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MODELLING AND SIMULATION OF THE INTEGRATION OF THE SUPPLY CHAIN OF FORWARD AND BACKWARD TYPE

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ABSTRACT. Background: The integration, besides synergy and convergence, is regarded as a leading orientation in modern logistics. The connection of various participants within supply chains enables the integration of actions and allows to fulfill growing customers' demands in an effective and economically efficient way. In times of a concept of the balanced development, growing interest in utilization of recycled material, connected with possibilities to consolidate logistic activities, can be observed. According to the scientific literature (integration models) as well as practical business cases, supply chains of forward and backward type (two-directional) are the area of logistics of the intensive development.

Material and methods: The paper presents the Authors' model and methodology of modeling of the integration of supply chains, which realizes the flows of forward and backward type (two-directions). The empirical material was obtained during modeling and simulation of processes in the environment of iGrafx Process 2013 for Six Sigma with the support of Minitab 17 (for planning of experiments). The method of the verification of statistical hypotheses was used. As a first step, the correlation between the level of the integration and the global service level for the supply chain was conducted using the method of Pearson's coefficient. The test of relevance of correlation coefficient was conducted by the use of t-distribution method. Then the verification of statistical hypotheses was made, based on the method using the Z-statistics.

Results: The obtained results indicate clearly the strong relationship between the level of the integration of a supply chain and the obtained service level (values of Pearson's correlation coefficient and results of t-test). The detailed statistical researches of authors indicate that the increased level of the integration leads to the increase of the average value of service level coefficient (results of Z-statistics). Concluded, the analyze of the service level indicator shows its growth together with the growth of the integration level.

Conclusions: Based of integration aims, the integrated systems should have bigger possibility of activity. The possibility to obtain higher customer service level is one of postulated effects ("gains") of the integration of supply chains. The results of Authors' researches confirmed such statement in quantitative way, and not only in a describing one. The conclusions from conducted researches encourage to integration activities within supply chains of forward and backward type.

Key words: supply chain of forward and backward type, supply chain models, methodology of integration of supply chain, customer service level in supply chain.

INTRODUCTION

The integration is the process of creation the wholeness from many parts [Sobol 2001]. The integration means connection, consolidation, merge or unification, which could embrace companies, departments of companies as well as whole processes (functions) covering business relationships between partners.

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According to the traditional approach, most of companies see themselves as individual units, operating independently and competing with others on the market. But in fact, not individual companies but whole supply chains should compete with each other. The first phase of the integration is the internal integration with the focus put on the creation of close interfunctional connections within the organization. The second direction of the integration is the external integration, focused on the creation of close connections between partners operating within the same supply chain as well as on the managing of this supply chain [Hadaś 2010].

The problem of the integration of different operational systems occurs during the process of the creation of a supply chain or a logistic network. There are various reasons of the connection of different systems. The most common one is the attempt to enlarge the power of the system as well as to increase the level of reliability and affectivity of the operational activity [Konieczny 1983]. The result of the integration process is the affiliation to one integrated system. And this is the source of gains as well as integration costs for every system. The integrated systems should have bigger operational possibility and at the same time lower system wastes (integration gain). The integration process gives also negative effects, especially in case when too many efforts are put into the support of integration connections. In such situations, the integration gain is very small and sooner or later the integration of systems breaks down [Brzeziński 2007]. The modeling and process simulation tools are presently used to support the researches of the integrations [Adamczak, Domański, Cyplik, Pruska 2013]. The main trend is to assure the effective complex material flow, which determines various factors [Śliwczyński, Koliński 2012].

Many scientists have opinion that the solution of problems in reality should be analyzed by the use of models [Cempel 2003]. The model means the simplified representation in time and space, created for better understanding of a real system. And the modeling process means searching for features and connections within the system, which are essential for a given aim. The simulation means the model manipulation in such a way, that it works in different scale in time and/or space-time dimension and enables to observe behaviors and influences, which are usually difficult or unable to be observed. Therefore the simulation means the compression or expansion of time-space scale of phenomenon on demand [Cempel 2006]. And thanks to this feature, the simulation is a desirable tool both in original as well as in applied researches [Cempel 2003].

LOGISTIC CHAINS OF FORWARD AND BACKWARD TYPE

The supply chains were originally created to support the flows from the production of raw materials up to finals customers. But at present the return flows within these chains become more and more important as well [Sadowski 2010]. The modern logistics has to be able to solve problems of remains of production batches, goods returns, warranty and post-warranty service, production wastes, packaging and packaging wastes. All these issues are covered by so-called reverse logistics [Brdulak 2012].

The common element of presented definitions is the direction of the flow - return to traditional operations of logistic chain, i.e. from the point of creation of wastes, consumer or consumption place to the place of the utilization or the place of the origin. The citied definitions differ from each other in the aim of undertaken operations - it could be the reuse of materials, return of the value of products taken from the market, the proper recycling or the optimization of after-sale services and the reduction of costs.

The logistic chain of forward type (traditional forward chain) covers the processes related to the production and the distribution of goods, i.e. their flow from the place of origin of raw materials to the place of their final consumption (i.e. final customer). The logistic chain of backward type (return chain) covers the processes of the return and the collection of used products [Seitz, Wells 2006], as well as the processes connected with their recycling, i.e. their flow from the place of final consumer to the producer (from the point

of view of a given chain). The returned product can be disassembled up to modules, parts or materials [Wikner, Tang 2008] during the backward processes. The aim of this process (e.g. during recycling) is to restore the original market value of the product [Gupta, Pochampally 2004]. The flow from the moment of the realization of any operation on the product such as segregation, washing, repairs or recycling, is considered to be the flow of forward type.

Table 1. Selected definitions of reverse logistics
Tabela 1. Wybrane definicje logistyki zwrotnej

APICS dictionary	The whole supply chain covering the return flows of goods and materials in order to return them, repair them, regenerate them and/or recycle them.
Council of Logistics Management	The reverse logistics covers the logistics management of abilities and operations of recycling and management of products' and packaging' wastes. It includes the reverse distribution, which causes the flow of goods and information in the opposite direction to standard logistic operations.
Reverse Logistics Association	All operations connected with the product or service, which take place after the moment of the sale transaction, focused mainly on the optimization of after-sale operations and therefore on the cost reduction.
Reverse Logistics Executive Council	The process of planning, implementation and controlling of the flow of raw materials, stocks and used products, as well as information flows connected with them, from the place of consumption to the place of origin of the goods, which is conducted to restore their value or at least of part of invested resources or leads to the proper utilization of the product

Source: own s [based on: Szołtysek 2009, Brdulak 2012]

OVERVIEW OF MODELS OF THE INTEGRATION OF SUPPLY CHAIN

The authors of 5-level model of the development of a supply chain (so called Compass model) state, that obtaining higher consecutive level depends on the implementation of more and more sophisticated information technologies [Simichi-Levi, Kaminsky, Samichi-Levi 2000]. These technologies change together with changes occurring in the supply chain and should be adjusted to present organization solutions and planning systems. According to authors of a described model, each type of company activity could be at different level of the integration of the supply chain.

Table 2. 5-level model of the development of a supply chain (so called Compass model)
Tabela 2. Pięciopoziomowy model rozwoju łańcucha dostaw - model Kompasu

Name of the level	Criteria			
	aim	organization	planning	information technology
I Basic	quality and cost	independent sections	calculating sheet	atomization and MRP
II interfunctional teams	customer service	creation of logistics departments and operational management	goals setting e.g. CPM, PERT	MRP II
III integrated company	reaction on profitable clients	integrated internal supply chain	planning of company's supply chain	ERP
IV expanded supply chain	profitable growth	integrated external supply chain	planning of sale points in a supply chain	CRM
V community of the supply chain	market leadership	ability of the prompt reconfiguration	synchronized planning of a supply chain	net trade

Source: Witkowski 2010

According to first version of Ch.C.Poirier's model, the advanced supply chain can be reached by the 4-step method, consisting of two levels of the internal integration and consecutive two levels of the external integration [Poirier 1999]. According to

Ch.C.Poirier, as many as 80% companies do not go further than only to the second level. The most difficult level is connected with overcoming the borders of an own company. Therefore the newest version of this model includes 5 levels of integration with one additional level of the external integration consisting in starting the cooperation with partners [Poirier, Quinn 2004].

Table 3. 4-level model of supply chain development according to Ch.C. Poiriera
Tabela 3. Czteropoziomowy model rozwoju łańcucha dostaw Ch.C. Poiriera

Elements	Level			
	internal		external	
	purchase and logistics I	internal perfection II	network construction III	leadership in sector IV
initiator	manager of purchase department (under pressure)	manager of IT department of future chain leader	leaders of business units	management team
profitability	increase of savings	priority improvement	results of best partnership	network profits, profitability
concentration	stocks, logistics, transport, orders fulfillment	redesigning of processes, improvement of systems	forecasting, planning, customer service, extended company	client, network
tools	team work, functional perfection	benchmarking, best examples, balance of operational costs	coefficients, databases, e-trade	Intranet, Internet, common information systems
area of operations	middle level of company	various levels of organization	whole organization	whole company
points of reference	cost registry	map of processes	advanced cost models, differentiation of cost	demand-supply relation
model	lack	internal supply chain	extended company	global market
alliances	consolidation of supplies	best partner	formal alliances	Joint venture
schooling	team	leadership	partnership	network

Source: Witkowski 2010

Table 4. Stevens' four-level model of the development of the supply chain, extended by Potter and others
Tabela 4. Czteropoziomowy model rozwoju łańcucha dostaw Stevensa rozwinięty przez Pottera i innych

Characteristics		**Phase I**	**Phase II**	**Phase III**	**Phase IV**
Flow of goods		functional, uncoordinated	internal coordination within the organization	external coordination within the organization	integrated within the supply chain
Stocks		high level, double stocks	buffered for each function	unaccepted within the organization	minimized within the supply chain
customers' service level		low	reduced within the organization	reduced within the supply chain	high
information flow	decisions centers	many	one for the process	one for organization	steering is coordinated within one center
	data transfer	traditional, paper documents	based on personal computers	E-commerce	E-business
	data availability	lack	within internal logistic processes	within the organization	full accessibility within the supply chain
information systems		separated, incompatible	MRP type	ERP type	integrated DRP
orientation		recourses	internal costs	external costs	oriented on client
relations management		contracts, agreements	extended cooperation	common management at the organizational level	common management at all levels
basic indicators		lack	functional	operational	for supply chain

Source: Potter et al., 2005

Stevens [1989] distinguished four phases of the evolution of a supply chain with the growing level of the integration. Potter, Mason, Naim and Lawlani [2005] extended this model und added four basic characteristics of the supply chain, which were referred to four integration phases.

The research model of the integration, based on the model of Cai, Jun and Kim [Cai, Jun, Kim 2009], is presented by M.D.Dobrzyński. The model consists of three main areas: supply chain, IT technologies and behaviors. The integration factors are selected within these perspectives. According to the author, the choice of integration measures is made quite freely by researchers and is weakly argued. The higher level of specification of the measurement of the integration of the supply chain allows the objective estimation of individual characteristics in practice [Dobrzyński 2008].

Table 5. Dobrzynski's four-level model of the development of the supply chain
Tabela 5. Czteropoziomowy model rozwoju łańcucha dostaw M.D. Dobrzyńskiego

Characteristics	Internal integration		External integration	
	phase I	phase II	phase III	phase IV
flow of goods	uncoordinated	internal coordination within the organization	external coordination within the supply chain	external coordination within the global supply chain
stocks management	many decision centers	one center for organization	common management within the supply chain	common management within the global supply chain
identification of stocks level	based on historical data for organization	based on current stocks for organization	based on historical data for supply chain	based on current stocks for supply chain
data transfer	traditional, on paper	local computer network LAN	Internet	Internet and Intranet
information systems	separated	MRP type	ERP type	DRP type
sale support	cooperation within the organization	occasional cooperation of sale represents within the supply chain	common marketing cooperation	cooperation at the level of designing and introduction of a product
management of relationships between participants	informal relationships	cooperation within organization	agreements, contracts, common standards of operational management	common standards of strategic management
effectiveness indicators	lack	operational ones for organization	operational ones for supply chain	strategic ones for supply chain

Source: Dobrzyński 2009

Three levels of the development of the supply chain were identified during the research conducted by the A.T. Kearney company, which correspond to levels of the integration of its parts [Rutkowski 1999]. In this case, the bigger number of characteristics (comparing to Compass model) to distinguish following levels of the perfection of integrated supply chains were adopted. According to authors, although the trend to the cost reduction is the most important one at the level of the internal integration, the main goal of the integrated supply chain is the maximization of gains and market shares, which leads to the increase of the value of participants.

The oldest type of models of a supply chain is so called model of maturity of the supply chain. The model of maturity of the supply chain is presented in SCOR model (Supply Chain Operations Reference) consisting of four levels [Cohen, Roussel 2004]:

– level 1 - functional integration - the goals are set for separate functional areas of the company,
– level 2 - internal integration - the goals are set for whole company, during optimization

processes, the best solutions are searched based on clients' needs and availability of resources,
– level 3 - external integration - the goal are set not only for one organization but as well for companies cooperated with it,
– level 4 - cooperation of companies - sharing of strategy, risks and market possibilities.

Table 6. Three-level model of the development of the supply chain accoridng to A.T. Kearney
Tabela 6. Trójpoziomowy model rozwoju łańcucha dostaw A.T. Kearney

Area	Level I	Level II	Level III
orientation on client	– treating each transaction uniquely	– all clients are treated in the same way – achieving internal goals – monitoring of clients' expectations	– providing differential services – fulfillment of clients expectations
integrated long-term planning	– partial planning – concentration on the budget of a department	– MRP philosophy – small range – (e.g. of production) – concentration on stocks – 1-3 years time fence	– full range of logistics services – optimization of integrated added value – integrated procedures and systems – (e.g. MRP, DRP) – 3-5 years time fence
partnership with suppliers	– crisis situations – spontaneity – contrast	– main criteria - costs – many sources – orientated on auctions (competition)	– main criteria - results – partnership – common improvement
above-functional planning of operational activities	– current – occasional (each transaction)	– periodical (e.g. quarterly) – based on budget period	– time continuity – integration of all functions
continuous improvement of processes	– improvement by "repairing of damages"	– formalization of the process – cost reduction – average quality	– acceptance of CEO – continuous improvement by objectives – quality and effectiveness
competences of employees	– management against employees	– limited engagement of employees	– schooling – competences – common goals (rewards)
integrated IT system	– IT processing of transactions – lack or not enough data – lack of analytical abilities	– periodical reports of financial results – fragmentary data – limited abilities of analysis	– planning process based on operational data – easy access to common data – flexible possibilities of analysis
monitoring, comparing and undertaking repair actions	– comparing costs with previous year – costs as percentage of sale	– costs vs. budget – increase of productivity – competitiveness of services	costs vs. standard productivity vs. aim services in accordance with clients' expectations

Source: Witkowski 2010

The other model of the maturity of the supply chain can be found in researches of Pache and Spalanzanihave [Pache, Spalanzanihave 2007]. They proposed five-level model including social elements:
– level 1 - internal maturity of the organization - effectiveness is achieved by the integration of various functional areas within the organization,
– level 2 - maturity among organizations - cooperated companies (suppliers, services suppliers and clients) are engaged in achieving better effectiveness,
– level 3 - extended cooperation among organizations - all cooperated companies (suppliers, services suppliers and clients) are engaged in achieving better effectiveness,
– level 4 - maturity among supply chains - companies, being a part of few supply chains at the same time, are able to increase the effectiveness through the cooperation with big number of other entities,
– level 5 - social maturity - organizations look for best solutions not only for themselves but also for the whole

community, within which they function, the emphasis is put on the balanced development.

MODELS OF A SUPPLY CHAIN INCLUDING THE BACKWARD FLOWS

The authors' team from Lisbon [Cardoso, Ana Paula, Barbosa-Povoa, Relvas 2013] proposed the model of a supply chain, realizing two-direction flows. The aim of this model is to create a structural solution (choice of the structure of a supply chain) to maximize NPV indicator (net present value) in the situation of the uncertainty of the demand. The elaborated model describes four levels:

- producer - conducts the production process, utilizes the raw materials, delivers final goods, disassembles the used goods,
- warehouse - stores the final goods, disassembles the used goods (including the completion for the purpose of sale),
- sale network - provides goods to the market and keeps them in form of stocks in distribution network,
- market - generates the demand, utilizes final goods, provides used goods.

The final goods, in the described model, can be destined to the market through the distribution network, from the warehouse or directly from the production plant. The backward flow of used goods takes place from a client (market) to various points of the supply chain. The used goods (or their parts) go also outside the described structure and are identified with wastes (are not used within the analyzed chain structure).

The authors' team from Indonesia and China [Jonrinaldi, Zhang 2013] presented the proposal of the model of the integration of products and stocks with regards to backward logistics in a finite time period. Total costs of functioning of the supply chain (of each part among mentioned below) are the aim function of this model. The model assumes the existence of a supply chain of 6-level structure. Its elements are:

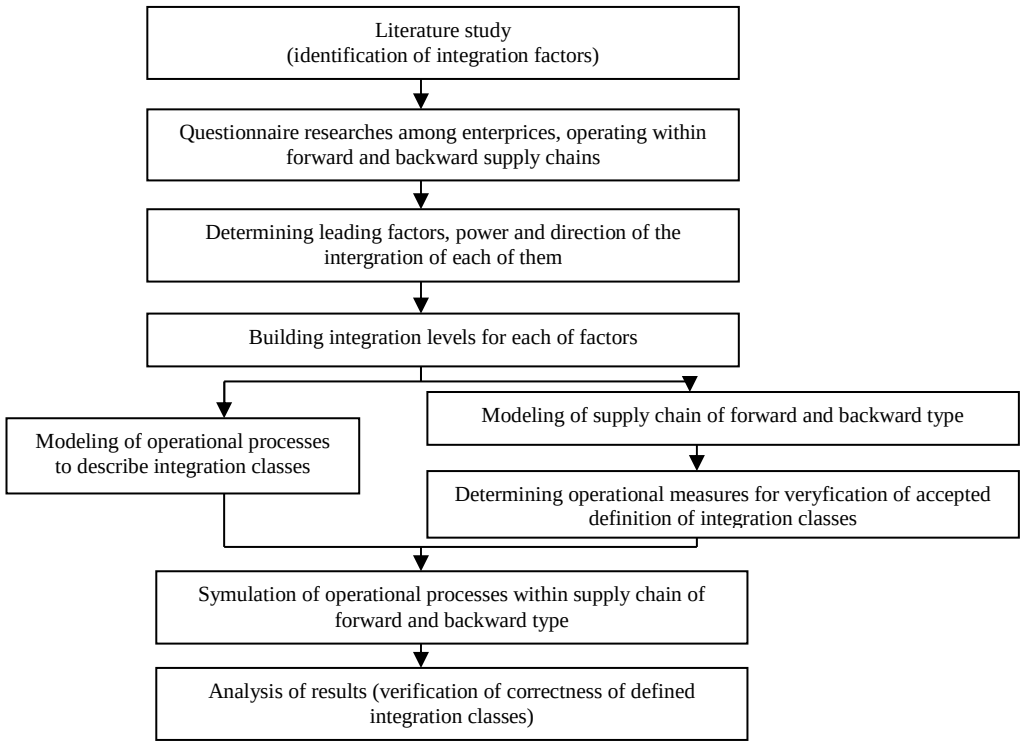
- suppliers of 2nd degree - e.g. suppliers of raw materials,
- suppliers of 1st degree - e.g. entities processes the raw materials into components,
- producer - entity manufactures components and assemblies final goods,
- distributors - entities, which are responsible for storing final goods and delivering them to sale networks,
- sale networks - deliver of final goods directly to final customers,
- logistic partner - entity, which specializes in collecting used goods from the market and delivering them to the producer.

The described model was used by authors to inspect the influence of the coordination of the production process with stocks in conditions of the supply chain performing both forward (from producer to client) and backward (from client to producer) goods' flow on total costs of functioning of such supply chain.

AUTHORS' METHODOLOGY OF MODELING OF THE INTEGRATION OF A SUPPLY CHAIN

Modeling of the integration of a supply chain is a process connecting both theoretical and practical aspects. The first step in preparing such model is the identification of integration factors by the analyze of the scientific literature. Based on the definite set of integration factors, the questionnaire form was prepared as a research tool. Then based on questionnaire results, the leading factors, powers and directions of the integration of each factor were determined. As a result of this, the integration levels within each factor were distinguished. Each of these levels (A, B, C, D, where A is the highest one) has a defined characteristics of activity, which allows to estimate its activity within the supply chain (by assigning to the proper level). While characterizing the integration levels, the focus was put by authors on the integration symptoms or the lack of them. The actions of the following step can be realized simultaneously. Namely, operational processes within a supply chain are modeled together with their measures of the effectiveness. Additionally the presentation of the integration

level is worked out. The realization of this last mentioned task means to modify operational processes in such a way, that the features, identified at the phase of building of integration classes of individual factors, are assigned to them. The last step of this methodology is the simulation of operational processes in various variants of the integration levels of the supply chain. The schematic presentation of the methodology of modeling of the supply chain is presented at the figure 1.



Source: own study

Fig. 1. Author's methodology of modeling of the integration of a supply chain
Rys. 1. Autorska metodyka modelowania integracji łańcucha dostaw

The most important element of presented methodology is the verification of the correctness of defined integration classes. This action allows to verify the correctness of accepted assumptions and at the same time to prepare the recommendations for practicians regarding the effectiveness of individual integration activities. The verification method is presented in the chapter "Results" of this paper.

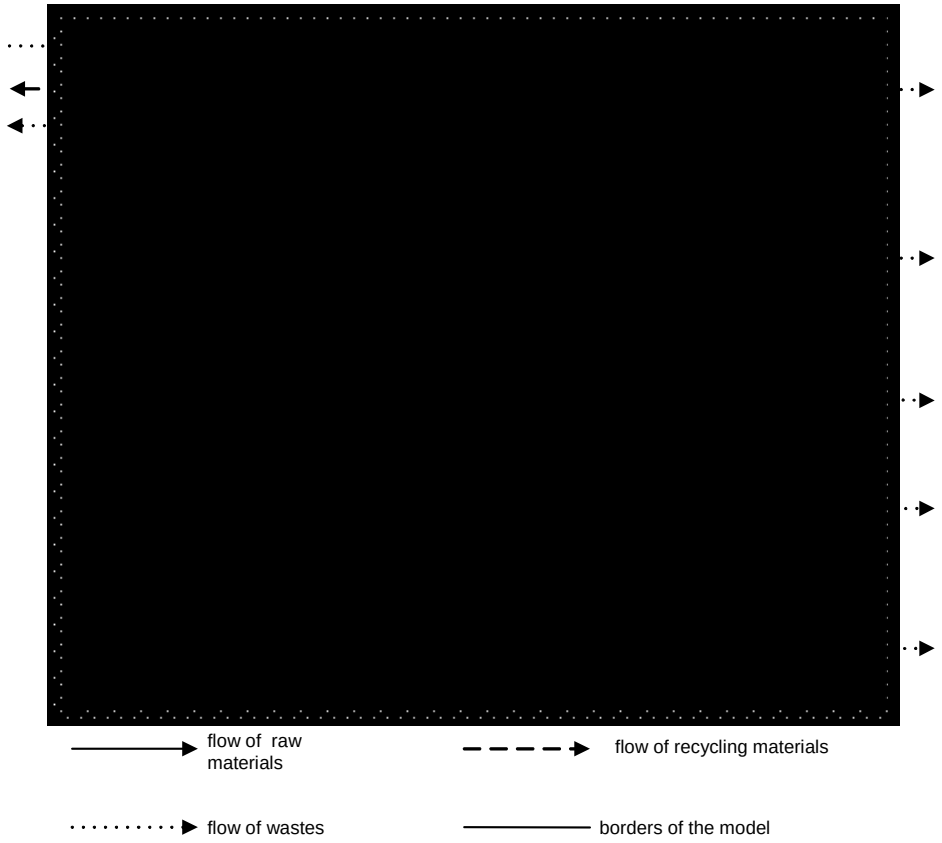
DESCRIPTION OF THE SIMULATION MODEL

Based on the models of the integration of the supply chain, both realizing only one-direction flow (only forward) or two-direction flow (both forward and backward), the authors of this paper created their own model of the supply chain, which covers both the flow of original materials as well as waste and recycling materials. The structure of modeled supply chain with the schema of the flow of raw materials, goods, wastes and recycling goods is presented at the figure 2.

The model assumes functioning of a supply chain of a 5-level structure. These levels are as below:

- suppliers of raw materials - e.g. companies offering raw materials,

- agents in trade of recycling materials - e.g. companies storing and offering recycling materials, recycling exchange,
- producer - company manufactures final goods and their parts, both from raw materials and recycling materials,
- distributors - companies responsible for storing of final goods and providing them to sale networks,
- sale networks - companies providing final goods directly to final customer.



Source: own study

Fig. 2. Authors' model of the integration of a supply chain realizing both forward and backward flows (two-direction)
Rys. 2. Autorski model integracji łańcucha dostaw realizującego przepływy forward i backward (dwukierunkowe)

Three basic measures were selected for the purposes of the estimations of the supply chain within the created model:

- customer service level - ratio of pieces of goods sold to final customers to pieces ordered by them (quantitative level of fulfillment of orders)
- profitability - ratio of obtained gains to incomes,
- cash flow - average quantity of cash, available at the given time in the company.

The integration of the supply chain in the presented paper is estimated only taking into account one of above mentioned measure, i.e. the customer service level.

RESULTS OF RESEARCHES

For the purposes of the analysis of the results of the simulation of processes realized within the supply chain with different

integration levels, the transcription of class symbols into values were made using the following system: A=4, B=3, C=2, D=1. The aggregated measure of the integration of the supply chain was presented as the sum of class values for each factor. Thanks to these assumptions, there was a possibility to calculate the value of correlation indicator for pairs of data built at the level of the integration and the selected measure indicator of the estimation of the supply chain. The service level was selected as an indicator due to the fact, that this indicator presents in the best way the perfection of the supply chain from the customer's point of view. The following hypotheses were taken into consideration during the analysis of results of the simulation:

- H_o: there is no correlation between the level of the integration of the supply chain and the value of service level indicator - $r_{xy} = 0$,
- H_1: there is a correlation between the level of the integration of the supply chain and the value of service level indicator - $r_{xy} \neq 0$.

To verify the above presented hypotheses, the correlation indicator between the integration level and the value of the service level indicator was calculated. The date for the calculation of the correlation indicator came from 96 simulations (each in different configuration of integration classes), conducted in situations related to business environment of real supply chains. The value of so calculated correlation indicator was r_{xy} = 0,9590. It shows the high correlation between the level of the integration of the supply chain and the offered customer service level. To confirm this statement, the test of significance of correlation indicator was conducted by the use of the t-test and by the implementation of the following formula:

$$t_{emp} = \frac{r_{xy}\sqrt{n-2}}{\sqrt{1-r_{xy}^2}}$$

where:

n - number of observations,

r_{xy} - Pearson's correlation indicator.

The calculated empirical value of t-statistics is equal to:

$t_{emp(0,9590)} = 32{,}8075$

The value t_{emp} was compared to limiting value taken from the statistical table of the t-Student distribution for two-side critical area of significance level α=0,05 and n=90 degrees of freedom. The critical value t is equal to:

$$t_{(0,05)}^{96-2} = 1{,}98667$$

In case when there is a relationship

$$|t_{emp}| \geq t_{(0.05)}^{96-2}$$

for calculated Pearson's correlation indicator, the hypothesis H_o has to be rejected.

The inequality authorizing to reject the hypothesis H_o occurs in favor for the hypothesis H_1. Therefore it was stated that there is a relationship between the level of the integration of the supply chain and the value of the service level indicator. Leading to further explanations of above presented relationships, the diagram was prepared to show the level of customer service realized at different levels of the integration of the supply chain (Fig 3).

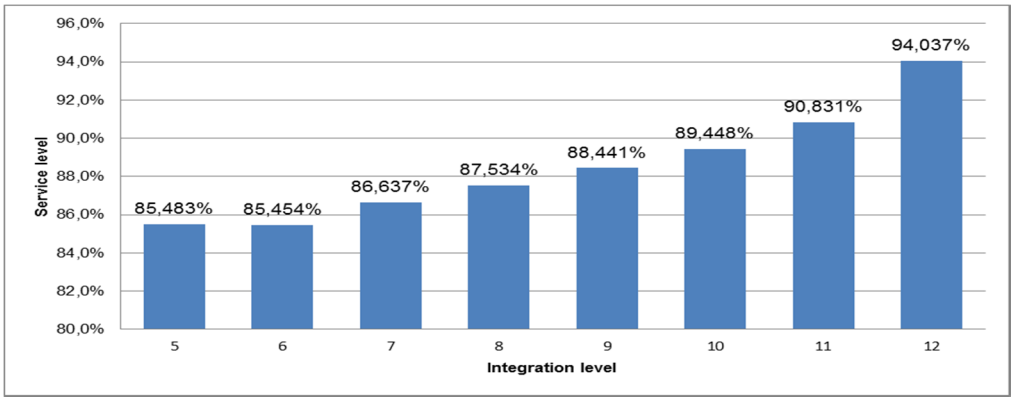
Based on the diagram presented on Figure 3, it can be concluded, that the customer service level offered by the supply chain increases with its integration level. But whether the increase of the integration level influences on the customer service level from the statistical point of view? To answer this question, the two hypotheses were taken:

- H_o : the increase of the integration level from 5-8 till 9-12 causes the decrease of average value of service level indicator or causes no change of this indicator $\mu_1 \geq \mu_2$,
- H_1 : the increase of the integration level from 5-8 till 9-12 causes the increase of average value of service level indicator $\mu_1 < \mu_2$.

Due to the big sample (n_1>30 and n_2>30) and known values of standard deviations, the verification of above-stated hypotheses was made by the use of Z statistics, the value of which was calculated by the formula:

$$Z = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{\delta_1^2}{n_1} + \frac{\delta_2^2}{n_2}}}.$$

The critical value of the statistics Z at the significance level $\alpha = 0,05$ in one-sided test is equal to $Z_\alpha = 1,645$. The calculated empirical value of statistics Z is $Z = -2,196$. Therefore there is a dependence $Z<-Z_\alpha$ which authorizes to reject the hypothesis H_o in favor of alternative hypothesis H_1. Based on that, the conclusion was made, that the increase of integration level from 5-8 to 9-12 causes the increase of the average value of the service level indicator.



Source: own study

Fig. 3. The customer service level realized at various level of the integration of the supply chain
Rys. 3. Realizowany poziom obsługi klienta na poszczególnych poziomach integracji łańcucha dostaw

The analysis of the operational indicator of the service level shows its value together with the increase of the integration level. This effect is one of postulated results of the integration of the supply chain (integration profit). At the same time the postulate made by J.Konieczny of the influence of the integration on the reliability of the system was confirmed. This confirmation is of a quantitative nature for selected set of factors of the integration of supply chains of forward and backward type.

CONCLUSIONS

Base of the previous literature review the following statements can be made:

- the process of the integration of the supply chain is of the evolutionary nature, usually the whole process is divided into several phases by authors. Special features are assigned to each of these phases,
- there are two basic integration phases: internal integration (within the organization) and the external integration (connecting the participants of the supply chain),
- authors freely choose the measures of the integration, but this choice is weakly argued,
- in case of using the integration model to research the real supply chains, authors mainly use the change from qualitative methods to the quantitative ones [Dobrzyński 2009],
- the integration can have a companies' dimension (concentrated on the quantity of companies involved in the process) or a functional dimension (related to the functions, among which the integration occurs),
- the integration has a positive influence on the operational measures of the supply chain (including service level indicator), independently whether the realized flow is of forward, backward or both types.

The possibility to estimate the integration of the supply chain based on values of levels of various integration factors allows to implement such methods for practical solutions. It enables various configurations of the supply chain starting from the designing phase (modeling phase) and finishing on its work (the phase of the simulation of operational processes within individual functional areas).

Simulation researches allows to determine precisely, in a quantitative way, the influence, direction (positive, negative, neutral) and

strength (significant, marginal) of the integration on operational measures of the supply chain. The presented results, referring to the service level indicator (one of integration measures) allows to choose the right strategy of the implementation of activities of the integration of supply chains. In the future, the authors plan to compare service level indicators with other measures - mainly profitability as well as cash flow. The confrontation of obtained effects (service level) with bearing expenses will make possible to conduct the estimation of the profitability of functioning of the supply chain in given configuration of integration levels. Then, the conviction of the correctly chosen strategy of the implementation of integration activities will be stronger, thanks to more convincing argumentation.

The methodology and the model of the integration of the supply chain, created during the research work, allow to predict results of the implementation of activities of the integration of the supply chain. The results of the service level indicator, presented in this paper, show the global functioning of supply chains in this range. Therefore, Authors' researches have no sign of local optimization, which often exclude and cancel each other. Although the aim of this research was the operational level, it should be remembered, that the chosen way of the configuration of the integration of the supply chain cannot conflict with goals, determined at the strategic level.

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MODELOWANIE I SYMULACJA INTEGRACJI ŁAŃCUCHA DOSTAW TYPU FORWARD I BACKWARD

STRESZCZENIE. Wstęp: Integracja, obok synergii i konwergencji, jest uważana za jedną z dominujących orientacji we współczesnej logistyce. Łączenie się podmiotów w łańcuchy dostaw umożliwia integrację działań, pozwalając realizować coraz bardziej specyficzne wymagania odbiorców w sposób nadal skuteczny i korzystny ekonomicznie. W dobie koncepcji zrównoważonego rozwoju rośnie zainteresowanie wykorzystaniem surowców wtórnych połączone z możliwościami konsolidacji działań logistycznych. W świetle analizy literatury naukowej (modele integracji) oraz obserwacji przykładów z praktyki biznesowej, łańcuchy dostaw typu forward i backward (dwukierunkowe) stanowią intensywnie rozwijający się obszar logistyki.
Metody: Praca zawiera autorski model oraz autorską metodykę modelowania integracji łańcucha dostaw realizującego przepływy forward (w przód) i backward (dwukierunkowe). Materiał empiryczny uzyskano w wyniku modelowania i symulacji procesów w środowisku iGrafx Process 2013 for Six Sigma, wykorzystując także pakiet Minitab 17 na potrzeby planowania eksperymentów. W pracy posłużono się metodą weryfikacji hipotez statystycznych. Najpierw przeprowadzono badanie korelacji pomiędzy poziomem integracji a globalnym poziomem obsługi klienta łańcucha dostaw metodą współczynnika Pearsona. Przeprowadzono również test istotności współczynnika korelacji z wykorzystaniem statystyki t. Następnie dokonano weryfikacji hipotezy statystycznej w oparciu o test, którego sprawdzianem jest statystyka Z.
Rezultaty: Wyniki autorów jednoznacznie wskazują na wysoki związek pomiędzy poziomem integracji łańcucha dostaw a uzyskiwanym poziomem obsługi klienta (wartość współczynnika korelacji Pearsona oraz rezultaty testu statystycznego t). Szczegółowe badania statystyczne autorów ukazują, że podniesienie poziomu integracji z niższych do wyższych stanów integracji powoduje zwiększenie średniej wartości wskaźnika poziomu obsługi klienta (wyniki statystyki Z). Konkludując, analiza wskaźnika poziomu obsługi klienta pokazuje, że wzrasta on wraz ze wzrostem poziomu integracji.
Wnioski: Zgodnie z celami integracji systemy zintegrowane powinny mieć większą możliwość działania. Jednym z postulowanych efektów ("zysków") integracji łańcucha dostaw jest m.in. możliwość osiągnięcia wyższego poziomu obsługi klienta. Rezultaty badań autorów potwierdzają taki stan faktów, co bardzo cenne w postaci kwantytatywnej a nie opisowej, wpisując się w poglądy nauki i praktyki. Wnioski płynące z przeprowadzonych prac badawczych zachęcają do podejmowania działań integracyjnych w łańcuchach dostaw typu forward i backward.

Słowa kluczowe: łańcuchy dostaw typu forward and backward, modele łańcucha dostaw, metodyka integracji łańcucha dostaw, poziom obsługi klienta w łańcuchu dostaw

MODELLIERUNG UND SIMULATION DER INTEGRATION INNERHALB DER LIEFERKETTE VOM TYP FORWARD UND BACKWARD

ZUSAMMENFASSUNG. Einleitung: Die Integration wird neben Synergie und Konvergenz als eine der dominierenden Ausrichtungen der gegenwärtigen Logistik angesehen. Der Zusammenschluss von Subjekten in Lieferketten ermöglicht eine weitgehende Integration von Aktivitäten und erlaubt es, den immer spezifischer werdenden Anforderungen der Kunden effektiv und wirtschaftlich vorteilhaft gerecht zu werden. In der Zeit der ausgewogenen und nachhaltigen Entwicklung wächst das Interesse für die Inanspruchnahme von Sekundärstoffen in Verbindung mit der Möglichkeit einer Konsolidierung der logistischen Aktivitäten. Angesichts der Analyse der betreffenden wissenschaftlichen Literatur (Integrationsmodelle) und der Wahrnehmung von Beispielen aus der Wirtschaftspraxis stellen die Lieferketten vom Typ forward und backward (in zwei Richtungen) einen sich sehr intensiv entwickelnden Bereich der Logistik dar.
Methoden: Die vorliegende Arbeit beinhaltet ein autoreneigenes Modell sowie eine autoreneigene Methodik für die Modellierung der Integration der Lieferkette, in der der Materialfluss vom Typ forward (vorwärts) und backward (in zwei Richtungen) vorkommt. Das empirische Material erzielte man in Folge der Modellierung und Simulation von Prozessen im Medium iGrafx Process 2013 for Six Sigma, wobei bei der Planung von Experimenten auch das Minitab 17-Paket in Anspruch genommen wurde. Im Rahmen der Arbeit griff man nach der Methode der Verifizierung statistischer Hypothesen. Eingans wurde eine Überprüfung der Korrelation zwischen dem Niveau der Integration und dem globalen Niveau des Kundenservices innerhalb der Lieferkette mittels der Methode des Pearson-Koeffizienten durchgeführt. Man hat dabei auch einen Test für die Relevanz des Korrelationskoeffizienten unter Anwendung der T-Statistik vorgenommen. Demzufolge wurde eine Verifizierung der statistischen Hypothese in Anlehnung an den Test, der mit Hilfe der Z-Statistik überprüft wird, durchgeführt.
Ergebnisse: Die Ergebnisse des Autoren-Teams weisen eindeutig auf eine hohe Korrelation zwischen dem Niveau der Integration der Lieferkette und dem Niveau des Kundenservices (der Wert des Koeffizienten der Pearson-Korrelation und die Resultate des statistischen T-Testes) hin. Die detailierten statistischen Forschungen der Autoren projizieren die Tatsache, laut deren das Erheben der Integration von niedriegeren auf die höheren Niveaus von Integrationszuständen

einen Anstieg des Mittelwertes des Koeffizienten in bezug auf das Niveau des Kundenservices (Resultate der Z-Statistik) zur Folge hat. Der Analyse des Koeffizienten des Niveaus des Kundenservice ist also zu entnehmen, dass er mit dem Anstieg des Integrationsniveaus wächst.
Fazit: Gemäß den Integrationszielen sollen die Integrationssysteme mit einer größeren Handlungsfreiheit ausgestattet werden. Einer der postulierten Vorteile ("Effekte") der Integration der Lieferkette ist u.a. die Möglichkeit der Erzielung eines höheren Niveaus des Kundenservices. Die vom Autoren-Team gewonnenen Forschungsergebnisse bestätigen die betreffenden, quantitativen und nicht nur die beschreibenden Gegebenheiten und Zustände, was den wissenschaftlichen Anschauungen und praktischen Erkundungen entgegentritt. Die aus den Forschungsarbeiten resultierenden Ergebnisse motivieren die daran Interessierten zur Aufnahme von Integrationsaktivitäten innerhalb der Lieferketten vom Typ forward und backward.

Codewörter: Lieferketten vom Typ forward und backward, Modelle der Lieferkette, Methodik für die Integration der Lieferkette, Niveau des Kundenservices in der Lieferkette

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