FÜR DIE DURCH DEN DREI-PARAMETER-VERDERB DER PRODUKTE UND DEN DADURCH BEDINGTEN PREISNACHLASS CHARAKTERISIERTE PRODUKTION

ZUSAMMENFASSUNG. Einleitung: Verderben ist bei den meisten Produkten ein natürlicher Prozess und darf daher von Produktionsmanagern nicht ignoriert werden. In den letzten Jahren veröffentlichte man viele Arbeiten, welche unterschiedlichen Modellen für Bestands -und Produktionsmanagement unter Berücksichtigung des Produktverderbs in verschiedenen praktischen Bedingungen gewidmet waren. Der bei den teilweise verdorbenen Produkten angewendete Preisnachlass stellt ein neues, in vielen, heutzutage entwickelten Modellen eingeführtes Konzept dar.
Methoden: Die vorliegende Arbeit berührt die mit Entwicklung eines brauchbaren Modells für die einem Verderb gemäß dem Weibull-Modells unterliegenden Artikel verbundenen Fragen. Produktion und Nachfrage sind konstante Größen, ferner nimmt man an, dass Kosten des Unterhalts einer Wareneinheit in der Zeit als ebenfalls konstante Größe anzusehen ist. Die total verdorbenen Produkte werden vom Bestand entfernt, dagegen die teilweise verdorbenen dürfen mit dem Preisnachlass verkauft werden. Die Warenmängel werden ausgeschlossen.
Ergebnisse und Fazit: Es wurde ein Management-Modell für die Produktion unter der Berücksichtigung des Drei-Parameter-Verderbs der Produkte sowie der Möglichkeit der Anwendung von Preisnachlässen bei den teilweise verdorbenen Waren vorgestellt. Es wurde eine optimale Länge des Nachschubzyklus festgelegt. Die Ergebnisse stellte man anhand eines Beispiels dar. Zwecks Ausarbeitung einer optimalen, die Veränderungen innerhalb anderer Parameter berücksichtigenden Lösung wurde auch die Empfindlichkeitsanalyse durchgeführt.

Codewörter: Modell für Produktionsmanagement, Verderbnisprozess gemäß dem Weibull-Modell, Preisnachlass.

Pradhan L.M.
Department of Mathematics
Silicon Institute of Technology
Sason, Sambalpur-768200, India
e-mail: lalitpradhan78@gmail.com
Tripathy C.K.
Department of Statistics
Sambalpur University
Jyoti Vihar, Sambalpur-768019, India
e-mail: c.tripathy@yahoo.com

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RISK MANAGEMENT - UNAPPRECIATED INSTRUMENT OF SUPPLY CHAIN MANAGEMENT STRATEGY

Wojciech Machowiak

Poznan School of Logistics, Poznań, Poland

ABSTRACT. Background: Unlike Enterprise Risk Management, which is certainly quite well rooted in business practice, Supply Chain Risk Management (SCRM) still continues to be dynamically developing subject of academic research, whereas its practical applications are rather scarce.
Material and methods: On the basis of broad review of the current state of the art in world literature, significant relevancies to the core processes and enterprise strategy are discussed.
Results: The paper shows some interesting from the enterprise's performance and competitiveness point of view additional benefits, potentially resulting from the proactive, consistent and effective implementation of the SCRM system.
Conclusions: Some additional advantages from proactive supply chain risk management account for perceiving SCRM as multifunctional instrument of strategic SC management, exceeding established understanding RM as security and threat-prevention tool only. Positive influence from SCRM onto SC performance and competitiveness can make reasonable to enhance its position within SCM strategy.

Key words: supply chain management, supply chain risk management, risk, risk management.

INTRODUCTION

There is rather not much controversy about still growing importance of supply chain management (SCM) as an efficient way leading to making contemporary business processes more resilient, more agile and as a result - more competitive. Even those, who call it the most common example of a buzz-word [Enarsson, 2006] agree, that SCM comprises some advantages and opens new perspectives for further progress, especially at the global markets. Signification of SCM concept is underlined from various points of view. Following Christopher [2005], as global supply chains become more complex and fragmented, the question of how they should be managed and governed becomes critical. SCM represents also one of the most significant paradigm shifts of modern business management [Chen and Paulray, 2004]. According to Bozart and Handfield [2006] the organization's survival depends on the diligent operations and supply chain management. SCM has become vitally important especially considering recent changes in global business [Hopkin, 2010]. From the marketing point of view the creation of market-facing and customer-responsive supply chains must become the goal as the rules of competition change dramatically and we enter the era of supply chain competition [Christopher, 2004].

Klassen and Johnson [2004] qualify striving for achieving competitive advantage as the target of the most advanced supply chain orientation. As - in fact - the essence of SCM is and will remain its contribution to the product (service) competitiveness, a matter of special concern should be all instruments enabling SC to improve performance and gain additional competitive advantage. Two superior criteria of business success - which are customer satisfaction and shareholder value - are

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crucially dependent on the supply chain competitiveness. This is what individual enterprises, being partners in SC, are ready to pay some price for, sacrificing some particular interests to gain ultimate advantage. Christopher [2010] calls it "the new model of competition", where "successful companies will be those, whose supply chains are more cost-effective than those of their competitors". Supply chain risk management (SCRM) as a part of supply chain strategy influences areas of performance and must fit in that pattern. The question about its real impact on SC competitiveness becomes timely and important.

Operations management and supply chain management are equally philosophical business approaches and a collection of tools and techniques [Bozart and Handfield 2006]. From such point of view, within the last decade, SCRM emerges as one of very important tools within SCM. The reason is admittedly the increased vulnerability of today's, global supply chains [Cranfield, 2002; Juettner, Peck, and Christopher, 2003; Kersten et al., 2006; Peck, 2006; Waters, 2007], continuously growing variety of threats resulting in supply chain disruptions [Kleindorfer and Saad, 2005; Sheffi, 2005; Hale and Moberg, 2005; Manuj and Mentzer, 2007, Tang, 2006a] but also development and practice of business strategies resulting in new or increased risk [Sheffi, 2005; Tang, 2006b; Trent and Roberts 2010] as a result of enhanced demand for solutions aiming in greater resilience, agility and competitiveness of supply networks [Christopher and Peck, 2004; Sheffi and Rice, 2005;Tang and Tomlin, 2008; Enyinda et al., 2008; Ponomarov and Holcomb, 2009; Peck, 2010] .

A more comprehensive review of the wide spectrum of SCRM problems represented in the literature may be found in the publications of Paulsson [2004]; Rao and Goldsby [2009] and others.

SCRM INTEGRATION WITHIN THE STRATEGY

Unquestioned desideratum of all contemporary approaches to RM is that risk management should be integrated with the organization's strategy. It is also confirmed by existing RM standards. The oldest, Australian RM standard AS/NZS 4360 [2004] recommended: "the risk management policy should be relevant to the organization's strategic context and its goals, objectives and the nature of its business". IRM standard [IRM, 2002] defines: "risk management is a central part of any organisation's strategic management". COSO II [2004] introduces as a fundamental notion the principle of including risk management in corporate strategy. This attitude is continued by the newest ISO 31000 [2009] points aligning of risk management objectives with the objectives and strategies of the organization as a strong and sustained commitment by management of organization.

This view was not always so obvious and evolved during last decades, being also substantially dependent on the top management attitude and involvement. In traditional, "financial" approach, subordinating all RM activities to internal audit or other financial unit was regarded as quite sufficient and reasonable. Nowadays "risk management is no longer solely a financial discipline, nor is it simply a concern for the internal control function" [CIMA, 2010]. Introduction of the Enterprise Risk Management construct moved RM competencies and responsibilities closer to the board. Hopkin [2002] suggested: "it is likely that the responsibilities will be allocated to board members" . Lam [2003] predicted transformation of audit committees into risk committees. Evolution of risk management to a strategic process was described by DeLoach [2000]. Advanced holistic approaches to risk and risk management already found the idea of RM as the board area of interest to be obvious. Lloyd's survey [2005] reported: "evidence suggests that boards are taking risk more seriously". Involvement of top managers is regarded as the best approach [Waters 2007]. Nevertheless, according to AON Global Risk Management Survey [2007] - "risk is now firmly on the board agenda, although there is not always a consistent approach". Many surveys show lack of sponsorship from the senior management as the main barrier to implementation of ERM [Strategic Risk, 2010], or one of primary reasons [The Economist Intelligence Unit , 2007].

The requirement of integration seems to be absolutely reasonable, however its understanding and realization differs from case to case and hasn't found its universal and commonly accepted interpretation. In business practice it is quite common, that "integration" is realized in a very formal,

bureaucratic way. When practically realized, imposing solutions elaborated within RM process meets mostly - sometimes strong - incomprehension and opposition from line managers and other staff. In numerous cases it leads to significant reduction of organization's engagement or even abandonment, resignation of already implemented RM systems.

SCRM AND CORE PROCESSES

In most cases RM is shaped as a process parallel to the core ones, supporting them and somehow subordinated to them. Anyhow, they remain to be at least to some extent autonomous. RM process is equipped with separate structures, procedures, and objectives. Also, what is extremely important - with "own" management. Nevertheless, the results of RM process refer to other processes and are impliedly supposed to be implemented in adequate core processes. They cannot exist independently. Such superposition frequently fails to bring expected results as solutions elaborated within RM process are perceived as a foreign body, a kind of implant - and rejected. It happens so because of substantial conflict of interests which takes place and which materializes as a result of performing RM process in an autonomous way, as a technical, passive or reactive tool "against risks". This may be successful in case of many risk categories - (mainly hazards, financial and operational risks etc.), where RM process yields rather passive or reactive solutions: insurances, financial instruments, technical means increasing resistance or contingency plans. In the SC scale similar functions may be assigned to such popular risk mitigating remedies as increased (safety, buffer) stocks, redundancies, spare capacities and risk sharing. Apart from sometimes limited effectiveness of such passive solutions, we must consider also a great variety of risks requiring much more sophisticated approach. Situation becomes complex and delicate, when considering for example strategic, process- or market-related risks. Than - because of e.g. market and/or process dynamics - such passive risk mitigation tools appear to be even less effective. Moreover, core processes are strongly oriented towards gaining competitive advantage, whereas RM measures frequently include some dose of opposite solutions. This is the case with lean practices. Just-in-Time strategy brings considerable advantages in reducing stocks and improved operations, but implies significant threat of SC disruption. The simplest and most effective way to mitigate that risk is to build in some additional inventory, although that increases costs and diminishes competitivity. Outsourcing may solve some technological or operational problems, however reduces visibility and control. Mitigating that risk sometimes leads to surprising solutions - in case of Boeing Dreamliner project it was ultimate purchasing the cooperating company [Tang et al., 2009]. LCCS and offshoring yield purposeful cost savings (material and/or labour), at the same time extend lead-times, complicate logistics and increase risk of disturbances (e.g. because of cross-culture problems). Those lean management generated risks, when subject to risk management processing - requiring e.g. some additional expenditures - may considerably reduce the assumed effect of pro-competitiveness efforts.

Here we have to face the conflict of interests mentioned above. Correlativeness between risk taking and gaining competitive advantage is often a kind of a feedback loop. Gaining additional competitive advantage mostly means taking more risk. Additional risk needs extraordinary actions to mitigate it whereas measures to be taken mostly diminish also effects of efforts established to increase competitiveness.

Such ambiguity is hardly solvable as long as RM process is perceived in a very technical way - as a tool to mitigate risks only. Complexity and subtle nature of interconnections between risk management and core processes require more general approach, based on the analysis of entire, multiaspectual influence exerted on the organization's performance from risk management.

EXTENDED POTENTIAL OF SCRM

Risk-competitiveness feedback loop displays also another important phenomenon. In majority of RM-bounded interrelations multiaspect correlation takes place. From famous "Albuquerque case" [Norman and Jansson, 2004] we learned a lot about risk management, SC disruption risks, single-sourcing risk and how to mitigate risk impacts, but also the fact, that it was effective risk management what allowed Nokia to gain extra competitive advantage. Similar example was the Mitch Hurricane story [Sheffi, 2005] when better risk management let Chiquita survive, concurrently bringing that banana company additional increase in revenues. In both cases risk management assured safety and survival in critical situation, but also yielded - as a "side effect" - some additional profits, which couldn't be gained without it. That positive influence mechanism works regardless of emergencies, which admittedly are and will be the main reason for existence of RM systems. Nevertheless, such extra phenomena seem to be noteworthy and let us perceive RM as something more than reactive safety assuring tool only. There are many other exemplifications. It happens more and more frequently, that choosing partner for strategic collaboration (esp. supplier) companies treat implemented RM system as an important criterion. Confidence between SC partners mitigates risk, but also vice versa: good risk management fosters confidence, necessary for better collaboration between partners and better SC synchronization [Christopher and Lee, 2004]. In the absence of efficient RM, risk of defective relations between SC partners is growing. At the same time, RM systems implemented by partnering organizations positively influence and reinforce relations. Lack of visibility and reliability implies increased risk, but again: good risk management leads to improved visibility and reliability, valuable from general SCM point of view. It is undoubted, that evidence of implemented risk management system improves entity's image and reputation and consequently - its position (as a reliable partner) against competitors.

Basically, the SCRM influence exerted onto the core processes may be considered at two reference planes: direct and derivative, indirect. First of them reflects fundamental expected impact of SCRM, lying at the grassroots of the RM concept itself . It corresponds to "traditionally" understood generic objective of SCRM, which is assuring SC processes safety (continuity of supply) and increasing their resistance to disruption. However, in some situations it may result also in gaining some additional competitive advantage as shown above. The other plane comprises may be not so spectacular (however also predictable) accidental impacts, a kind of "side effects". They may be regarded as derivatives of intricate co-relations within organization's processes and structures. These influences may have both - internal and external character - and include such features as relationships between SC partners, visibility and confidence, information flow and SC alignment and excellence (internal) also market-related issues, image and reputation, customer satisfaction etc. (external). Altogether they create quite interesting perspective of stimulating the organization's competitive potential, as each of them may be recognized as associated with or referred to significant drivers of organization's competitiveness.

Contrary to the broad spectrum of books and articles on general problems of RM and SCRM - there is a little literature on the risk management benefits other than safety, security, disruption resistancy etc., however some authors remark such likely consequences. When a disruption hits many companies at once, or affects a whole region, prepared companies may be able to take advantage of the reduction in market capacity to enter new markets and serve new customers [Sheffi, 2005]. Dairy giant Danone gained a lead at the baby food market as a result of well-thought-out SCRM policy [Schaafsma, 2009]. Hopkin [2010] as RM outputs quotes achieving enhanced performance of the organization in three important areas: efficacious strategy, effective processes and efficient operations. Sadgrove [2005] points such benefits of risk management as "good defence" in law, lower risk exposure, greater profits, better use of resources and making the organization alert to changes in the market and society. Similar relevancies result also indirectly from other works on SCRM. Brindley and Ritchie [2004] constate that "the key issue for the organization is one of balancing increased risks with the potential opportunities to improve the financial performance and the overall corporate performance". Elkins, Handfield, Blackhurst and Craighead [2008] point the importance of building responsive and resilient supply chains that can withstand the impact of major supply chain disruptions and catastrophes,

without impacting the end customer and without incurring excessive recovery costs. Khan et al. [2008] discuss interactions between product design, SCRM and SC agility. Somewhat inspiring, close to these questions are publications on interdependencies between risk and performance [DeLoach, 2000; Winkler and Kaluza, 2006; Ritchie and Brindley, 2007, 2008; Wagner and Bode, 2008], between RM and SC relationships management [Ritchie, Brindley and Armstrong, 2008] also between risk and agility [Braunscheidel and Suresh, 2009].

Awareness of synergistic, mutually driven correlations between RM and core processes, in particular that of additional positive impact from RM onto SC performance and image, leads to some modification of the RM capabilities as well as its role played in the enterprise and SC strategies. From strategic point of view, in the face of fundamental tasks of RM but also regarding its contributory potential, generic objectives of SCRM may be now re-articulated as:

- ensuring business safety at the SC scale, that is to say securing cost-effective and operationally efficient continuity of supply, and
- contributing to SC competitive advantage creation.

This makes from SCRM something more than defensive, safety-assuring tool only. Consciously and competently applied it might play a role of sophisticated, multi-functional instrument of strategic management, assuring safety, but simultaneously reinforcing SC performance and competitiveness. Such broad understanding of SCRM concept may also be helpful in overcoming boards' distantness and cautiousness to SCRM, being so frequently pointed as one of main obstacles in implementations.

CONCLUSIONS AND FURTHER WORKS

In the paper some additional advantages from proactive supply chain risk management transcending mitigation of direct negative risk impacts have been discussed. They account for perceiving SCRM as multifunctional instrument of strategic SC management, exceeding established understanding RM as security and threat-prevention tool only. Positive influence from SCRM onto SC performance and competitiveness can make reasonable to enhance its position within SCM strategy.

Considering extended RM potential as discussed above, it seems rational to continue in-depth exploration of mechanisms of correlation between RM and other processes. Of special interest should be research on mutual dependencies between risk management and performance. Particularly, RM contribution to organization's competitiveness is a purposeful issue.

Another area of research activity could be positioning of RM within organization's structures and strategy, as extended objectives suggest, also because of some negative experiences with implementations.

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ZARZĄDZANIE RYZYKIEM - NIEDOCENIANY INSTRUMENT STRATEGII ZARZĄDZANIA ŁAŃCUCHAMI DOSTAW

STRESZCZENIE. **Wstęp:** W przeciwieństwie do zarządzania ryzykiem przedsiębiorstwa (ERM), które z pewnością jest nieźle zakorzenione w praktyce biznesu, zarządzanie ryzykiem łańcucha dostaw (SCRM) będąc przedmiotem dynamicznie rozwijających się badań akademickich, znajduje ciągle jeszcze raczej niewiele praktycznych zastosowań.
Metody: na podstawie obszernego przeglądu stanu badań w bieżącej literaturze światowej autor przeprowadza dyskusję odniesień SCRM do procesów podstawowych i strategii przedsiębiorstwa
Wyniki: Artykuł pokazuje pewne - interesujące z punktu widzenia m. in. wyników i konkurencyjności przedsiębiorstwa - dodatkowe korzyści potencjalnie możliwe do uzyskania z proaktywnego, konsekwentnego i skutecznego wdrożenia systemu zarządzania ryzykiem w łańcuchu dostaw.
Wnioski: Pewne dodatkowe korzyści z proaktywnego zarządzania ryzykiem w łańcuchu dostaw przyczyniają się do postrzegania SCRM jako wielofunkcyjnego instrumentu strategicznego zarządzania łąńcuchem dostaw, wykraczającego poza ugruntowane rozumienie zarządzania ryzykiem jedynie jako narzędzie zapewniające bezpieczeństwo i zapobiegające zagrożeniom. Pozytywny wpływ SCRM na wyniki i konkurencyjność łańcucha dostaw może uzasadniać wzmocnienie jego pozycji w strategii łańcucha dostaw..

Słowa kluczowe: zarządzanie łańcuchem dostaw, zarządzanie ryzykiem w łańcuchu dostaw, ryzyko, zarządzanie ryzykiem.

RISIKOMANAGEMENT - EIN UNTERSCHÄTZTES INSTRUMENT DER STRATEGIE VON SUPPLY-CHAIN-MANAGEMENT

ZUSAMMENFASSUNG. Einleitung: Im Gegensatz zum Management von Unternehmensrisiko (ERM), das in der Geschäftspraxis sicherlich ganz gut eingewurzelt ist, findet das Supply-Chain-Risikomanagement, als Subjekt der sich dynamisch entwickelnden, akademischen Untersuchungen, eher selten praktische Anwendungen.
Methoden: Auf der Basis der umfassenden Recherche in der aktuellen Fachliteratur der Welt werden Relationen von SCRM zu den Basisprozessen und Unternehmensstrategie diskutiert.

Ergebnisse: Der Artikel zeigt bestimmte - vom Standpunkt u.a. der Ergebnisse und der Konkurrenzfähigkeit des Unternehmens - zusätzliche, potentiell erreichbare Vorteile, die mit einer proaktiven, konsequenten und erfolgreichen Implementation des SCRM-Systems möglich sind.
Fazit: Bestimmte zusätzliche Vorteile des proaktiven Managements von Supply-Chain-Risikomanagement tragen dazu bei, dass SCRM als multifunktionales Instrument des strategischen SCM verstanden wird, was weit über bisherige Auffassung hinausgeht, als ein Werkzeug, das lediglich Sicherheit garantiert und Bedrohungen vermeiden hilft. Der positive Einfluss von SCRM auf die Ergebnisse und die Konkurrenzfähigkeit des Supply-Chains kann die Verstärkung seiner Position im SCM begründen.

Codewörter: Supply-Chain-Risikomanagement, Enterprise Risk Management, Risiko, Risikomanagement

Wojciech Machowiak
Poznan School of Logistics
ul. Estkowskiego 6
61-755 Poznań, Poland
e-mail: wmachowiak@wsl.com.pl

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MULTI-VARIANT CONFIGURATIONS OF SUPPLY CHAINS IN THE CONTEXT OF SYNCHROMODAL TRANSPORT

Joanna Pleszko

Maritime University of Szczecin, Szczecin, Poland

ABSTRACT. Background: Transport needs are specific expectations of business organizations and depend on customers' preferences, availability of supra- and infrastructure and ecological awareness. This study aims at outlining global efforts towards sustainable development by utilizing transport means with optimized solutions and specific advantages of each transport mode. Novel concepts within multi-variant transport, such as co-modal or synchromodal transport, make up a basis for creating a higher standard of process organization, characterized by individual customized solutions.
Material and methods: Have been described the features and main characteristics of modern concepts synchromodal transport and identifies differences in relation to the well-known multimodal system. The paper presents a statistical analysis of the share of various modes of transport in intermodal transport in the last ten years. Conducted the examination of the significance of quality features of transport services on a sample of 613 companies chosen deliberately. The collected data were analyzed using two marking scales indicated determinants of composite supply chain.
Results and conclusions: The presented analysis of transport service qualities in the context of prospective synchromodal transport included participants of complex supply chains. The results show that they aim towards improvement of relations, co-operation and partnership in future process-related and strategic solutions.

Key words: supply chain, future logistics, synchromodal transport, commodity, multi-variability transport, transport service quality.

INTRODUCTION

Modern entrepreneurs determine new strategies and trends aiming at successful business in the face of dynamically changing environment, global competition and clearly defined customer requirements. Major changes are also visible in the efficient organization of processes making use of various modes of transport and service quality.

There are new concepts in the logistics of cargo flows supported by many implementation programs on the domestic and international market. Effective use of transport vehicles, route optimization, grouping of destination points, reduction of redundant packages, skilful use of infrastructure and appropriate investment projects result in competitive advantage and attract customers. Fundamental object is outlining global efforts towards sustainable development by utilizing transport means with optimized solutions and specific advantages of each transport mode.

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MULTIMODAL TRANSPORT AS AN ELEMENT OF INTEGRATED SUPPLY CHAIN STRATEGY

The main task of supply chain is to guarantee uninterrupted flow of cargoes, information and payments. These flows make up a system, defined as a set of logistic elements interconnected through transformation processes. The strategy of integrated management comprises all areas of a company, i.e. procurement, distribution, customer service, and it aims at the co-operation, integration and shortening of flow cycles and customer orientation [Rydzykowski, 2010]. These would not be possible without efficiently operating transport, coordinated on various levels: engineering, technology, organization. Various transport modes are used depending on transport needs, affected by: volume of supplies, type of cargo, location of markets, available infrastructure, carriage time, location of resources. The choice is also dependent on costs, safety and promptness of deliveries, recently the environmental impact. The creation of a responsible and sustainable transport policy based on the above aspects was supposed to change significantly the transport structure by increasing the share of other transport systems alternative to road, especially by intermodal configurations [Hajdul, 2009 and Nagurney, Liu, Wooley, 2007].

Conventional combinations of transport modes enable using optimal solutions and advantages of each mode, which should result in agile, unimpeded and flexible carriage in the bimodal, intermodal or multimodal system. Publications on the subject, particularly those in the English language, present a variety of concepts and definitions of multimodal transport. The characteristics of and relations between these concepts are presented in Table 1.

Table 1. Characteristics of multi-variant transport systems models and their interrelations
Tabela 1. Charakterystyka modeli systemowych transportu wielo-gałęziowego i związki między nimi

Type of transport system	Multimodal transport	Intermodal transport	Bimodal transport
Main idea to the transport system	Carriage of cargoes by using at least two different modes of transport	Carriage of cargoes in one unit load using successive at least two modes of transport without handling the load	Transportation involving use two means of transport: road and rail, without reloading unit load
Features of the system	There is one contract of carriage obliged, in charge of the delivery of goods is a responsible contractor. Each carriers performs its task subordinated to the needs of transport processes across the supply chain which means reduction or loss of autonomy of the individual modes of transport [Szołtysek, 2009]	One contract of carriage obliged, only one contractor responsible for the course deliver. Each carrier realizes more or less autonomous tasks in the supply chain	Last section of road transport carries
Handling of cargo	Integrated unit loads, e.g. containers, swap bodies, semitrailers or motor vehicles, special containers; *Cargo discretisation*, which means that only cargo unit is subject to manipulation	There is a need to load units with means that the cargoes are subject to handling and manipulation of constituent in full and container or means of transport.	Reloads the whole trailer from railway carriages to truck and vice versa
Sample projects implementations	GeCoTraM – Electronic system for container circulation management In multimodal transport for the European integration on the transport corridors cross Romania; SUPERGREEN – Supporting EU's freight transport logistics action plan on green corridors issues	INTERMODA – Integrated solutions for intermodal transport between the UE and the CEECs; PROMIT –Promote innovative intermodal freight transport	BiMo- Flexible transport chain: Integration of bi-modal transport into a closed loop transport services concept; POSTRAIN - Bimodal innovative vehicle with two locomotive configuration

Combined transport is a form of intermodal transport (included in the multimodal transport). Its characteristic feature is the fact that the major part of carriage is executed between terminals by rail,

inland or short-sea shipping, while feeder services are provided by road carriers over strictly specified distances.

Although there are favorable premises for intensive development of multimodal transport (location at major junctions of European transport corridors and growing transit traffic) [Krystek, 2005] Polish cargo transport market is dominated by road transport. Combined transport is perceived as a system that does not offer a real alternative to road transport, because technically it is not sufficiently flexible, too slow and unreliable in terms of delivery, and too expensive [Fagerholt, 2010 and Kazakov, 2010]. This opinion is supported by research on delivery promptness [Kwaśniowski, Nowakowski, Zając 2008]. Its results show that among many difficulties in timely delivering of cargo units by intermodal transport the most frequent delays are caused by the rail operator (as much as 65% of the examined sample, due to lack of proper rolling stock, delays due to previous delays, strikes, insufficient manning, errors in shipment sorting, equipment failures, railway works). Other causes include: delays during cargo preparation and carriage to terminals (11%), delays caused by terminal operators (3%), others (customs, automatic data identification, unidentified 21 %).

National efforts to implement sustainable transport policy are supported by a number of initiatives and the execution of programs (see Table 1, line: Sample projects implementations) aimed at the restoration of balance between the modes of transport, provision of open access to each transport market and reduction of harmful impact on the environment.

THE CONTEXT OF CO-MODALITY WITHIN MULTI-VARIANT TRANSPORT

The processes of cargo flow concentration are accompanied by globally unprecedented in magnitude new logistic forms of organization and management, a prerequisite for time and cost effective control of information and financial glows, and for the satisfaction of demand for cargo quantities generated by globalization [Jain, Wadhwa, Deshmukh, 2009 and Tongzon, Chang, Lee, 2009]. Among the factors necessitating the changes in traditional approach are changing expectations of customers, including their environmental awareness, growing role of general cargo in trade and the location of production centers.

The co-modality of supplies, a relatively new term in transport logistics, first appeared in 2006. EU policy in this respect indicates the need to optimize the use of each mode of transport as a method for achieving a simple and efficient transport system by replacing competition with the concept of complementarity. Such approach gains importance in European transport and logistics as it is economically attractive in terms of flexibility, accessibility, promptness, multiplication of financial efforts for infrastructure, cost reduction and availability of information in real time.

With the objectives defined as above, it may turn out that in a given transport process only one mode of transport can be employed, and that is 'heavy' road transport, e.g. in the modular system. The very idea of co-modality does not assume that intermodal transport is necessary and justified. What it assumes is that to strive for the above mentioned objectives, the decision on one or more modes of transport should be considered. However, it is assumed that shifting a part of long distance road transports to other modes will be encouraged in the light of growing congestions on European road network, lengthening travelling time of vehicles and delivery delays [Archutowska, 2009].

It should be borne in mind, though, that each transport process, according to sustainable development and main guidelines of co-modality of supplies, will be evaluated in respect to eco-logistic solutions, meeting customer expectations and cost reduction. The latter factor still remains the most significant for a majority of companies.

Creating a modern intelligent transport policy by synchromodal system

Innovative actions aimed at the effective organization of transport processes require that all participants of the supply chain maintain bilateral co-operation, based on mutual trust and partnership,

especially long-term relation of trust. The concept of synchromodal transport creates a multimodal transport policy at a higher level of process organization (see Figure 1), based on combinations of co-modal transport with proper scale of individualized solutions.

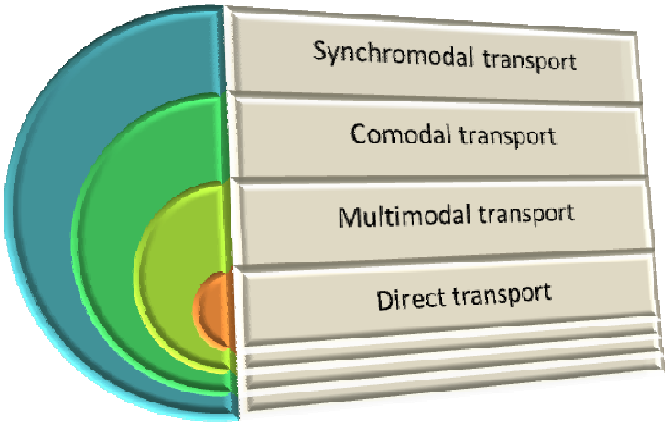

Fig. 1. The levels of process organization in transport multi-faceted
Rys. 1. Poziomy organizacji procesowej w transporcie wielogałęziowym

Synchromodal transport is an innovative, promising idea of flexible and sustainable utilization of transport resources based on the co-operation of carriers representing various transport modes, adjusted to customer requirements and current transport capacities [Fernandez, Cea, Soto, 2003 and Holmgren, 2012]. Unlike intermodal transport, where cargo is moved in a specific direction, i.e. from a point of shipment to its destination by an initially chosen transport vehicle, synchromodal transport assumes that at any moment one of several options of transport connections is chosen. This means that in real time the best available methods of transport are used.

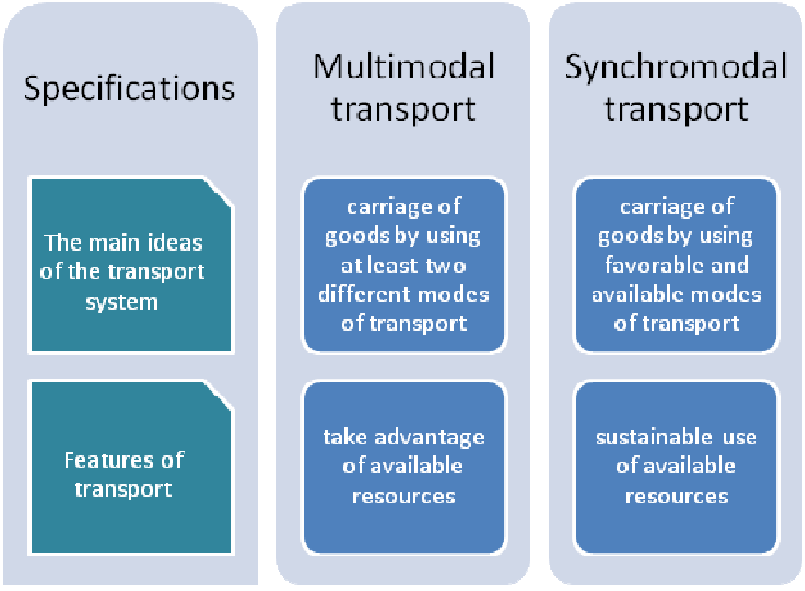

Fig. 2. Main assumptions synchromodal concept in combinations with multimodal transport
Rys. 2. Główne założenia koncepcji sychromodalnej w zestawieniu z transportem multimodalnym

An optimal decision is preceded by detailed recognition of customer preferences, analysis of multi-variant combinations of services and the estimation of possible results. Such approach demands from supply chain participants honest and up-to-date information exchange, for which a properly configured

computer platform cannot be overestimated. The key requirement for smooth and dynamic operation of the system is the creation of skeleton networks as a backup of main seaports, logistics centers, container terminals. The system needs a compatible network, efficient operators, appropriate allocation of transmission capacities, effective utilization of infrastructure and suprastructure, and the implementation of intelligent transport systems. General assumptions of innovate concepts and differences compared to the multimodal transport shows Figure 2.

Synchromodal transport furthermore implies making optimum use of the factor time: push instead of pull. Containers no longer remain at the deep-sea terminals in anticipation of action on the part of the recipient (pull), but are directly moved by barge or train to the inland terminals in the hinterland in a pro-active fashion (push). The realization of a synchromodal transport system is not that easy. The consolidation of volumes is essential in this respect. Only then frequent connections are possible between all the hubs using all three modalities: rail, inland shipping and road [Fransoo, 2011]. The result is an optimal sustainable and reliable transport system.

In terms of technology, innovative solutions are related to increased capacity of a road vehicle, e.g. by using double loads on the bottoms of trailers and semi-trailers, increasing the maximum vehicle length, or wider use of standard Euro-pallets for cargo unitizing. It is worth noting that of all EU countries there are only two that allow the movement of road trains longer than 18.75 meters: Finland (25.25 m) and Sweden (24.00 m). Regulations on allowable maximum mass of vehicles in road traffic also vary: from 38 tons in Austria, 40 tons in Poland, 50 tons in Holland, to 60 tons in Sweden. Therefore, the best instrument for promoting synchromodality in supply chains will be revised and harmonized transport regulations. Apart from the variety of vehicle parameters, other obstacles for the idea of synchromodality are coordination problems in individual transfer junctions, demurrages, insufficient infrastructure, lack of standardized data exchange, unequal engagement of co-operating parties. Pilot implementation of the innovate concept is currently realize between Rotterdam and Tilburg in the south of the Netherlands. This concept entails the optimal operational alignment of shippers and carriers in their choice of transportation modality and infrastructure. This operational alignment is characterized by 1) the ability to switch freely between modalities and logistics networks whenever desirable and 2) by being able to aggregate and bundle transport loads to enjoy the benefits of economies of scale.

Quality services in a multi-faceted supply chain - case study

Effective organization of transport processes becomes increasingly difficult due to minor role of rail, sea and inland waterway transport in cargo traffic compared to the market share of road transport (see Picture 3).

According to analyses of the Railway Transport Office (UTK) the fraction of intermodal transport in the first three months of 2011 showed a rising trend compared to the same period a year before. By the end of March the following results were recorded: carriage of 980,000 tons of commodities, overall transport work covered 418 million ton-kilometers, which compared to the previous year meant an increase of railway freight in combined carriage by, respectively, 18.2% and 19.3%. However, it is still a slight fraction in the transport market oscillating at 1.95% of the mass carried and 3.96% of performed carriage work.

Although in the short run frequent and prompt deliveries by road meet customer needs and contribute to the improvement of processes, the use of more vehicles in the available road infrastructure may lead to congestions and reduced average speed of deliveries, with consequent delays and reduced traffic safety. Inclusion amount of cargoes transport in 2010 year, with the context of the average distance traveled by the mode presented Figure 4. It is concluded that the dominant road transport (84.4% of transported cargoes) while performing traffic on the shortest average distance equal to 144 kilometers and the railroads that transported 11.8% of the average distance cargo transport recorded at 225 kilometers.

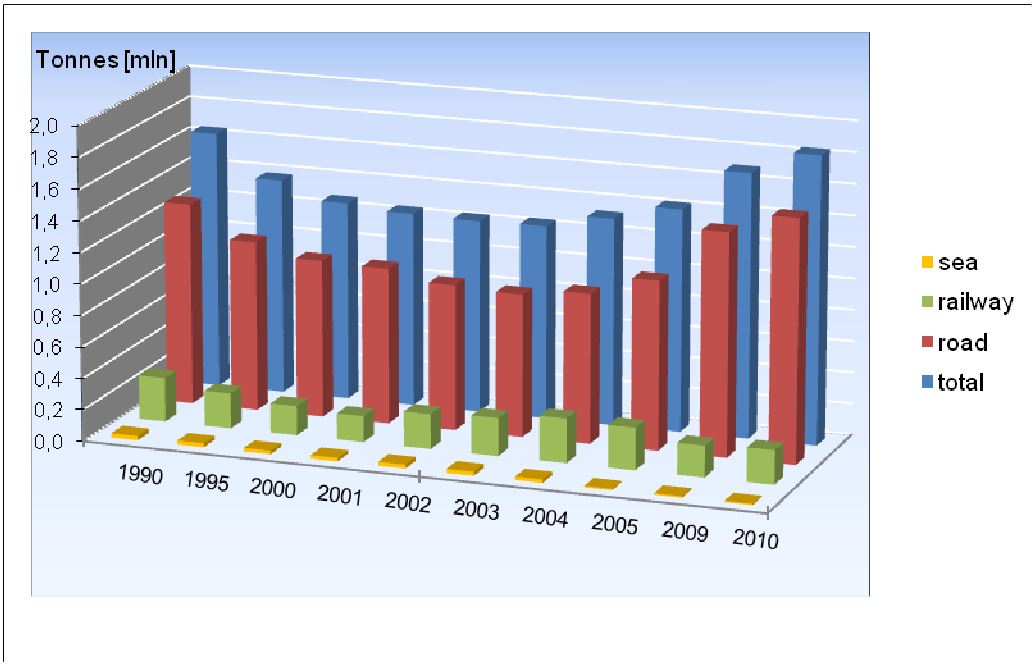

Fig. 3. The volume of freight transport based on mode of transport
Rys. 3. Wielkość przewozów towarowych z uwzględnieniem rodzaju transportu

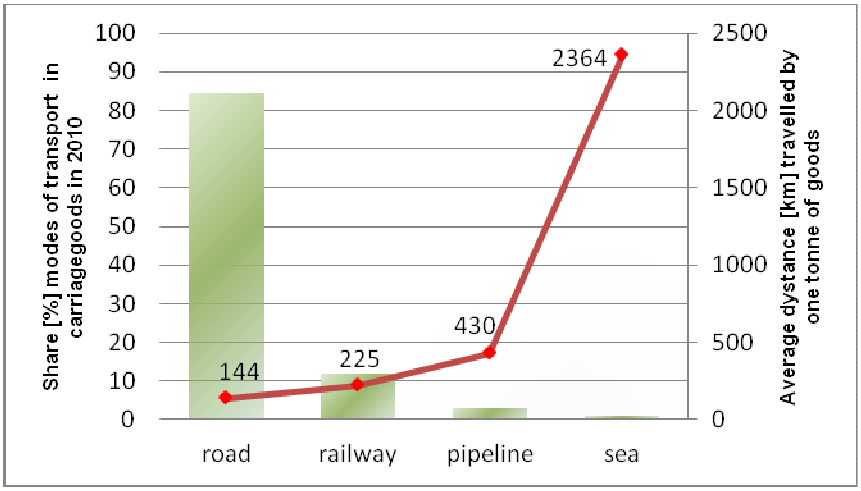

Fig. 4. Participations in various modes of freight transport in comparison with average distance a tone of cargo
Rys. 4. Udział poszczególnych gałęzi transport w przewozach towarowych w zestawieniu ze średnią odległością jednej tony ładunku

It should be noted here that the transport service quality depends on the satisfaction of customers from the service, but also their overall assessment they make by balancing positive and negative impressions related to the organization and all services it provides. Notably, among reasons for contacting a particular service provider may be the felt intensity of the customer's needs, their financial capacity and the flexibility of service offer of the provider [Łańcucki, 2010]. Taking into account the evaluation of customer satisfaction from services provided, we analyzed a number of features determining the suitability of a given mode or vehicle for fulfilling a transport need.

The examination of the significance of quality features of transport services in the complex supply chain in the context of innovative strategy of synchromodal transport included 613 samples. The companies were selected on purpose, i.e. those actively participating in organized cargo flows. Respondents showed a stable opinion, that is their long time presence on the market guaranteed

objective opinions. Results from companies operating less than seven years or those with financial liquidity defined as 'low' or 'close to zero' were omitted. Completely filled out questionnaires were delivered by 141 respondents. Transport processes taking place in multi-level supply chains were evaluated using two marking scales. One covered descriptive research based on bipolar interval scale, identifying essential determinants of transport services by the prioritizing of features indicated in the questionnaire. The other accounted for the significance of a feature in terms of dynamic relations between an attribute and attribute significance, comprising such determinants: readiness, continuity, credibility, safety, mobility, promptness, flexibility, reliability. These were analyzed in two areas: direct deliveries - one vehicle used, usually a road truck, and multimodal deliveries with various configurations of available means of transport (at least two different modes).

The level of participant supplies satisfaction is shown in Figure 5.

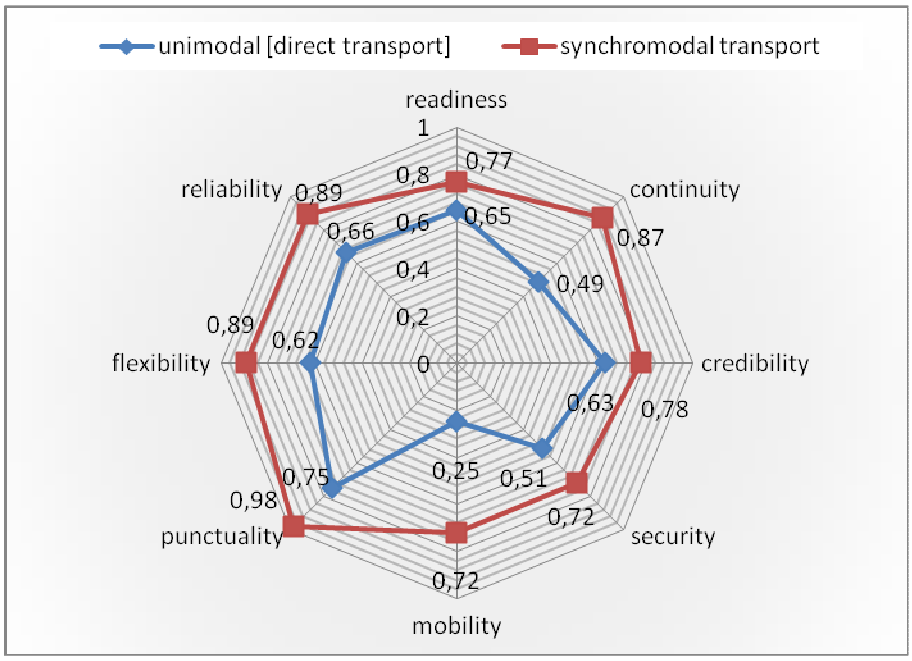

Fig. 5. Significance of quality features of transport services provided in direct and combined deliveries
Rys. 5. Ważność cech jakościowych realizowanych usług transportowych w dostawach bezpośrednich i złożonych

It will be noted that all examined quality features of services provided as direct deliveries or combined transport have attained a significance level higher than 50%. Interestingly, only 25% of respondents representing road transport participants indicated 'mobility' as an essential feature for customer satisfaction, although this mode of transport is most frequently used for door-to-door services. Multimodal transport requires from its participants more involvement, service integration and better arrangement of distribution structures - the significance level of the features ranged from 72% (safety and mobility) to 98% (promptness), which may indicate that each individual feature as well as all of them combined play a significant role in the complex transport process.

CONCLUSIONS

Innovative concepts of transport process management leading to effective adjustment to market requirements point out directions in which modern companies should develop. Customized offers of integrated and comprehensive services based on mutual trust, co-operation and partnership will be determinants of effective and progressive logistics. The following conclusions can be formulated:

- coordination creates efficiency,
- data exchange is really crucial to raise logistics to a higher level,
- synchromodality is an essential pre-condition for optimally and sustainably organizing transport in the future,
- customer criteria in that respect are (in varying orders) reliability, efficiency, price, speed and, increasingly, sustainability,
- strategic collaboration alone will not suffice. To further streamline logistics in the future, the business community must also simply cooperate at the operational level.

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WIELOWARIANTOWOŚĆ KONFIGURACJI ŁAŃCUCHÓW DOSTAW W KONTEKŚCIE KONCEPCJI TRANSPORTU SYNCHROMODAL-NEGO

STRESZCZENIE. **Wstęp:** Potrzeby transportowe są pożądanymi przez gospodarkę oczekiwaniami zależnymi od preferencji klientów, dostępności supra- i infrastruktury, świadomości ekologicznej. Celem opracowania jest wskazanie światowych dążeń do zrównoważonego rozwoju i wykorzystania środków transportu z uwzględnieniem optymalnych rozwiązań i zalet każdej z gałęzi. Nowatorskie koncepcje w obszarze transportu wielowariantowego, jak transport komodalny, czy synchromodalny stanowią fundamenty kreowania wyższego poziomu organizacji procesowej z uwzględnieniem rozwiązań zindywidualizowanych.
Metody: Opisano cechy i główne założenia nowoczesnej koncepcji transportu synchromodalnego oraz wskazano różnice w odniesieniu do znanego systemu multimodalnego. Przedstawiono analizę statystyczną w zakresie udziału poszczególnych gałęzi transportu w przewozach intermodalnych w ostatnich dziesięciu latach. Przeprowadzono badania ważności cech jakości świadczonych usług transportowych na próbie 613 przedsiębiorców dobranych celowo. Zebrane dane przeanalizowano w przekroju dwóch skal ocen uwzględniając wyróżnione determinanty dostaw wielogałęziowych.
Wyniki i wnioski: Przeprowadzona analiza cech jakości świadczonych usług transportowych w kontekście perspektywicznej koncepcji synchromodal transport obejmująca uczestników złożonych łańcuchów dostaw wskazuje na dążenia w kierunku doskonalenia relacji, wzajemnej współpracy i partnerstwa przyszłościowych rozwiązań procesowych i strategicznych.

Słowa kluczowe: łańcuch dostaw, logistyka przyszłości, transport synchromodalny, komodalność, transport wielogałęziowy, jakość usług transportowych.

MEHRVARIANTEN-KONFIGURATION VON LIEFERKETTEN IM KONTEXT DES SYNCHROMODALEN TRANSPORTS

ZUSAMMENFASSUNG. Einleitung: Transportbedarf ist eine von der Wirtschaft sehr gefragte Erwartung, die von Kundenpräferenzen, ferner Zugriffsmöglichkeiten an die Supra- und Infrastruktur sowie vom ökologischen Bewußtsein abhängig ist. Das Ziel der Abhandlung ist es, auf die Welttrends zur nachhaltigen Entwicklung und Inanspruchnahme von Transportmitteln unter Berücksichtigung optimaler Lösungen und Vorteile jeder Transportart hinzuweisen. Innovative Konzepte im Bereich des Mehrvarianten-Transports wie ko- oder synchromodalen Transports bilden eine Basis für Ausgestaltung eines höheren Niveaus innerhalb der Prozeßorganisation unter Berücksichtigung der individualisierten Lösungen.
Methoden: Im vorliegenden Beitrag wurden Eigenschaften und Hauptgrundsätze des modernen synchromodalen Transport-Konzeptes beschrieben und Differenzen in Bezug auf das multimodalne Transportsystem geschildert. Dabei stellte man die statistische Analyse im Bereich der Beteiligung einzelner Transportzweige an den intermodalen Transporten innerhalb der letzten zehn Jahre dar. Ferner wurden Nachprüfungen der Gültigkeit von Qualitätsmerkmalen in Bezug auf die Transportdienstleistungen anhand einer Probe von 613 gezielt ausgewählten Unternehmen durchgeführt. Die ermittelten Daten wurden bei Inaspruchnahme und Vergleich von zwei Beurteilungsskalen unter Berücksichtigung der ausgesonderten Determinanten von Mehrzweig-Anlieferungen analysiert.
Ergebnisse und Fazit: Die durchgeführte Analyse der Qualitätsmerkmale von Transportdienstleistungen weist im Kontext des zukunftsträchtigen Konzeptes des synchromodalen Transports, welches Teilnehmer der komplexen Lieferketten umfaßt, auf die auf die Vervollkommnung von gegenseitigen Relationen sowie der Zusammenarbeit und Partnerschaft innerhalb von zukünftigen strategischen Prozesslösungen ausgerichteten Versuche hin.

Codewörter: Lieferkette, Zukunftslogistik, synchromodaler Transport, Komodalität, Mehrzweig-Transport, Qualität von Transportdienstleistungen.

Joanna Pleszko
Institute of Transport Engineering
Maritime University of Szczecin
Pobożnego 11 st, 70-507 Szczecin, Poland
e-mail: j.pleszko@am.szczecin.pl

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EFFICIENCY ANALYSIS SYSTEM OF MATERIAL MANAGEMENT

Bogusław Śliwczyński, Adam Koliński

Poznan School of Logistics, Poznan, Poland

ABSTRACT. Background: Significant scope of enterprise's efficiency management is improving of material management process both the strategic and operational level. The complexity of material flow processes can lead to a threat such as distraction and disintegration of analysis focusing on many different factors influenced on effective sourcing and procurement management, transport and warehousing processes, inventory management, working capital and cash flow management.
Material and methods: The presented article focuses on multidimensional and multi-criteria analysis of material management efficiency that is considered as decision support system. Authors have presented results of the research regarding ineffective material management confirm insufficient analytical supporting in various decisions of procurement operations.
Results and conclusions: Based on research results authors presented in the article model of efficiency analysis system of material management.

Key words: efficiency, controlling, material management, sourcing & procurement.

INTRODUCTION

The complete cycle of material management support beginning from sourcing and purchase decision by internal control of production materials, planning and control of work-in-process, the warehousing and shipping, to distribution of finished products [Johnson, Malucci 1999]. Combining the activities of material management does not merely represent a linear chain of one-on-one business relationships, but a web of multiple business networks and relationships [Min, Zhou 2002]. In complex analysis of material management relationships authors have used assumptions of net thinking methodology elaborated by P. Gomez, G. Probst and H. Ulrich [Probst, Gomez 1989; Ulrich, Probst 1990].

The efficiency management of enterprise's processes requires coordination between multidimensional measurement process (with using financial and operational indicators) and in feed-back planning and organizing of operations that ensures effective business adjustment to achieve the planned objectives [Śliwczyński 2010]. The complexity of material flow processes can lead to a threat such as distraction and disintegration of analysis focusing on many different factors influenced on effective sourcing and procurement management, transport and warehousing processes, inventory management, working capital and cash flow management.

The model of material management decision support system requires detailed analysis of all relationships in general model of enterprise and supply chain process management. Depending on the characteristics of the product, two distinct material flow in supply chain configurations offer competitive advantage: one based on efficiency and a second based on market responsiveness [Parmigiani, Klassen, Russo 2011]. General model of enterprise's process management, that was assumed by authors as basis for analysis various relationships, is shown in figure 1.

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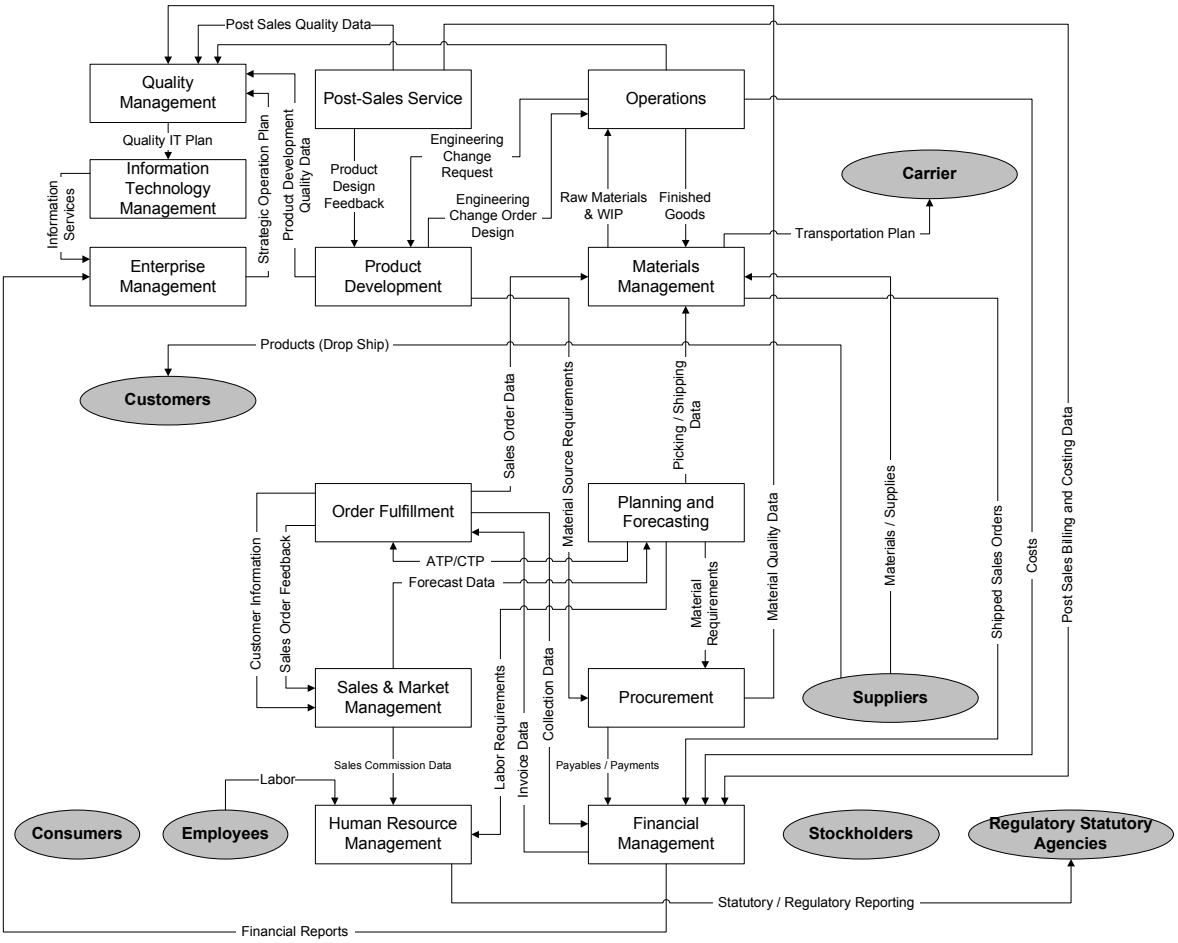


Source: own study

Fig. 1. General model of enterprise's process management
Rys. 1. Ogólny model procesu zarządzania przedsiębiorstwem

The objectives for material management derived from general business relationships analysis (shown in Fig 1) were categorized by authors to two groups - primary objectives:

- efficient materials planning (e.g. S&OP and MRP level),
- sourcing and purchasing,
- good supplier relationship,
- procurement and transport,
- storing and inventory control,
- financial management and controlling (e.g. costs, cash flow and working capital),
- quality assurance.

and secondary objectives of materials management:

- efficient activity and assets using scheduling,
- standardization of materials and procedures,
- assisting in product design and development
- forecasting material requirements,
- quality control of materials purchased,

- material handling and warehousing,
- use of value analysis and value engineering,
- smooth flow of materials in and out of the organization

Taking into account the practical aspect of material flow in enterprises, there often occur the lacks of analytical and planning tools for effective execution of material management and adjusting of material flow processes (e.g. purchasing, transport, inventory management and warehousing) to the assumed strategy. Results of the research regarding ineffective material management (shown in table 1), carried out by the authors of this paper, confirm insufficient analytical supporting in various decisions of procurement operations.

Table 1. Research results of insufficient analytical supporting in various procurement operations decisions
Tabela 1. Wyniki badań niewystarczającego wsparcia analitycznego w różnego typu decyzjach w obszarze zakupów

Results of insufficient analytical supporting in material management decisions	Percentage share of studied enterprises
Non-benefit conditions of purchasing contract in relation to procurement requirements	21,0%
Non- adequate level, allocation and structure of material inventories	28,7%
Non- adequate scale and frequency of purchases and supplies	25,6%
Non-optimal transport planning and conditions of transport outsourcing	18,4%
Non- adequate capacity and efficiency of transport and warehousing infrastructure	34,6%
Non-optimal execution of material flow processes – delay, waiting and queue, bottleneck in transport, handling and warehousing processes	31,3%

Source: Own study; It was conducted in the years 2011-2012 via audits in 92 enterprises and by means of an interview and opinion poll among managers of 176 enterprises. The study was conducted in 4 sectors - automotive, building, apparel and household devices - in production sector, with an even quantitative distribution in the group of small, medium and big enterprises.

In this same group of enterprises were carried out research of knowledge about efficiency factors of material management at managers. Results of the research are shown in table 2.

Table 2. Research results of knowledge about efficiency factors of material management at managers
Tabela 2. Wyniki badań dotyczących wiedzy o czynnikach wpływających na efektywność zarządzania materiałowego posiadanej przez zarządzających

Efficiency factors of material management at managers	Percentage share of managers
Inventory costs (replenishment, warehousing, capital)	18,0%
Material value along supply chain	13,7%
Standard costs and operation norms in material process flow	24,2%
Benchmark of outsourcing rates	63,5%
Various methodologies of analysis and calculation algorithms (e.g. value, costs, ABC/XYZ, material safety, EOQ, supply chain scenarios)	32,6%
Normative range of material management indicators	43,7%

Source: Own study; It was conducted in the years 2011-2012 via audits in 92 enterprises and by means of an interview and opinion poll among managers of 176 enterprises. The study was conducted in 4 sectors - automotive, building, apparel and household devices - in production sector, with an even quantitative distribution in the group of small, medium and big enterprises.

The results of the studies conducted in Polish enterprises show that analytical supporting and efficiency factors knowledge are insufficient from the point of view of effective material management. On that basis, authors elaborated and presented in the article model of efficiency analysis system of material management.

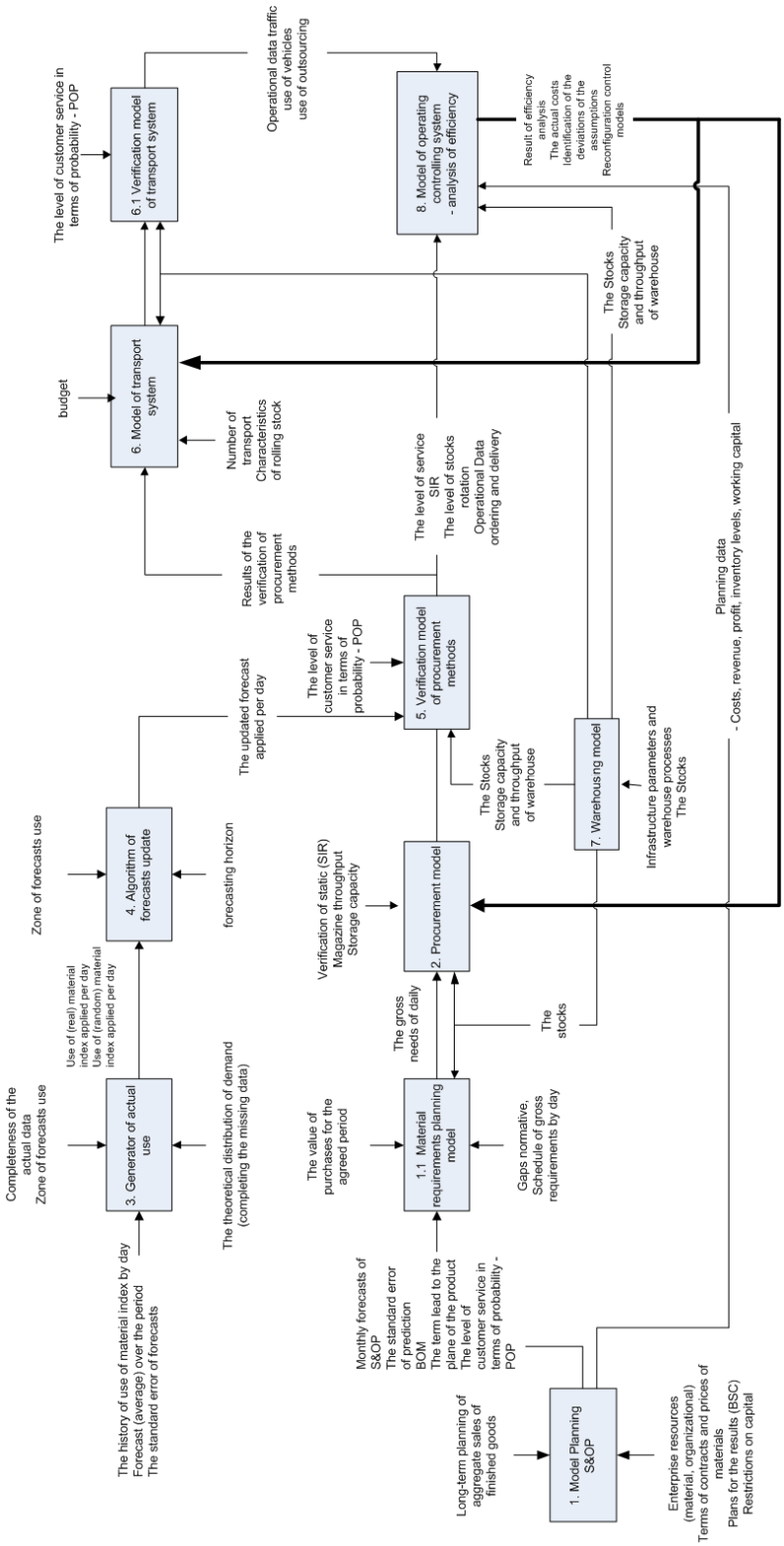
THE MODEL OF EFFICIENCY ANALYSIS SYSTEM OF MATERIAL MANAGEMENT

Carrying out a detailed analysis of the suggested controlling system one needs to look at the process of material management using the reference methodology of the SCOR process approach and take into consideration component models (SCOR - Supply-Chain Operations Reference Model - Model Overview Version 9.0. - a referential model of supply chain operations integrating five basic processes- planning, supplies, realisation, distribution and service of the turning streams, developed by managers and academics associated in a global organisation Supply-Chain Council. The model consists of representative methods of describing supply chain processes, a set of standards for the assessment of processes and their results as well as the best practical actions of managing processes in a supply chain):

- S&OP planning model- makes it possible to plan operations in a supply chain including transposing the needs of sales into the level of planning the stream of goods from production process,
- the model of planning material needs- including material structure of a product, which is necessary for material count, technologies and production itineraries, necessary for scheduling material needs, and store states; simulation is carried out with the net values of material needs,
- the model of commission- making it possible to simulate individual variants according to estimated net material needs,
- the generator of real consumption and the algorithm of updating prognoses, which should be treated as auxiliary simulation models of real consumption for examined material indices; they are necessary for simulating the real environment of material supplies realisation, transport processes and supplies availability at the stage of verifying the commission models,
- the model of verifying the commission methods- facilitating a multi-criteria analysis and choice of satisfactory models according to set criteria values,
- the model of a transport system and the model of verifying that system including the model solution for a multi-criteria load and routes planning as well as means straining and transit scheduling,
- the model of storing, which is also an auxiliary model necessary for defining the capability of receiving and servicing transport processes and maintaining supplies.

Presented models are components from which the system of material management analysis takes input data for efficiency analysis. The logical schema of efficiency analysis system of material management process is presented in Fig. 2.

Criteria and measures for analysis of anomalies of the real state of things from the one that has been planned, on an operational level, are not only long-term but also very general when it comes to the obtained data, e.g. market share. However, it needs to be remembered that it is already on an operational level where it is necessary to monitor gradually the aims realisation and alternatively correct current actions so as to increase the probability of gaining the result that has been planned [Koliński 2012].



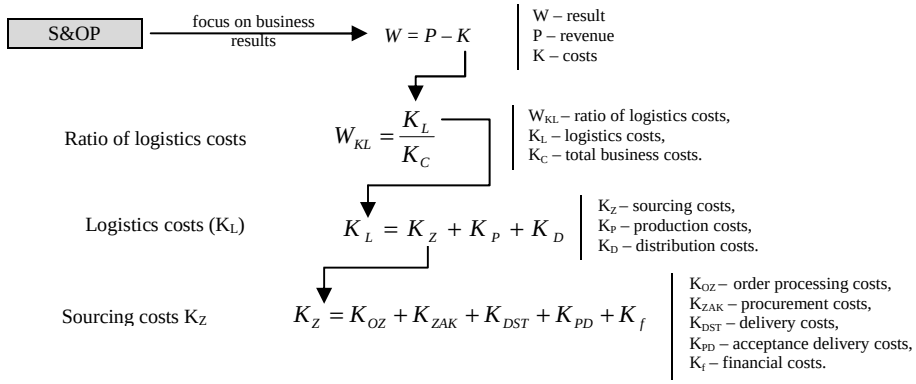
Source: own study, base on [Research project "Simulation of managing..."]

Fig. 2. Logical schema of efficiency analysis system with the information from the material management process
Rys. 2. Schemat logiczny systemu analizy efektywności na podstawie informacji z procesu zarządzania materiałowego

Transposing a strategic aim in an expenses aspect is possible due to a detailed analysis of a S&OP plan which includes programming the choice and the size of sales on individual markets and operations securing the sales in a complete supply chain. The S&OP plan is a decisional process thanks to which all tactical plans are coordinated with each other. However, an effective analysis should be supported by input data that is not financial. This data should be received from earlier stages of material management process. The data crucial for carrying out an effective S&OP plan is the following:

- data concerning suppliers' location and formulated offer inquiries,
- criteria for initial offers and tenders selection,
- data and criteria for qualifying suppliers,
- criteria for ranking and rating suppliers,
- data concerning permanent conditions of realising the supplies set by the recipient.

It is just a multi-criteria analysis of the S&OP plan that can be a reliable basis for transposing company's aims to the operational level of the sourcing process. That is why the developed system of operational controlling requires a detailed analysis of the role that sourcing expenses play in a logistic process. Accepting the basic dependence of logistic expenses and transposing them to sourcing expenses, other expenses should be treated as permanent, or known, to the decision maker of the controlling system. Transposing company's result to sourcing expenses is shown in Fig. 3.



Source: own study

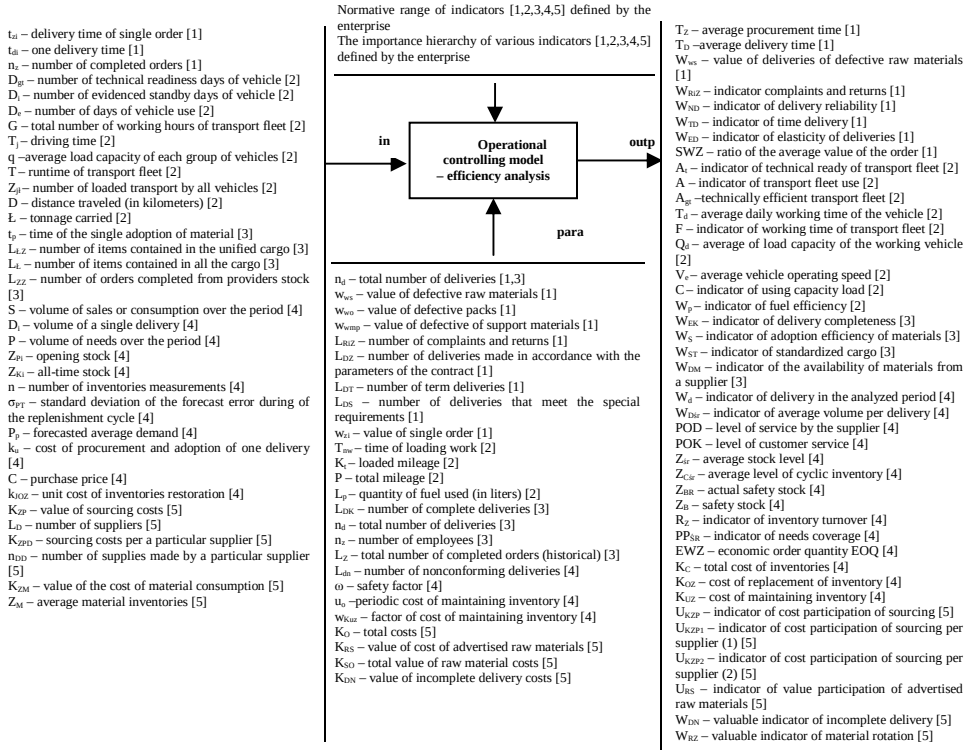
Fig. 3. Transposing company's result to sourcing expenses
Rys. 3. Transpozycja wyniku przedsiębiorstwa do wydatków

The idea shown in Fig. 3 is based on the assumption of expenses optimisation as a more efficient tool of improving company's result. Expenses optimisation is about rationalising factors which can be steered by a company and for this reason it has a tremendous effect on the possibility to generate higher profits. However, it needs to be remembered that optimum concentration on the analysis of sourcing expenses is advisable only in a situation when the value of logistic expenses rate, meaning the share of logistic expenses in company's total expenses, is significant.

The following components of efficiency analysis system aim at supplementing and specifying analytical data. The result data of the following models: S&OP, commission, transport and stock is, at the final stage of simulation, analysed in a model of final verification using the model of operational controlling. Algorithmisation of many functions for estimating the results of, among others, expenses and efficiency, reliability, productivity, stock level and rotation as well as operational capital involved in a sourcing process is the basis of the final assessment of material flow management [Hadaś, Cyplik, Domański, Fertsch 2009]. Identifying anomalies from the values set in S&OP module in the confines of adopted tolerance is the basis for handing over, in feedback, expenses and operational data to operational modules for the needs of new configuration of the parameters and models regulation.

The basic input data for the model are defined already on the level of the S&OP plan. One also needs to remember about the assumptions directly proceeding efficient sales and operations planning which are connected with, among others, classifying the suppliers and contracting them. Aims and indicators used in an efficiency analysis should result from a company's vision and strategy. An efficiency analysis can be named complete when it does not only refer to indicators which apply to past results but also when it allows to monitor what affects future results. Taking into account multi-criteria aspect, the problem of efficiency assessment can be based on the assumptions of Balanced Scorecard developed by R. Kaplan and D. Norton. The authors proposed the analysis of efficiency from four perspectives: financial, customer, internal business process, and learning and growth.

Many companies already have performance measurement systems that incorporate financial and nonfinancial measures. What is new about a call for a "balanced" set of measures? While virtually all organizations do indeed have financial and nonfinancial measures, many use their nonfinancial measures for local improvements, at their front-line and customer facing operations. Aggregate financial measures are used by senior managers as if these measures could summarize adequately the results of operations performed by their lower and mid-level employees. These organizations are using their financial and nonfinancial performance measures only for tactical feedback and control of production process in short-term [Kaplan, Norton 1996].



Source: own study based on [Twaróg 2005]

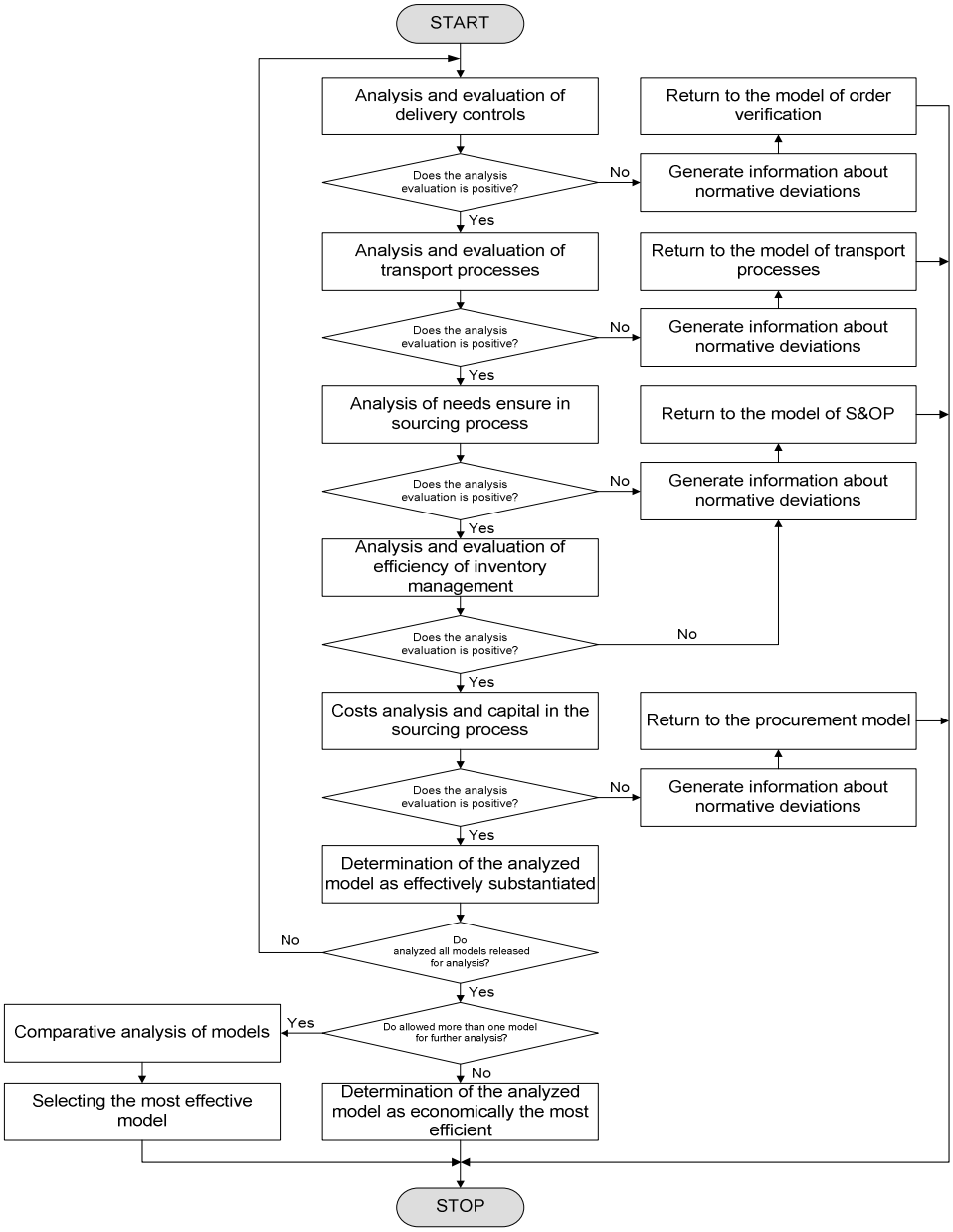
Legend:
[1] Data, parameters or indicators necessary for the analysis and evaluation of delivery controls
[2] Data, parameters or indicators necessary for the analysis and evaluation of transport processes
[3] Data, parameters or indicators necessary for the analysis of needs ensure
[4] Data, parameters or indicators necessary for the analysis and evaluation of efficiency of inventory management
[5] Data, parameters or indicators necessary for the costs analysis and capital in the sourcing process

Fig. 4. Defining input and output data as well as parameters necessary for an effective analysis of the efficiency of material management processes
Rys. 4. Definiowanie danych wejściowych i wyjściowych jako parametrów niezbędnych do efektywnej analizy efektywności procesów zarządzania materiałowego

A set of standards [Watson, Blackstone, Gardiner 2007; Śliwczyński 2011; Twaróg 2005] used for building an operational controlling system have been developed thanks to an analysis of the efficiency of material management processes in the four discussed perspectives.

Multi-criteria parametric analysis

A complex assessment of the efficiency of managing the material flow in an analytical system has been based on the systems of standards as well as generated basic data necessary for defining these standards (compare Fig. 4). Further detailed analyses of the model for assessing the efficiency of managing the commissions and materials supplies have been based on algorithmic assumptions presented in Fig. 4.



Source: own study, base on [Research project "Simulation of managing..."]

Fig. 5. A general algorithm for assessing the efficiency of material flow management
Rys. 5. Ogólny algorytm oceny efektywności zarządzania przepływem materiałowym

An algorithm, presented in Fig. 5, for assessing efficiency has been purposefully divided into individual elements because of the existing feedback in the process of managing the material flow and because of containing the perspectives of the Strategic Scorecard.

In its detailed analysis of efficiency of material flow management (Fig. 5) is as follows the input data and measures, which are necessary for multivariate assessment. The following list was compiled with the division into analyse elements in accordance with the stages of the algorithm.

Input data and measures for analysis and evaluation of delivery controls is shown in Tab. 3.

Table 3. Input data and measures for analysis and evaluation of delivery controls
Tabela 3. Dane wejściowe i współczynniki dla analizy i oceny kontroli dostaw

Analysis area	**Input data and measures**
Delivery control	number of purchased parts, materials or raw materials
	weight of incoming cargo
	number of orders in a given period of time
	place of delivery
	time of each delivery
	lead times of each procurement
	number of completed orders during the period
	number of realized deliveries during the period
	value of the defective raw materials, defective packaging and defective support materials
	unit cost of raw materials delivery, packaging delivery and used support materials
	unit cost of possible loss of continuity of production due to the delivery of defective raw materials
	unit cost of possible loss of continuity of production due to the delivery of defective packaging
	unit cost of possible loss of continuity of production due to the lack of sufficient of support materials
	unit cost of additional delivery of support materials
	number of complaints and returns during the period
	qualitative normative
	the number of deliveries of inconsistent assortments parameters of the orders
	the number of deliveries of inconsistent quantitative parameters of the orders
	the number of deliveries of inconsistent qualitative parameters of the orders
	assortment and quantitative order parameters
	complaint handling time
	number of deliveries made in accordance with the parameters of the order
	number of deliveries made in accordance with the deadline during the period
	number of delayed deliveries of raw materials, packaging and support materials
	number of deliveries that meet the special requirements
	deliveries list
	delivery time normative
	normatives of economic order quantity
	packaging normatives of delivery
	list of available modes of transport
	value of single order

Source: own study based on [Twaróg 2005].

Input data and measures for analysis and evaluation of transport processes is shown in Tab. 4.

Table 4. Input data and measures for analysis and evaluation of transport processes
Tabela 4. Dane wejściowe i współczynniki dla analizy i oceny procesów transportowych

Analysis area	Input data and measures
Transport process control	weight of incoming cargo
	amount of kilometers driven during the period
	number of days of technical readiness
	number of days of registration standby
	number of working days
	number of transport working hours
	running time of the rolling stock
	cargo handling time
	average capacity of particular groups of vehicles
	course loaded (in vehicle-kilometers)
	total course (in vehicle-kilometers)
	number of rides made by all the loaded vehicle or group of vehicles
	ridden road (in kilometers)
	tonnage carried
	quantity of fuel used (in liters)

Source: own study based on [Twaróg 2005].

Input data and measures for analysis of needs ensure in sourcing process is shown in Tab. 5.

Table 5. Input data and measures for analysis of needs ensure in sourcing process
Tabela 5. Dane wejściowe i współczynniki dla analizy i oceny procesu zakupu

Analysis area	Input data and measures
Operational needs ensure in sourcing process	time of the single material adoption
	number of employees
	number of items contained in the cargo unified
	number of items contained in all cargo
	normatives of cargo
	number of orders made from supplier stock

Source: own study based on [Twaróg 2005].

Input data and measures for analysis and evaluation of efficiency of inventory management is shown in Tab. 6.

Table 6. Input data and measures for analysis and evaluation of efficiency of inventory management
Tabela 6. Dane wejściowe i współczynniki dla analizy i oceny zarządzania zapasem

Analysis area	Input data and measures
Inventory management	size of single delivery
	size requirements (e.g. demand) during the period
	volume of sales or consumption during the period
	number of nonconforming delivery
	initial stock during the period
	final stock during the period
	number of measurements
	safety indicator
	standard deviation of forecast error
	standard deviation of the cycle time of replenishing
	expected life cycle inventory complete
	forecasted average demand
	cost associated with the order and the adoption of a single delivery
	purchase price
	cost indicator of periodic maintaining stocks
	unit cost of replacement stock
	ratio of maintenance of stocks

Source: own study based on [Twaróg 2005].

Input data and measures for costs analysis and capital in the sourcing process is shown in Tab. 7.

Table 7. Input data and measures for costs analysis and capital in the sourcing process
Tabela 7. Dane wejściowe i współczynniki dla analizy kosztów i kapitału w procesie zakupu

Analysis area	Input data and measures
Costs and capital in the sourcing process	number of incoming goods for the period
	number of employees in the execution of orders
	number of employees in the goods adoption
	procurement costs
	total cost of goods adoption
	costs of wrong deliveries
	costs of returns
	costs of delayed delivery
	value of procurement costs generated during the period
	value of total costs generated during the period
	value of procurement costs attributable to a particular supplier
	amount of deliveries made by a particular supplier
	value of advertised raw materials cost
	total value of raw material costs
	value of incomplete delivery costs
	value of total delivery costs
	value of material consumption cost
	average material inventories

Source: own study based on [Twaróg 2005].

The data and metrics for evaluating of the material flow efficiency, may of course occur in different parts of the analysis simultaneously. In this statement the individual data included only once - at the point of first use.

Detailed algorithmic processes refer to input data and the parameters presented in Fig. 5, with the division according to the key, as well as to appropriate calculation formulas included in the literature of the subject matter. From the point of view of material management controlling system in an analytical scheme a special attention should be paid to processes connected with:

- comparative analysis of commission models,
- an analysis of economic benefits of the commission model.

CONCLUSIONS

The system of efficiency analysis of material management, if developed in detail, can facilitate rationalisation of the scenarios of sourcing and managing the materials involving the criterion of the highest, or satisfactory, efficiency of a company. The present article has defined the relation of company's processes efficiency to the processes of material flow and sourcing which together create a complex decisional system in accordance with the fundamental aim of the article. Sourcing processes, which should be treated as basic economic processes [Porter 1998], define a set of rules as well as input data necessary for the efficiency of the operational controlling system. It leads us to the conclusion that the optimum of functions necessary for efficient management of material flow in a so defined system can imply, in accordance with the methodology of a systemic approach, elimination of sub-optimisation and concentrating the efficiency on sourcing processes. A very important issue is also an analysis of the sensitivity of efficiency function for a defined system of a complex material flow including also factors of the efficiency of supplies and stock management, total procurement cost and organisation of supplies system.

Creating an efficiency model it needs to be borne in mind that an in-crease in one department's efficiency does not have to result in an increase in whole company's efficiency. Only an increase in key processes efficiency will result in an increasing the indicators of efficiency of a company's business activity. A very important aspect is also coordination of operational and strategic aims. If operational aims do not reflect accurately strategic aims, then a result can be generating contradictory indicators which have a negative influence on material management efficiency.

The presented suggestion for building an efficiency analysis system includes an analysis of economic processes in the aspect of the following systems: a system of transposing an aim, a control system and an analytical system. The presented idea, however, should be made more specific by carrying out further analyses in a decisional and control systems, which requires further literature research and confrontation in simulation studies. Literature research and observations of economic practice reveal that the management of companies incessantly search for the tools which would support making decisions concerning the choice of sourcing variants in order to achieve the most efficient decisions at the stage of planning process, which only confirms the importance of research in this area.

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SYSTEM ANALIZY EFEKTYWNOŚCI ZARZĄDZANIA MATERIAŁOWEGO

STRESZCZENIE. **Wstęp:** Istotną częścią zarządzania efektywnością przedsiębiorstwa jest udoskonalanie i poprawa procesu zarządzania materiałowego, zarówno na poziomie strategicznych jak i operacyjnym. Kompleksowość procesów przepływów materiałowych stwarza takie zagrożenia jak rozproszenie analizy skoncentrowanej na wielu różnych czynnikach wpływających na efektywne zarządzanie procesem zakupu, transportu, magazynowania, poziomem zapasu, kapitału pracujacego i przepływem środków pieniężnych.
Materiały i metody: w prezentowanej pracy główny nacisk położono na wielowymiarową i wielokryterialną analizę efektywności zarządzania materiałowego, która wspomaga system podejmowania decyzji. Autorzy zaprezentowali wyniki badań dotyczące nieefektywnego zarządzania materiałowego i potwierdzające niewystarczające wsparcie analityczne decyzji w obszarze operacji zakupu i zaopatrzenia.
Wyniki i wnioski: w oparciu o wyniki badań autorzy zaprezentowali model analizy efektywności przepływu materiałowego.

Słowa kluczowe: efektywność, controlling, zarządzanie materialowe, zakupy i zaopatrzenie.

SYSTEM DER EFFIZIENZ-ANALYSE IM MATERIAL-MANAGEMENT

ZUSAMMENFASSUNG. Einleitung: Ein wesentlicher Teil des Effizienz-Managements im Unternehmen besteht in der Vervollkommnung und Verbesserung der Prozesse innerhalb des Material-Managements, sowohl auf dem strategischen als auch operativen Niveau. Die Komplexität von Materialfluß-Prozessen verursacht jedoch Gefährdung des effektiven Managements wegen einer potenziellen Zerstreuung der betreffenden Analyse, die auf viele unterschiedliche Faktoren konzentriert ist. Solch eine Effizienz-Analyse vermag jedoch effektives Management von Einkaufs- , Transport- und Lagerprozessen und des Vorratsniveaus, ferner des rotierenden Kapitals sowie des Finanzmittel-Flusses positiv zu beeinflussen.

Material und Methoden: Die Entscheidungssystem unterstützende Mehrdimension- und Mehrkriterien-Analyse der Effizienz des Material-Managements ist in der vorliegenden Arbeit zum Schwerpunkt der betreffenden Forschung geworden. Die Autoren haben die uneffektive Material-Managementsysteme anbetreffenden Forschungsergebnisse präsentiert und die mangelnde Unterstützung seitens analytischer Entscheidungen im Bereich von Einkaufs-und Beschaffungsprozessen bestätigt.
Ergebnisse und Fazit: Angesichts der Forschungsergebnisse haben die Autoren ein Modell für die Analyse der Effizienz des Materialflusses dargestellt.

Codewörter: Effizienz, Controlling, Material-Management, Einkauf und Beschaffung.

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Bogusław Śliwczyński
Poznan School of Logistics
ul. Estkowskiego 6
61-755 Poznań, Poland
e-mail: boguslaw.sliwczynski@wsl.com.pl
Adam Koliński
Poznan School of Logistics
ul. Estkowskiego 6
61-755 Poznań, Poland
e-mail: adam.kolinski@wsl.com.pl

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THEORETICAL ASPECTS OF SYNTHETIC MEASUREMENT OF THE DEVELOPMENT DYNAMICS IN THE CONTEXT OF CITY

Zbyszko Pawlak

Poznan School of Logistics, Poznan, Poland

ABSTRACT. Background: The paper presents the theoretical basis for the proposal of modeling of the dynamics of the modern cities' development by the use of a properly constructed synthetic indicator. Additionally to the possibility of the quantification of the development of social and economic systems of cities, its implementation allows the identification of nonlinear processes as phase transitions, which occur e.g. under influence of technological and social innovations. The economic and physical approach to this allows to learn more about the nature of these processes and to set new instruments supporting the management of urban areas in conditions of an increasing competiveness.
Methods: The mathematical modeling of social and economical processes and economical and physical approach to dynamics of systems of nonlinear development.
Results and conclusions: Based on conducted simulation researches, it can be concluded that the synthetic measure of the development of urban areas can be a good tool supporting the city management by local authorities. The economical and physical approach to the nonlinear dynamics of urban systems marks out new areas for further researches, the determination of minimum required conditions (the necessary level) for stimulation of the phase transition and the analysis of factors allowing to avoid the negative consequences of a phase transition, especially in smaller cities areas, seems to be the most important ones.

Key words: city management, nonlinear development of city, phase transition, synthetic measurement of development dynamics.

INTRODUCTION

The urban areas, being the dynamic systems, like substances in physical processes, are subjected to transformation processes. One type of such transformation is a change of the state of matter - a phase transition. One of the most known and clear example of such phase transition is the transition of the state of matter of the water: from solid one (ice), through liquid one up to the gas one (steam). The transition between these states is conducted by the processes of freezing, melting, liquefaction, condensation, sublimation and resublimation. The urban agglomerations undergo the analogous processes of social and economical transformations, and as results of them, the changes can occur in their role, size or the range of their tasks on various levels (beginning from local one up to international one). Although most of occurrences of social and economical life of cities can be described by linear functions [Domański 2000], they can pass not exactly to results of observations, e.g. the increase of the effect is not proportional to the increase of one of the reasons. They can be not only of the continuous nature but also of incidental one, which causes additional complications to relations in social and economical systems. The identification of positive and negative nonlinearity can be useful in the recombination of factors, which have impact on the development of the infrastructure environment. It is very important, that thanks to technical and social innovations, the new possibilities

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of the development of societies and communities and, at the same time, the economical development of cities is possible [Domański 2006]. The transformations, which occur due to them, are typical transformations of the nonlinear nature - described as phase transition in economical and social aspects. The new structure, which is created during each phase transition, has different properties from the previous one [Domanski 2000].

While analysing the analogy between states of matter of physical bodies and the processes of the development of cities, it must be stated, that the thermodynamics reactions can be described by the use of physical equations, which explain the factors and their influences on the transition processes (e.g. pressure, temperature or others) but there is a lack of such quantitative description of the analysis of phase transitions of cities. In other words, there is no synthetic indicator, like the temperature in the thermodynamics, which allows describing, determining and explaining whether the community of a given city was, is or will be in the phase transition. It is also of a great value to attempt to indentify such factors, responsible for these transitions, interpreted as a quantity jump in the development process of an information society.

Due to the shortage of such form of the description of processes of the urban transformation (indispensable as one of tools of the city management), the aim of this paper is to propose the solution for the synthetic measurement of the development dynamics, which would enable the quantitative analysis of processes of phase transitions of cities.

MICRO- AND MACRO-VARIABLES AND INDICATORS OF THE DYNAMICS

There are many indicators which describe various social and economic aspects of cities' dynamics. For example, the dynamics of the economic growth can be described by the use of the gross domestic product indicator (GDP), as well as by the unemployment rate or the production of the electricity. It was stated that the GDP indicator is quite well correlated with both the employment rate and the production of the electricity, and therefore the analysis only of the GDP indicator should be enough to reflect the economic situation of the city. Taking into consideration additionally the employment rate or the production of the electricity could complicate unnecessarily the quantitative analysis and weaken the statistical analysis. In this case, the GDP indicator is the macrovariable, which reflects the dynamics of microvariables such as the employment rate or the production of the electricity. However, the proper definition of macrovariables is a difficult task, taking into consideration the complexity of social and economical processes occurring within the cities as well as the accessibility of statistical data.

Based on statistical data, the following procedure for the determination of macrovariables is proposed:

1. To create the correlation matrix (of Pearson correlation coefficients) using both all available variables and their functions: logarithmic and quadratic ones.
2. To identify potential macrovariables, which will have the high correlation ratios with other variables (microvariables).
3. To apply the linear regression analysis for potential macrovariables: a macrovariable as a variable being explained and microvariables as explanatory ones. Therefore it will be possible to check the quality of the relationship between variables and their potential causality. It can be expressed, that the macrovariable x will be in relation with microvariables a_1, a_2, ..., a_n according to the equation:

$$x = \beta + \alpha_1 a_1 + \alpha_2 a_2 + ... + \alpha_n a_n + \varepsilon$$

where:
x – macrovariable (explained)
a_1, a_2, a_3,..., a_n – microvariables (explanatory)
α_1, α_2, α_3,..., α_n – regression coefficients
β - constant coefficient
ε – value of statistical error

In this case, if the above mentioned relation is fulfilled, i.e. it is statistically significant and could be explained in a logical way, the coefficient x could be considered to be the macrovariable. For example:

Assuming, the correlation between the values of GDP indicators and the indicators of employment rate and the production of the electricity is statistically significant and can be expressed by the following equation:
$GDP = \beta + \alpha_1 EMPLOYM + \alpha_2 PROD.ELECTR + \varepsilon$

It means, that both the analysis of the employment dynamics as well as the analysis of the production of the electricity are taken into consideration during the analysis of the GDP dynamics. Therefore the GDP is the macrovariable and the indicators of the employment rate and the production of the electricity are microvariables.

4. Micorvariables, recognized to be significant and not correlated with other available indicators due to the lack of data, can be taken as macrovariables.

SYNTHETIC INDICATOR OF THE DYNAMICS

The synthetic indicator of the development dynamics of cities **Ω i**n year **t** can be defined as the weighted mean of the growth rate of variables, which describes the social and economical processes of cities and can be presented by the following equation:

$$\Omega_t = \sum_{i=1}^{N} w_i z_i$$

where:
Ω – value of synthetic indicator of city dynamics
w – arithmetical weight of variable *i* in year **t**
z – growth rate of variable *i* in year **t**
N – number of variables describing city dynamics.

As a result of that, the given indictor includes information about the dynamics of individual variables and can be a new (synthetic) variable describing the progress of city transformation processes, i.e. having the similar role as the temperature in thermodynamic processes.

It can be noticed, that this indicator is dependent on the value of two factors: the weight of the variable **w** and the value of growth rate of the variable **z**.

Many various social and economical factors have the influence on the city development. It can be very often observed, that not only its own dynamics but also the interdependence with other factors leads to synergistic effects and creates very complex situation of the development of urban areas. The cognition of these processes (at least partially) is a very challenging task. Due to the fact, that various

factors affect differently the development of urban areas, it is necessary to assign the proper weight to each of them, which will describe the function of its dynamics during the process of the city development. The arithmetical weight of a given variable indicates the significance of factors represented by this value in the process of the city development and their potential to induce phase transitions.

The Multinomial Logit Model (MLM), known in scientific literature, was applied to determine these weights. It can be presented in the following generalized form [Ben-Akiva, Lerman 1985]:

$$\mathbf{P}(i) = \frac{e^{V_i}}{\sum_{j=1}^{N} e^{V_j}}$$

where:
P(i) – probability of the occurrence of a given even (result) **i**
N – number of possible events (results)
$\mathbf{V_j}$ – function describing the nature of a given event **j,** which has influence on its chances to its existence, the higher the value of this function, the higher the probability of the occurrence,
$\mathbf{V_i}$ – the value of the function V for an event **i.**

The Multinominal Logit Model can be applied in economical and mathematical analyses, e.g. the discrete decision analysis or the stochastic analysis of inhabitants' flows in urban areas [Pawlak 2008]. Its application for the explanation of the arithmetical weight in case of variables describing the dynamics of the development of the urban centre is based on the nature of such form of a function:

1. MLM takes into account the fact, that the sums of probabilities of possible results of a given experiment as well as the arithmetical weights for each mean, have to have a value equal to 1, i.e.:
$$\sum_{i=1}^{N} P(i) = 1$$
2. MLM allows to describe arithmetical weights of any number of events or (in the context of conducted researches) macrovariables.
3. For each event, if the value of the function V_i increases, then the value of obtained arithmetical weight will lead asymptotically to value 1. It means, there are no limits for the value of the function V_i, because the obtained weight will always be within the range from 0 to 1. It allows quite a big flexibility in the choice of a type and values of this function for individual macrovariables.
4. Transparent and computational convenience of the estimation of parameters of this function.

Taking into account the above mentioned facts, the following version of mathematical presentation of arithmetical weights of individual variables is proposed:

$$w_{it} = \frac{e^{\beta_{it}}}{\sum_{i=1}^{N} e^{\beta_{jt}}}$$

where:
w_{it} – weight of a variable **i** in year **t**
β_{it} – function describing the meaning of the dynamics for any variable **j** in year **t**
β_{it} – the value of the function describing the meaning of the dynamics for any variable **i** in year **t**
N – number of variables
t – the reference year

Having the above presented form, it should be considered how to estimate the value of the function β for each variable in year **t**. Practically it means that it must be estimated, which factors have the higher potential to stimulate the development. The higher this potential in a given period of a variable **i**, the higher value of the function β. The time dependence is also significant, due to the fact that the importance and the role of individual factors stimulating the development can be changed over a period of time. For example, the high share of heavy and mining industries could be stimulating factors for the development of a given city in a given period. However such heritage could be a big problem considering the progressive technological progress or the economical transformation in the direction of the economy based on modern electronical technologies. American Detroit, British Manchester or Polish Katowice are examples of cities, which suffered from such process.

The weight of a variable can be also of a synthetic nature, what is often of a great significance when the general competiveness of cities is analyzed. Individual components can have the following shares [Watson, Sudhir 2012]: economical power (30%), institutional efficiency (15%), human resources (15%), financial maturity (10%), global importance of the city (10%), physical capital (10%), environmental and natural threats (5%) and the social and cultural character of the city (5%).

Beside the arithmetical weight of a variable, its dynamics influences also the way and the nature of the development of the city. Having the variable x_i, it is possible to determine the value of its growth rate z_i in year t:

$$z_{it} = \frac{\mathbf{d}\ln(x_i)}{dt} = \frac{\frac{dx_i}{dt}}{x_i} \approx \frac{\frac{\Delta x_i}{\Delta t}}{x_i}$$

Assuming that period t is equal to one year, the equation can be simplified to the following form:

$$z_i \approx \frac{x_i(t) - x_i(t-1)}{x_i(t-1)}$$

Therefore it is the gain of the value of the variable between year t-1 and year t (given in a form of a fraction or percentage). Such a form allows using available statistical data in an optimal way for the determination of the general dynamics of various factors, which have impact on the development.

GENERALIZED FORM OF THE SYNTHETIC INDICATOR OF THE DYNAMICS OF THE CITY DEVELOPMENT

Based on the above contemplations, it is possible to create the synthetic indicator of the dynamics of city development for a given year, which can be defined as a mathematical function dependent on analyzed variables:

$$\Omega_i(t) = \sum_{i=1}^{N} w_i z_i = \sum_{i=1}^{N} \left(\frac{e^{\beta_{it}}}{\sum_{j=1}^{N} e^{\beta_{jt}}} * \frac{\partial \ln[(x]_i(t))}{\partial t} \right) \approx \sum_{i=1}^{N} \left(\frac{e^{\beta_{it}}}{\sum_{j=1}^{N} e^{\beta_{jt}}} * \frac{x_i(t) - x_i(t-1)}{x_i(t-1)} \right)$$

The indicator is the weighted mean of the growth rate of variables. The weights of them are described by the polynomial logit function dependent on time and parameters of the function β, which explains the meaning of a given variable in the process of the city development. Practically, this

indicator is the synthetic expression of available variables, describing the development of an urban centre.

Taking into consideration the fact, that the above mentioned function describes the development rate of a city in a general way, it can be assumed, that the function D(t) fulfilling the following dependence:

$$D(t) = \int_{t=0}^{T} \Omega \, dt = \int_{t=0}^{T} \left[\sum_{i=1}^{N} \left(\frac{e^{\beta_{it}}}{\sum_{j=1}^{N} e^{\beta_{jt}}} * \frac{\partial \ln[(x]_i)}{\partial t} \right) \right] dt$$

will be the description of the level of the city development. In other words, assuming that the initial level of the city development is equal to 0, the function describes the inconstancy of the development in the synthetic way.

Due to the fact, that social and economical factors subject also to the short-term fluctuation, e.g. one-year one, it is necessary to reduce the effects of short-term fluctuations on the dynamics, i.e. to suppress the influence of such fluctuations by the use of proper statistical methods. For example - the *k-means* method can be implemented here, which enables to minimize the effect of short-term fluctuations on the analysis of the proper trend of the city development. Therefore, the proper analysis process must be conducted on the set of values of the synthetic indicator of the dynamics of the city development to display the trend of the development rate of the city.

TESTING THE HYPOTHESIS OF THE NONLINEAR DEVELOPMENT OF A CITY

Based on the estimated trend of the synthetic indicator of the development dynamics, the linear regression method should be used once again. Due to the fact, that phase transitions are the nonlinear phenomena, their detection consists in the localisation of the nonlinear function, describing the development of the city. It can be done in two equivalent ways:

1. By the use of the sythetical indicator of the development dynamics **Ω:** if the development of the city is of the linear nature, then the function **Ω**, as a function describing the development rate, should be a constant function. In such case, the line of the simple linear regression can be fit in the values of the function **Ω.** This line, like any linear function, will have its own directional and constant coefficients. In case of a constant function, the directional coefficient should be equal to zero. Then the test for *zero* hypothesis should be conducted for the directional coefficient not equal to zero for such regression line and it should be based on t-Student test. In case of the rejection of such hypothesis, it can be concluded, that the development of this city is not of linear nature.
2. By the use of function D, which describes the normalized level of the city development. If the development is of a linear nature, then the function D(t) should be a linear function. Therefore, based on the values of the function estimated for each year, the simple linear regression analysis can be done and especially the analysis of statistical significance of the estimated directional coefficient and the determination coefficient. Based on that, it can be concluded whether the phenomena, typical for nonlinear dynamics of the system, took place.

In practice, the first method is the preferred one, because it does not require the transformation of the discrete function into a constant one - the process, which will be necessary to perform the further integration. Additionally the further proceeding (test for *zero* hypothesis) will be quite clear one as well as enabling to obtain three variants of results (indispensable for the confirmation of the reliability

of the synthetic indicator of the dynamics of the city development, used as a tool for the management of urban areas):

1. The city development was of nonlinear nature and there was a present of phase transitions,
2. The city development was of linear nature, but non-monotonic one (there were both increasing as well as decreasing periods),
3. there was a statistical error and the *zero* hypothesis was rejected despite of its truthfulness.

CONCLUSIONS

The theoretical basis of the proposal of modelling of the development dynamics of modern cities, by the use of properly constructed synthetic indicator, was presented. Beside the possibility of the quantification of the development of social and economical systems of cities, its use allows to identify the non-linearity of these processes as phase transitions - which occur e.g. under the influence of technological and social innovations. It should be an irreversible process and lead to the movement of the whole city system and, at the same time, of their inhabitants to the new quality, which is e.g. the city of a greater efficiency and more friendly to its inhabitants. The physic-economical approach allows learning a nature of these processes in a better way and shows new areas for further researches. The most important ones seem to be the determination of the minimum of indispensable requirements (required level) stimulating the phase transition as well as the analysis of factors allowing to avoid the negative phase transition - especially in smaller urban centres.

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TEORETYCZNE ASPEKTY SYNTETYCZNEGO POMIARU DYNAMIKI ROZWOJU JAKO INSTRUMENTU ZARZĄDZANIA MIASTEM

STRESZCZENIE. **Wstęp**: Artykuł zawiera teoretyczne podstawy propozycji modelowania dynamiki rozwoju współczesnych miast, przy pomocy odpowiednio skonstruowanego syntetycznego wskaźnika. Jego zastosowanie oprócz możliwości kwantyfikacji rozwoju systemów społeczno-gospodarczych miast, pozwala przede wszystkim na zidentyfikowanie nieliniowości tych procesów jako przejść fazowych - występujących przykładowo pod wpływem innowacji technologicznych i społecznych. Ujęcie ekonofizyczne pozwala niewątpliwie lepiej poznać naturę tych procesów oraz wyznacza nowe instrumentarium wspomagające zarządzanie obszarami zurbanizowanymi, w warunkach rosnącej konkurencyjności.
Metody: Modelowanie matematyczne procesów społeczno-gospodarczych, ekonofizyczne ujęcie dynamiki systemów rozwoju nieliniowego.
Wyniki i wnioski: Z przeprowadzonych badań o charakterze symulacyjnym wynika, że syntetyczny pomiar dynamiki rozwoju obszarów zurbanizowanych może być dobrym instrumentem wspomagającym władze samorządowe w procesach

zarządzania miastami. Ujęcie ekonofizyczne nieliniowej dynamiki systemów miejskich wyznacza nowe obszary poznawcze dla dalszych badań, wśród których za najistotniejsze wydaje się określenie minimum warunków koniecznych (niezbędnego poziomu) stymulującego przejście fazowe oraz analiza czynników pozwalających na uniknięcie społeczeństwom negatywnych przejść fazowych - zwłaszcza w mniejszych ośrodkach miejskich.

Słowa kluczowe: zarządzanie miastem, rozwój nieliniowy miast, przejścia fazowe, pomiar syntetyczny dynamiki rozwoju.

THEORETISCHE ASPEKTE DER SYNTHETISCHEN BEMESSUNG VON ENTWICKLUNGSDYNAMIK ALS BRAUCHBARES INSTRUMENT FÜR EFFIZIENTES STADT-MANAGEMENT

ZUSAMMENFASSUNG. Einleitung: Der Artikel beinhaltet theoretische Grundlagen für Modellierung der Entwicklungsdynamik von gegenwärtigen Städten mittels einer entsprechend generierten, synthetischen Kennziffer. Deren Anwendung erlaubt vor allem, außer der Möglichkeit einer Quantifikation der Entwicklung von städtischen, sozial-wirtschaftlichen Systemen, die Nichtlinearität der Prozesse als Phasen-Übergänge, die unter dem Einfluss technologisch und sozial bedingter Innovationen vorkommen, zu ermitteln. Solch ein ökono-physisches Herangehen an den Themenkomplex ermöglicht, die Natur der betreffenden Prozesse zweifelsohne besser kennen zu lernen, und die neue Methodik kennzeichnet im wachsenden Wettbewerbskampf ein neues Instrumentarium, das das Management von städtischen Ballungsgebieten effektiv unterstützen kann.
Methoden: Mathematische Modellierung von sozial-wirtschaftlichen Prozessen, das ökono-physische Herangehen an die Systeme von nichtlinearer Entwicklungsdynamik.
Ergebnisse und Fazit: Aus den durchgeführten Forschungen von simulationsmäßigem Charakter geht eindeutig hervor, dass die synthetische Bemessung der Entwicklungsdynamik von städtischen Ballungsgebieten ein für die jeweilige Stadtverwaltung bruchbares Instrument für Unterstützung der städtischen Management-Prozesse werden kann. Das ökono-physische Herangehen an die nichtlineare Entwicklungsdynamik von städtischen Systemen kennzeichnet neue Erkundungsgebiete für die weitere Erforschung, wobei die Ermittlung eines unentbehrlichen Minimums (Mindest-Niveau) von den die Phasen-Übergänge stimulierenden Bedingungen sowie die Analyse der Faktoren, die gegenwärtige Gesellschaften negative Phasen-Übergänge meiden lassen, am wichtigsten zu sein scheinen - insbesondere innerhalb der Städte kleineren Typs.

Codewörter: Stadt-Management, nichtlineare Stadtentwicklung, Phasen- Übergänge, synthetische Bemessung der Entwicklungsdynamik.

Zbyszko Pawlak
Poznań School of Logistics
ul. Estkowskiego 6
61-755 Poznań
e-mail: Zbyszko.Pawlak@wsl.com.pl

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BERLIN BRANDENBURG INTERNATIONAL (BER): PLANNING AND IMPLEMENTATION OF A CONCRETE SUPPLY CHAIN FOR THE AIRPORT CONSTRUCTION SITE

Guido Riedel

LMBG Logistik und Management Beratungsgesellschaft mbH, Berlin, Germany

ABSTRACT. Background: With the decision to extend the airport Berlin-Schönefeld to the new airport Berlin Brandenburg International (BER) in 2006, a construction of superlatives has emerged. One of the biggest challenges was the supply of around 2.5 million cubic meters of high quality concrete that had to be produced for the construction of the airport. Due to the scale of this enterprise as well as its environment, the logistic solution of raw material supply has to be found.
Method: The planning of the concrete supply chain for the airport construction site BER had to be carried out with two major goals: the stability of the supply chain to assure that the demands of the construction site are met and delays are prevented, as well as assurance of the high quality standards of the concrete production and to avoid an alkali silica reaction and the resulting unavoidable disaggregation of the concrete. External effects, such as the carbon dioxide emission and the effect of the supply chain on adjoining residents were key factors that had to be integrated in a holistic supply chain concept. The principle underlying method is an analysis of limiting conditions for two approaches: a centralized supply chain with on-site concrete factory and upstream transport of raw materials versus a decentralized supply chain with off-site factories and downstream transport of ready-mixed concrete.
Results: The analysis of constraints and the effects on key requirements of the concrete supply chain for the BER airport construction site lead to the installation of the most modern concrete plant in Europe. The benefits of a centralized supply chain are significant. On one hand, the high quality standards can be met with the on-site mixture of the concrete and centralized quality assurance, on the other hand, the majority of the supply traffic for the construction site was moved from the road to train-bound logistics, meeting the emission requirements of the planning permission for the airport.
Conclusions: Every logistical supply chain has its own individual requirements and constraints. This approach shows how a centralized supply chain could be installed that meets all the individual constraints of this construction site. The key components of the concept are the on-site concrete plant, the delivery of raw material by train, a centralized quality assurance and a specific contract structure with the operator of the concrete plant.

Key words: Construction of the new airport Berlin Brandenburg International (BER), supply chain, concrete, ecological and social sustainability, planning and implementation.

INTRODUCTION

With the decision to extend the airport Berlin-Schönefeld to the new airport Berlin Brandenburg International (BER) in 2006, a construction of superlatives has started. The planning and implementation of the new Capital Airport is associated with major challenges for the airport operator, the Flughafen Berlin Brandenburg GmbH (FBB). About 2.5 million cubic meters of concrete had to be worked up for the construction of terminals, the run- and taxiways and other infrastructure measures such as the terminal station of the Deutsche Bahn and the highway connection to the Airport. To ensure the supply security of the site, peak loads of 10,000 cubic meters of concrete per day or 900 cubic meters per hour must be achieved. This is comparable to approximately 100 truck mixers per hour. To manage these processes the FBB is working with experienced partners such as the Logistik

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und Management Beratungsgesellschaft mbH (LMBG) for the planning and with the Becker Bau GmbH & Co. KG for the implementation and operation of the concrete plant. The following article describes the key challenges for the concrete supply of the BER airport construction site, evaluates these major constraints in light of two different supply chain approaches and summarizes the analysis with the presentation of the selected supply chain concept.

CONSTRAINTS AND EVALUATION

SECURITY OF SUPPLY The biggest challenge for the logistical supply chain concept for this construction site of superlatives lies in the high peak loads [Caldwell, Roehrich, Davies 2009; Wickramatillake et. al. 2007]. To be able to assure the security of the supply of the site, risks have to be minimized. For this specific site, the adjoining streets and highways connecting the airport to the public street network are under construction themselves, leading to a limited accessibility. However, an analysis of surrounding concrete plants and the matching of availability of concrete with the accessibility of the numerous construction sites showed that a decentralized supply chain is possible. In contrary, in a centralized supply chain, traffic congestions on the road can be avoided, as the centralized supply chain entails delivery of the raw material of the concrete by train.

Fig. 1. Constraints for the Supply Chain
Rys. 1. Ograniczenia łańcucha dostaw

QUALITY ASSURANCE In addition to the high demands on the quantity there are equally important requirements to the quality of the concrete. This is caused by the large spectrum of types of concrete. Manufacturers now are able to consider up to 250 different types of concrete. Especially for the use to build runways, the highest quality standards are required [Lingard, Eowlinson 1994]. This is mainly due to the usage of de-icing agents in the airport operations. After penetrating into the concrete surface it results a risk of alkali silica reaction. If such a reaction starts, known colloquially as "concrete cancer", there is no turning back of a complete destroying of the surface. The quality of the concrete is predominantly determined by the quality of its raw materials. In a centralized logistical supply chain, the effect on the quality of the concrete becomes inevitable. By minimizing the sources of raw materials to a few sources, quality assurance becomes much more effective [van Weele 2010].

CONTRACT STRUCTURE Besides these previous key constraints, an important aspect in the decision process for a logistical supply chain concept lies in the legal differences of the approaches. Whereas in a decentralized concept a somewhat classical contract structure with clear liability of the suppliers is applied, the contract structure in a centralized concept is more complex and involves certain risks. The antitrust law requires a legal unbundling of the operator of a centralized concrete plant and the individual contractors of the construction projects. Furthermore, contractors cannot be liable to obtain all concrete from a single plant in a monopolistic structure. As a result, in a centralized concept, the building owner has to provide the concrete for the individual contractors and the liability for the quality of the concrete lies on the operator of the concrete plant and respectively on the building owner himself. Therefore, the legal structure implies a considerable risk when applying a centralized logistical concept.

ECOLOGICAL AND SOCIAL SUSTAINABILITY The ecological and social sustainability of a supply concept is also significant. In a decentralized supply chain, approximately 500 daily trips by truck for the delivery of almost three million tons of gravel and 400,000 tons of cement have to be realized by truck on the public road network. In a centralized supply chain, these truck movements can be avoided and achieved train-bound. This leads to a reduction of traffic congestion and the emission requirements of the planning permission can be met [Ibrahim et. al. 2010].

THE DECENTRALIZED SUPPLY CHAIN

The decentralized supply chain implies the delivery of all necessary concrete from surrounding concrete plants. The analysis of the regions concrete plant structure shows, that all capacity as well as peak-loads can be handled from numerous plants within a radius of 30km around the airports construction site.

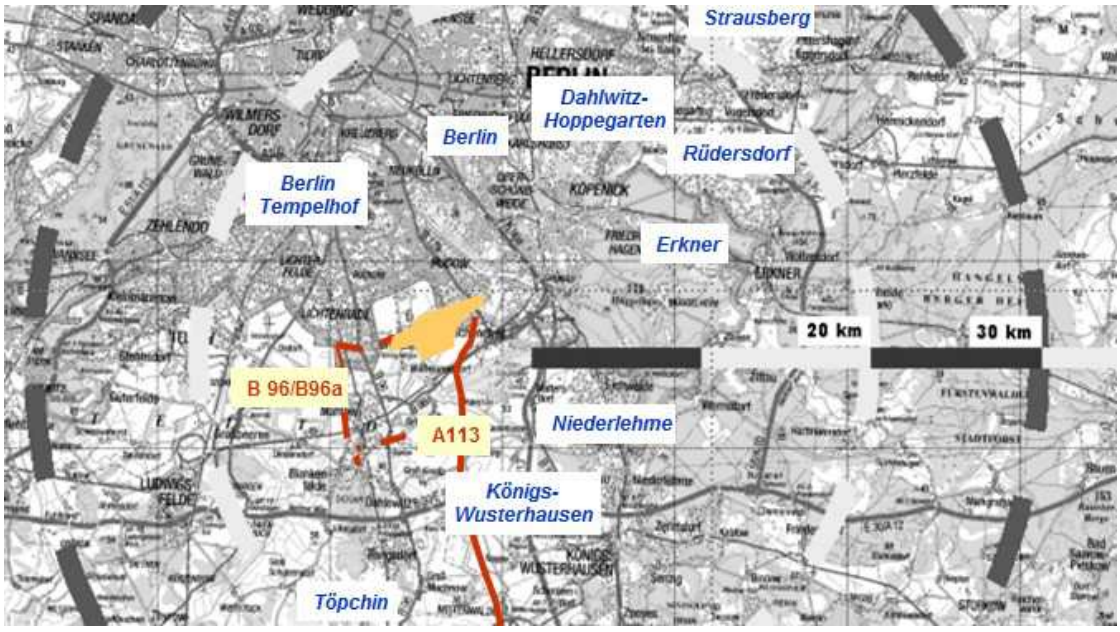

Fig. 2. Concrete Plants in surrounding area
Rys. 2. Wytwórnie betonu w analizowanej okolicy

The benefits of a decentralized supply chain concept lie in the simplicity of the legal structure as well as reduced investment costs. However, in this specific case, the fallbacks of a decentralized solution are significant. The risk of a breakdown of the supply of the construction site as well as the

risk of poor quality of the concrete outweighs the benefits of a decentralized concept. The feasibility of a centralized supply chain has to be tested.

THE CENTRALIZED SUPPLY CHAIN

In the decision process for a centralized solution, the security of the site and the quality assurance were of the utmost significance. By mixing the concrete on site, the usage of quality-reducing retarders could be prevented. The number of major suppliers is reduced to a few and simplifies the quality control drastically. Bottlenecks by road, just where the road connecting to the airport itself is constructed, could be circumvented. The logistical concept has its own consequences. The solution is associated with the construction of the most modern concrete mixing plant in Europe.

Fig. 3. Centralized Concrete Mixing Plant
Rys. 3. Scentralizowana wytwórnia betonu

With the help of six computer controlled mixing units, the factory can produce up to 960 cubic meters of concrete of different exposure classes. To assure the quality of the concrete, internal and external quality control with scientific support has been established to meet the high standards and prevent a concrete cancer.

Fig. 4. Concrete Plants in surrounding area
Rys. 4. Wytwórnie betonu w analizowanej okolicy

However, the central concept also has bottlenecks. The concrete components are carried over a single-track railway which is parallel used for the fuel delivery for the ongoing operations of the airport Berlin-Schönefeld. At peak times of up to eight trains per day, an excellence in the management of the trains is required. With a lack of redundancy, delays are fatal. With a specially designed tilting edge for the gravel processing and an air evacuation for cement trains the high discharging frequencies could be achieved. A safety stock, which covers the demand of four days, was part of the contract to assure the security of supply.

CONCLUSIONS

The requirements for the logistical supply chain for the construction site of the BBI airport are challenging. However, a centralized logistical supply chain could be implemented that meets all the individual constraints of the construction site. The key components of the concept are the on-site concrete plant, the delivery of raw materials by train, a centralized quality assurance and the specific contract structure with the operator of the concrete plant. Up-to-date, 2.5 million cubic meters of high quality concrete were delivered on time - the supply chain worked.

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BERLIN BRANDENBURG INTERNATIONAL (BER): PLANOWANIE I WDROŻENIE ŁAŃCUCH DOSTAW BETONU NA TEREN BUDOWY LOTNISKA

STRESZCZENIE. **Wstęp:** W wyniku podjętej decyzji o rozszerzeniu istniejącego lotniska Berlin-Schönefeld w nowe lotnisko Berlin Brandenburg International (BER) w 2006 r., wystąpiła konieczność budowy odpowiedniej bazy. Jednym z największych wyzwań było zapewnienie dostaw ok. 2,5 miliona metrów sześciennych betony najwyższej jakości potrzebnego do budowy nowego lotniska.
Ze względu na skalę przedsięwzięcia oraz uwarunkowania terenowe i środowiskowe, należało opracować nowe rozwiązanie logistyczne związane z zaopatrzeniem budowy w surowce.
Metody: Proces planowania zaopatrzenia budowy lotniska BER w dostawy betonu miał dwa podstawowe cele: stabilność dostaw pokrywających zapotrzebowanie budowy, tj. uniknięcie wszelkich opóźnień tych dostaw oraz zapewnienie najwyższych standardów dostarczanego betonu w celu uniknięcia reakcji alkalicznej w betonie i niepożądanej dezagragacji betonu. Efekty dodatkowe, jak na przykład emisja dwutlenku węgla lub wpływ realizacji dostaw na życie okolicznych mieszkańców tego regionu, stanowiły również kluczowe czynniki, które należało brać pod uwagę przy tworzeniu koncepcji łańcucha dostaw betonu. Analizie z punktu widzenia czynników ograniczających poddano dwie propozycje rozwiązania: dostawy zcentralizowane z wytwórni betonu położonej w bezpośredniej bliskości placu budowy wraz z organizacją dostaw surowców potrzebnych do produkcji tego betonu oraz zdecentralizowane dostawy z dalej położonych wytwórni - dostawy na teren budowy gotowego już betonu.
Wyniki: Przeprowadzona analiza ograniczeń i wpływu na kluczowe zapotrzebowania dostaw betonu potrzebnego do budowy lotniska BER doprowadziła do budowy najbardziej nowoczesnej wytwórni betonu w Europie. Korzyści z wyboru zcentralizowanego sposobu organizacji dostaw były bardzo istotne. Z jednej strony zapewniono dostawy najwyższej jakości betonu, z drugiej strony większość dostaw surowców, potrzebnych do wyrobu betonu, zostało realizowanych za pomocą połączeń kolejowych a nie drogowych, co przyczyniło się do przestrzegania zakładanych poziomów emisji.
Wnioski: Każdy logistyczny łańcuch dostaw ma swoje specyficzne wymagania i ograniczenia. Przedstawione podejście pokazuje, w jaki sposób zcentralizowane dostawy mogą spełniać wszystkie stawiane mu ograniczenia. Kluczowe komponenty koncepcji to: wytwórnia betonu zlokalizowana na terenie budowy lotniska, dostawy surowców transportem kolejowym, zcentralizowane zapewnienie jakości oraz indywidualna umowa z operatorem wytwórni betonu.

Słowa kluczowe: budowa nowego lotniska Berlin Brandenburg International, (BER), ekologiczny i społeczny zrównoważony rozwój, łańcuch dostaw, beton, planowanie i realizacja.

BERLIN BRANDENBURG INTERNATIONAL (BER): PLANUNG UND UMSETZUNG EINER BETONVERSORGUNGSKETTE FÜR DIE FLUGHAFENBAUSTELLE

ZUSAMMENFASSUNG. Hintergrund: Mit dem Entschluss zum Ausbau des Flughafens Berlin-Schönefeld zum neuen Flughafen Berlin Brandenburg International (BER) im Jahre 2006 entstand eine Baustelle der Superlative. Eine der größten Herausforderungen war dabei die Versorgung mit rund 2,5 Millionen m³ hochwertigem Beton, welche für den Bau des Flughafens benötigt wurden. Aufgrund des Ausmaßes dieses Vorhabens, sowie der Lage der Baustelle, , musste eine logistische Lösung für die Rohstoffanlieferung gefunden werden.
Methode: Die Planung der Betonversorgungskette für die Flughafenbaustelle BER musste im Hinblick auf zwei Hauptziele durchgeführt werden: Die Stabilität der Versorgungskette, um sicherzustellen, dass die Baustellenanforderungen erfüllt und Verzögerungen verhindert werden, wie auch die Sicherstellung der hohen Betonqualität und die Vorbeugung einer Alkali-Kieselsäure-Reaktion und des daraus resultierenden unvermeidlichen Zerfalls des Betons. Externe Auswirkungen wie der Kohlenstoffdioxidausstoß und die Auswirkung der Versorgungskette auf Anwohner waren Schlüsselfaktoren, welche in ein ganzheitliches Versorgungskonzept integriert werden mussten. Bei der Analyse wurden Randbedingungen für zwei verschiedene Ansätze betrachtet und gegeneinander abgewägt: Für eine zentrale Versorgungskette mit einer Betonfabrik vor Ort und vorgelagertem Transport von Rohstoffen versus einer dezentralen Versorgungskette mit Fabriken außerhalb und nachgelagertem Transport von fertig-gemischtem Beton.
Ergebnisse: Die Analyse von Randbedingungen und ihre Auswirkungen auf Schlüsselanforderungen der Betonversorgungskette für die Flughafenbaustelle BER führten zur Errichtung des modernsten Betonmischwerkes von Europa. Die Vorteile einer zentralen Versorgungskette sind bedeutend. Einerseits können die Qualitätsansprüche mit der Betonanmischung vor Ort und der zentralen Qualitätssicherung erfüllt werden, andererseits wurde der überwiegende Anteil

des Versorgungsverkehrs für die Baustelle von der Straße auf die Schiene verlagert und das Konzept erfüllte somit die Emissionsanforderungen der Planfeststellung für den Flughafen.
Fazit: Jede Logistikversorgungskette hat ihre eigenen individuellen Anforderungen und Einschränkungen. Dieser Ansatz zeigt, wie eine zentrale Versorgungskette eingeführt werden konnte, die alle diese individuellen Beschränkungen dieser Baustelle erfüllt. Die Schlüsselkomponenten des Konzepts sind das Betonmischwerk vor Ort, die Rohstoffanlieferung per Zug, eine zentrale Qualitätssicherung und eine spezifische Vertragsstruktur mit dem Betreiber des Betonmischwerkes.

Codewörter: Bau des neuen Flughafens Berlin-Brandenburg International (BER), Versorgungskette, Beton, ökologische und soziale Nachhaltigkeit, Planung und Umsetzung.

Guido Riedel
LMBG Logistik und Management Beratungsgesellschaft mbH
Möckernstraße 26, Tor 17, D-10963 Berlin, Germany
e-mail: riedel@lmbg.com

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STUDYING BRAND LOYALTY IN THE COSMETICS INDUSTRY

Usman Yousaf[1], Rida Zulfiqar[2], Madiha Aslam[2], Mohsin Altaf[2]

[1)]University of Sargodha, Pakistan, [2)]University of Sargodha, Pakistan

ABSTRACT. Background: The purpose of this research is to know the brand loyalty and contribute to the knowledge that how brand credibility, brand awareness, brand association, perceived quality, and product knowledge is important to build brand loyalty.
Method: Data were collected from the female's students of department from the university of Sargodha Final analysis was performed on 125 valid respondents. Cronbach's Alpha statistic was used in order to check the reliability of the scale. Regression was used in order to test the hypothesis. Correlation analysis was used to study the relationship between the variables such that this analysis studied the positive relation of all the independent variables (brand credibility, brand awareness, brand association, perceived quality and product knowledge) with the dependent variable (brand loyalty).
Results and Conclusion: The results indicate the positive relationships between brand credibility, brand awareness, brand association, perceived quality, product knowledge (independent variables) and brand loyalty (dependent variables). Further among all the variables studied brand awareness has the highest impact on brand loyalty and according to this research L'Oreal consumer is more as compare to other brands. Although this research specifically studies the Brand Loyalty in University of Sargodha. However more importantly, the purpose of this study is that cosmetic industry must focus on brand association, perceived quality, product knowledge, brand credibility in order to build Brand Loyalty. To the best of researcher's knowledge, this research is first of its kind in the University of Sargodha which studies student's credibility, awareness, association, perceived quality, product knowledge and loyalty toward their favorite cosmetics brand. The results of this study are limited by the specificity of the geographic context by taking a sample of 125 students of one department from total population of University of Sargodha. This study can be expanded to different universities of Pakistan.

Key words: Brand Credibility, Brand Awareness, Brand Association, Perceived Quality, Product Knowledge, Brand Loyalty.

INTRODUCTION

In today's highly competitive environment, organizations are looking all the time for new ways to maximize their brand loyalty in consumers and there are some factors due to which loyalty toward brand can be increase. Those are brand credibility, brand association, brand awareness, perceived quality and product knowledge. This research "BRAND EQUITY IN COSMETIC INDUSTRY" is conduct to know the brand loyalty of the consumers towards their brand.

The main reason for choosing this organization is that there is no previous research on brand loyalty in University Of Sargodha. Where there are a large number of consumers of different brand studied. We can guess that youngster will place a high value on brand equity in cosmetics industry.

The brand credibility is a factor that could holds the buying behavior of consumers. However, just like with any type of triggers, it can have a positive or negative effect. In this case, it relates to your reputation of brand, information of brand and its ability (or inability) to convert that into sales.

The effect of brand credibility (market repo) on choice of brand and consideration across multiple product categories that may vary in regard to potential uncertainty about attributes and information

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that associated with acquisition costs and perceived risks of consumption. We find that brand credibility increases loyalty of a consumer toward brand and probability of inclusion in brand choice conditional on consideration.

The term brand equity means the increase in the value of brand due to the name of that product or brand.

Brand loyalty is a power of brand earned over time by its goodwill and name recognition which increases its sales volume and higher profit margins against competing brands.

Brand awareness is an important way of promoting a product. This is because for these products, there are some reasons and factors that differentiate one product from the other competitor product. Therefore, the product that has the highest brand awareness as compared to its competitors will usually get the highest sales.

The way by which a specific brand is associated with the other product category in consumers mind (share of mind). Often a consumer will call the product by its name of that brand rather than the general name.

Perceived quality refers to a consumer's intangible perception of the whole quality or superiority of a product or service - their overall feeling about the brand

Perceived quality is that providing information and values by giving reasons that why customer or consumer should buy that brand and by differentiating their brand from other competing brand. It is concluded that consumer perception of quality will be associated with their brand loyalty. Customer wants to buy or perceive such brand that is offering superior quality .and is become loyal with that brand.

Providing information about the brand is also important to attract customer and build loyalty of the brand.

LITERATURE REVIEW

Brand Credibility

Names of a brand have high credibility; and a line can easily lunch by the company and company can easily extend their brand. Above all, it relates to your reputation of brand, information of brand and its ability (or inability) to convert that into sales.

The belief on the information contained by the brand and ability of a firm to deliver what they promise. The brand credibility is the believeability of brand which entails brand promises [Erdem and Swait, 1998]. The concept of credibility conytains two dimensions includes trustworthiness and expertise where as trustworthiness denotes the brand promise and expertise denotes willing to deliver or capability of delivering [Erdem and Swait, 1998].

Brand Awareness

The ability of the consumer to identify a brand is called brand awareness. [Keller, 2003]. Brand awareness takes the form of recognition of a brand and recall of a brand. Recognition of brand is full explanation of the brand and provides full information about the brand to consumer, consumers can easily differentiate the brand from other competing brand and can identify previously seen or heard [Ergin et. al 2005, Papista, Dimitriadis 2012]. Many brands can be recognized by the consumer but they recall only small number and sometimes recall only one brand. Recognition of brand is considered as the minimum level of awareness of the brand and provides help to recall a brand [Holden, 1993; Laurent et al., 1995; Mariotti, 1999]. Recognition of brand is important by consumer while chooses or selecting a brand at the point to purchase a brand.

Loyalty begins when the customer knows about the product and have full information about the product [Aaker, 1991, Jamal et al. 2012]. The possibility of a product purchase will be increase if customer has information and he knows about the product.

Brand Association

Brand associations are difficult, consist of many ideas and are connected with one and provide strong facts that made brand knowledge [Yoo et al., 2000]. Brand association is formed by the believability of the consumer on brand, which may or can be built by the marketer or by the consumer personally by experienced or by using the product himself [Aaker, 1991]. The belief of the consumer on the brand has impact on their repurchase and in choosing a brand.

Brand association is considered as important for loyalty of a consumer toward their brand [Aaker, 1996, p. 8]. Anything relates to a brand is called brand association [Aaker 1991]. Brand Association is the combination of product related attributes and nonproduct related attributes [Kaller, 2003] but in services, it contains core services and some supporting services [Gronroos, 2007].

Brand loyalty

The composite perspective of loyalty of a brand firstly suggested by Day [1969] and later other researchers supported it. [E.g. Jacoby, 1971; Dick and Basu, 1994, Kim, Lee 2011]. The approach to claim the loyalty that one is truly loyal with the brand, consumer must have a favorable attitude toward the brand in order to repurchasing it.

Brand loyalty is defined as the result from non-random, long existence response of behavior and it was a process of mental purchase formed by some certain decision units who considered more than one brands [Jacoby and Olson, 1970, Chen et al. 2011]. Loyalty toward brand is a commitment to re-buy or repurchase a specific product consistently in the future, [Oliver, 1999].

Dick and Basu, [1994] explained loyalty construct, the mixture of "relative attitude and patronage behavior". The other dimension of loyalty included the cognitive loyalty, this dimension is higher level dimension which involved customer decision making process to evaluate alterative products. Gremler and Brown, [1996] extended the concept of loyalty to the intangible products and their definition of service quality contains three components included purchase, attitude and cognition. Purchase means the repeat purchase, attitude means that customer shows the positive feelings towards service provider and the cognitive process means to use only this provider when a need of service exists.

Perceived quality

Perceived quality is defined as a buyer's subjective evaluation of a product [Zeithaml, 1988; Grewal, Monroe and Krishnam, 1998]. Perceived quality is defined as an intangible perception of the consumer on whole quality or superiority of a product or service .consumer feeling the brand [Ramaseshan and Tsao, 2007]. Percieve Service Quality means consumer judgements about product or brand values [Aaker, 1991] and the product dominance that leads consumer towards selection of particular goods or services [Aaker and Jacobson, 1994].

Differentiating the brand from other brand and giving value to customers by providing reason to repurchase the brand again and again. It is observed that consumer perception of quality will be associated with their brand loyalty. Customer wants to buy or perceive such brand that is offering superior quality [Bolton and Drew 1991, Khraim 2011].

Product Knowledge

Product knowledge that estimates how the brand is perceived by the customers and how the customers evaluate the brands; product knowledge measure the bond between the consumer and the brand.

The knowledge that helps to differentiate products or services from the others is known as product knowledge [Kotler and Keller, 2009, Lai et al., 2010]. The evaluation of a brand by the consumer and the information about the brand in the mind of consumer is called product knowledge.

HYPOTHESIS

H1: There is a significant, positive relationship between brand credibility and brand loyalty.

H2: There is a significant, positive relationship between brand awareness and brand loyalty.

H3: There is a significant, positive relationship between brand association and brand loyalty.

H4: There is a significant, positive relationship between perceived quality and brand loyalty.

H5: There is a significant, positive relationship between product knowledge and brand loyalty.

METHODOLOGY

This research has been conducted in order to find out the brand loyalty in the cosmetic industry of Pakistan and to find out the loyalty of customers for these cosmetics brands. For this purpose a sample of 150 questionnaires was filled from the University of Sargodha, Sargodha. This is one of the well renowned universities of Pakistan. The questionnaire for this research was adopted from the study (Ms. Amanda Spry, Dr Ravi Pappu, and Professor T. Bettina Cornwell). The questionnaires were filled from the students of different departments of the university who were the customers of any one of the cosmetic brand user from the four main cosmetics brand in Pakistan named as L'Oreal, Ponds, Johnson & Johnson, and Etude. From a total of 150 questionnaires, 133 completely filled questionnaires were returned, 4 questionnaires were lost during the process and the remaining 4 were wrongly filled.

The questionnaires were filled in the month of March, 2011. The questionnaire consisted of the total 19 questions which were classified according to the variables of this study, each variable consist of 3 questions, independent variables are brand credibility, brand awareness, brand association, perceived quality, product information. Measures for brand credibility were sourced from brand signaling research [Erdem and Swait, 2004]. Awareness was measured using a three-item scale adopted from the branding literature [Yoo and Donthu, 2001]. Measure for brand value and organizational association were sourced from Aaker [1991]. Perceived quality was measured using items originally suggested by Aaker [(1991]. Brand loyalty was measured using item from the work of [Yoo and Donthu 2001]. Product knowledge was measured using three item adopted from [Cole and Balasubramanian 1993]. One additional question was used about the name of the cosmetic brand used by the respondents. The questionnaires were filled from female respondents. The five-point Likert-type scale was used ranging from strongly disagree to strongly agree.

Descriptive statistics and the comparison of mean have been used to study the response of the sample. The Cronbach's Alpha revealed the result for the overall homogeneity between the variables of this research and the items of scale used in this research to measure the variables. Correlation analysis were used to study the relationship between the variables such that these analysis studied the positive relation of all the independent variables (brand credibility, brand awareness, brand association, perceived quality, product knowledge) with the dependent variable (brand loyalty).Regression analysis was used in order to test the hypothesis for this research.

Table 1. Frequency
Tabela 1. Częstotliwość

		Frequency	Percent
Valid	L'Oreal	41	32.8
	ponds	36	28.8
	Johnson & Johnson	24	19.2
	etude	21	16.8
	Total	122	97.6
Missing	System	3	2.4
	Total	**125**	**100.0**

Table 1 shows that frequency of L'Oreal is (41) at 32.8 percent, frequency of ponds is (36) at 28.8 percent, frequency of Johnson & Johnson is (24) at 19.2 percent and frequency of etude is (21) at 16.8 percent. L'Oreal has maximum frequency then all other cosmetics brand and etude has minimum frequency from all other brands.

DATA ANALYSIS INTERPRETATION

Table 2. Descriptive statistics
Tabela 2. Statystyki opisowe

	N	Mean	Std. Deviation
brand loyalty	124	3.9113	.52756
product knowledge	125	3.2667	.51773
brand association	123	3.9485	.54494
perceived quality	123	4.1545	.59183
brand credibility	125	4.0187	.68552
brand awareness	122	4.0437	.79650
Valid N (list wise)	117		

Table 2 shows the mean of all the variables used. Most of the means shows that the students have a positive perception about the questions asked .As mostly means are higher than 3 and 4, 3 is considered indifferent and after 3 there is agree and strongly agree options respectively. The variables brand loyalty, product knowledge, brand association, perceived quality, brand credibility, brand awareness have the mean (3.9113),(3.2667),(3.9485),(4.1545),(4.01287) and (4.0437) respectively. This shows that the variable perceived quality has higher effect on brand equity and the variable product knowledge has lower effect, so we need to focus and work on this area.

Table 3. Means
Tabela 3. Średnie

Please select your favorite brand of cosmetics from the following	Mean	N	Std. Deviation
L'Oreal	4.1789	41	.54313
ponds	3.7524	35	.70174
Johnson & Johnson	3.7917	24	.76020
etude	3.8889	21	.71751
Total	3.9284	121	.68476

Table 3 shows mean of L'Oreal is 4.1789, mean of bonds is 3.7524, mean of Johnson & Johnson is 3.7917 and mean of etude is 3.8889.loreal has maximum mean then other cosmetics brand and ponds has minimum mean from all other brands. This indicates most of the people use L'Oreal.

INFERENTIAL STATISTICS

Table 4. Reliability Statistics
Tabela 4. Statystyka wiarygodności

Cronbach's Alpha	N of Items
.858	18

Table 4 indicates the value of Cronbach's alpha for the combined scale. It can be observed that the Cronbach's Alpha reliabilities are good for the combined scale (0.858).

Table 5. Correlation Analyses
Tabela 5. Analiza korelacji

	1	**2**	**3**	**4**	**5**	**6**
Brand loyalty	1					
Brand credibility	.471(**)	1				
Brand awareness	.584(**)	.550(**)	1			
Brand association	.462(**)	.460(**)	.458(**)	1		
Perceived quality	.531(**)	.515(**)	.550(**)	.607(**)	1	
Product knowledge	.274(**)	.122	.315(**)	.097	.269(**)	1

** Correlation is significant at the 0.01 level (2-tailed)

Table 5 shows the correlations between dependant and independent variables. On the basis of this the following hypothesis has been formulated:

H1: There is a significant, positive correlation between brand credibility and brand loyalty.

Table 1 shows that there is a positive correlation (R: 0.471) between Brand Credibility and Brand Loyalty which is also significant at 0.000 level. Therefore we accept H1.

H2: There is a significant, positive correlation between brand awareness and brand loyalty.

Table 1 shows that there is a positive correlation (R: 0.584) between Brand Awareness and Brand Loyalty which is also significant at 0.000 level. Therefore we accept H2.

H3: There is a significant, positive correlation between brand association and brand loyalty.

Table 1 shows that there is a positive correlation (R: 0.462) between Brand Association and Brand Loyalty which is also significant at 0.000 level. Therefore we accept H3.

H4: There is a significant, positive correlation between perceived quality and brand loyalty. Table 1 shows that there is a positive correlation (R: 0.531) between Perceived Quality and Brand Loyalty which is also significant at 0.000 level. Therefore we accept H4.

H5: There is a significant, positive correlation between product knowledge and brand loyalty.

Table 1 shows that there is a positive correlation (R: 0.274) between Product Knowledge and Brand Loyalty which is also significant at 0.002 level. Therefore we accept H5.

H6: Brand Credibility, Brand Awareness, Brand Association, Perceived Quality, Product Knowledge significantly explain the variance and Brand Loyalty.

Regression

Table 6. Model Summary (b)
Tabela 6. Podsumowanie (b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.671(a)	.450	.425	.50484	1.885

a. Predictors: (Constant), product knowledge, brand association, brand credibility, brand awareness, perceived quality
b. Dependent Variable: brand loyalty

Table 6.1. ANOVA (b)
Tabela 6.1. ANOVA (b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	23.108	5	4.622	18.133	.000(a)
	Residual	28.290	111	.255		
	Total	51.398	116			

a Predictors: (Constant), product knowledge, brand association, brand credibility, brand awareness, perceived quality
b Dependent Variable: brand loyalty

The results in Table 6.1 indicate that there is a positive correlation (R: 0.671) between the independent variables (brand credibility, brand awareness, brand association, perceived quality, product knowledge) and the dependent variable i.e. Brand Loyalty. The value of Durbin-Watson statistic (1.885) also falls within the acceptance range therefore indicating that there is no autocorrelation among the variables being studied. Similarly the ANOVA table shows that the F-statistic value of 18.133 is significant at 0.000 levels. Therefore we accept H6.

Table 7. Coefficients (a)
Tabela 7. Współczynniki (a)

	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	-.145	.471		-.309	.758
brand credibility	-.005	.126	-.004	-.041	.968
brand awareness	.543	.128	.400	4.259	.000
brand association	.196	.114	.160	1.720	.088
perceived quality	.201	.113	.182	1.777	.078
product knowledge	.091	.062	.112	1.482	.141

a. Dependent Variable: brand loyalty

Table 7 Indicates the value for Adjusted R Square (0.425) which shows that the independent variables (brand credibility, brand awareness, brand association, perceived quality and product knowledge) and explain 42.5% of variance in Customer Loyalty. Brand Awareness has a greater influence on brand loyalty as it has the highest Standardized Beta Coefficient (β=0.400) which is also significant at 0.000 level.

FINDINGS

The findings of the analysis reveals that there is a significant positive relationship between brand loyalty(dependent variable) and brand credibility, brand awareness, brand association, perceived quality, product knowledge (independent variables). So hypotheses are supported by statistical analysis. So according to researcher's knowledge in university of Sargodha most of the students are satisfied with their brand and consumer are more loyal with L'Oreal brand.

CONCLUSIONS AND DISCUSSION

Good brand is vital to an organization and this research has reflected how cosmetic industry has managed to be just that. it is clear from the analysis survey carried out that the cosmetic industry adopting global branding to its higher standard and that exactly how global presence of any cosmetic industry is taken to highest level of success. So far cosmetic industry has been able to be one of the best businesses.

The research is conducted to know the brand loyalty of consumers toward their favorites brand and how brand credibility, brand awareness, brand association, perceived quality effects brand loyalty. Brand credibility can increase loyalty of a consumer toward brand and it has positively effect on brand loyalty as previous researcher [Erdem and Swait, 1998]. The relationship between brand awareness and brand loyalty is significant and brand awareness is highly effect the brand loyalty as previous researcher founded [Aaker, 1991], brand association influences on brand loyalty and have significant positive relation with brand loyalty and the result of this research supports the previous research [O'Cass and Lim (2002]. The relation between perceived quality and brand loyalty is also significantly positive and quality that consumer perceived also influences brand loyalty and [Kayaman and Arasli, 2007].

However, the study found that brand awareness in cosmetic industry is the most important dimension among other independent variables (brand credibility, brand awareness, brand association, perceived quality, product knowledge) effecting brand loyalty and knowledge about a product is also important for loyalty toward brand if consumer have max knowledge about the product he became loyal with his brand.

LIMITATIONS AND RECOMMENDATIONS

Loyalty of a consumer toward four cosmetics brand of Pakistan. Limited research had done on this topic and according to the researcher's knowledge it's first of its kind in Sargodha. The researcher's carried out research only in Sargodha city and the results of this study are limited by the specificity of the geographic context by taking a sample of 125 students of only one department from population of total University of Sargodha so on larger scale reality may differ. Increase sample size will help in increasing generalizability and validity of study more research should be done on the topic in Pakistan to reveal the facts according to this research no doubt most of the students have trust on their brand that they consume but there is always a room for improvement so there is a need to enhance brand trust. Like overall reliability on brand loyalty. We suggest further study will be large size and can be expanded to more universities in areas near to Sargodha for more specific results. Cosmetic industry must focus on brand association, perceived quality, product knowledge, brand credibility in order to build Brand Loyalty.

The results of present research shows that the brand awareness is highly influence on brand credibility and cosmetic industry can increase the loyalty of their consumer toward their brands by providing them awareness about their brands. More the awareness, more the loyalty toward their brand [McCarthy et al., 2001] and the consumer are more loyal with the L'Oreal brand then all other brands.

So organization can increase the loyalty of consumer toward their brand by providing them awareness which is highly influence on the brand loyalty and by providing them the quality they want to perceived, by providing knowledge about their brand.

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LOJALNOŚĆ MARKI W PRZEMYŚLE KOSMETYCZNYM

STRESZCZENIE. Wstęp: Praca jest poświęcona zagadnieniu lojalności marki. Jej celem jest rozpoznanie wpływu na budowanie lojalności marki takich czynników jak wiarygodność marki, znajomość marki, wizerunek marki, jakość odbioru oraz znajomość produktu.
Metody: Dane do analizy zostały zebrane wśród studentek jednego z wydziałów Uniwersytetu Sargodha. Ostateczna analiza została przeprowadzona dla 125 poprawnych odpowiedzi. W celu sprawdzenia wiarygodności skali została zastosowana statystyka Cronbach's Alpha. Metoda regresji została użyta w celu przetestowania hipotezy. Natomiast analiza korelacji została zastosowana w celu zbadania zależności między zmiennymi niezależnymi (wiarygodność marki, znajomość marki, wizerunek marki, jakość odbioru oraz znajomość produktu) oraz zmienną zależną (lojalność marki).
Wyniki i wnioski: Wyniki wykazały dodatnią zależność pomiędzy wiarygodnością marki, znajomością marki, wizerunkiem marki, jakością odbioru oraz znajomością produktu (zmienne niezależne) a lojalnością marki (zmienna zależna). Wszystkie zmienne związane ze znajomością marki miały największy wpływ na lojalność marki oraz zgodnie z wynikami badań najbardziej rozpoznawalną marką była L'Oreal. Praca ta została poświecona zbadaniu lojalności marki na Uniwersytecie Sargodha. Jednak co należy podkreślić, celem tych badań było ustalenie czy przemysł kosmetyczny powinien skupić się na wiarygodności marki, znajomości marki, wizerunku marki, jakości odbioru oraz znajomości produktu w celu budowania lojalności marki. Według wiedzy posiadanej przez Autorów, badania te były pierwszymi tego typu przeprowadzonymi na Uniwersytecie Sargodha, które miały na celu zbadanie świadomości studentów w zakresie wiarygodności marki, znajomości marki, wizerunku marki, jakości odbioru oraz znajomości produktu odnośnie wyrobów kosmetycznych. Wyniki badań są ograniczone ze względu na ograniczenie geograficzne grupy studentów, wśród których przeprowadzono badania (jeden wydział Uniwersytetu Sargodha). Badania mogą być przeprowadzone na innych uniwersytetach w Pakistanie.

Słowa kluczowe: wiarygodność marki, znajomość marki, wizerunek marki, jakość odbioru, znajomość produktu, lojalność marki.

MARKENLOYALITÄT IN DER KOSMETISCHEN INDUSTRIE

ZUSAMMENFASSUNG. Einleitung: Die vorliegende Forschungsarbeit ist den Fragen der Markenloyalität gewidmet. Ziel der Arbeit war die Ermittlung von Einflussfaktoren wie Glaubwürdigkeit der Marke, Kenntnis der Marke, Marken-Image, Qualität des Marktempfanges sowie Kenntnis des Produktes, die den Aufbau der Markenloyalität mit einprägen.
Methoden: Die Daten, die der Analyse zugrunde liegen, wurden unter Studentinnen einer der Fakultäten der Universität Sargodha erfasst. Die endgültige Analyse wurde auf Grund von 125 richtigen Antworten durchgeführt. Zwecks Überprüfung der Skala-Glaubwürdigkeit wurde das Cronbach's Alpha-Statistikverfahren in Anspruch genommen. Die Methode der Regression wurde zum Durchtesten der Hypothese angewendet. Die Analyse der Korrelation dagegen wurde für die Zwecke

einer Untersuchung des Verhältnisses zwischen den unabhängigen Variablen (Glaubwürdigkeit der Marke, Kenntnis der Marke, Marken-Image, Qualität des Marktempfanges sowie Kenntnis des Produktes) und der abhängigen Variable (Markenloyalität) beansprucht.
Ergebnisse und Fazit: Die Ergebnisse zeigten eine positive Abhängigkeit zwischen der Glaubwürdigkeit der Marke, der Kenntnis der Marke, dem Marken-Image und dem Marktempfang sowie der Kenntnis des Produktes (unabhängige Variablen) und der Markenloyalität (abhängige Variable) auf. Alle mit der Kenntnis der Marke verbundenen Variablen haben den größten Einfluss auf die Markenloyalität ausgeübt. Demzufolge war gemäß den Untersuchungsergebnissen die Marke L'Oreal am meisten erkennbar. Die Arbeit wurde auf der Universität Sargodha der Erforschung des Themenkomplexes Markenloyalität gewidmet. Das Ziel dieser Forschungen war in erster Linie, was hervorzuheben ist, die Festlegung, ob die kosmetische Industrie sich auf die Glaubwürdigkeit der Marke, die Kenntnis der Marke, das Marken-Image, die Qualität des Marktempfanges sowie die Kenntnis des Produktes zwecks Aufbau der Markenloyalität konzentrieren sollte. Nach dem Wissensstand der Autoren waren die betreffenden Untersuchungen dieser Art, die ersten, die an der Universität Sargodha vorgenommen wurden und denen die Untersuchung des Bewusstseins der Studenten hinsichtlich der Glaubwürdigkeit der Marke, der Kenntnis der Marke, des Marken-Images, der Qualität des Marktempfanges sowie der Kenntnis des Produktes in Bezug auf die kosmetischen Erzeugnisse zugrunde lag. Die Forschungsergebnisse sind wegen der geographischen Begrenzheit der in die Untersuchung einbezogenen Studentengruppe (nur eine Fakultät der Universität Sargodha) raummäßig eingeschränkt. Die betreffenden Forschungen können jedoch auf anderen Universitäten in Pakistan fortgesetzt werden.

Codewörter: Glaubwürdigkeit der Marke, Kenntnis der Marke, Marken-Image, Qualität des Marktempfanges, Kenntnis des Produktes, Markenloyalität.

Mohsin Altaf
Department of Commerce
University of Sargodha, Pakistan
e-mail: mohsin.iltaf@gmail.com