RESEARCH IN LOGISTICS & PRODUCTION

ACCUMULATION OF THE KNOWLEDGE ABOUT DISRUPTIONS IN THE NETWORK SUPPLY CHAIN

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Abstract The proposed approach accumulation knowledge about disruptions which will allow modelling material flows and constructing the strategy of strengthening the resistance of a network supply chain was verified in a selected organization fulfilling the assumptions of the material decoupling point of a network supply chain. The IT system composed of a module for identification of disruptions in material flows and a simulation model is a proposal dedicated to organizations controlling material flows in a network supply chain in the conditions of disruptions.

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1. INTRODUCTION

The first stage of knowledge management is knowledge gathering and acquisition in the organization and in its environment (Probst, Raub & Romhardt, 2002). Information turns into knowledge when it is interpreted and related to a context by its holder. Knowledge management in supply chains refers to a wide spectrum of issues, including the manner of decision making in particular organizations, gaining and processing knowledge about customers, etc. Relatively little attention is devoted in the research to factors causing deviations from the planned material flows. Gathering and accumulation knowledge about disruptions is an essential task of the flagship enterprise whose part is to silence disruptions so that they will not transfer to the subsequent supply chains. The flagship enterprise controls material processes in supply chains, coordinates tasks performed by participants of the network and, having knowledge on disruptions in the entire supply chain, stands a chance to strengthen its resistance.

The paper presents the idea of accumulation and gathering knowledge in order to strengthen the resistance of a network supply chain.

The first part of the paper indicates approaches to building the resistance of a supply chain which have been presented for the past years in the literature. The second part indicated the author′s idea and the resulting methodology of accumulation and gathering knowledge within the range of disruptions in material flows, referring to contemporary solutions in this field. In the next stage variants of strenghtening resistance were suggested.

2. THE RESISTANCE OF A NETWORK SUPPLY CHAIN

The complexity of the relations in contemporary supply chains results from dynamic changes in the environment as well as variable recipients' needs. Because of the fact that contemporary supply chains are characterized with a complex structure on each stage of creating the value added, in this paper they will be defined as "network supply chains”. Creating network relations is especially justified in extremely innovative sectors and in those industries where products are diversified according to the recipients' needs (Brzóska, 2013), (Chan, Wang, Luong & Chan, 2009). Harryson, Dudkowski, Stern (2008) point out that not only the number of network relations but also the variability of their forms constitute the basis which provides the foundation for organizations to develop new ideas and skills using their key competences and resources.

When defining the role of each link in the network it is worth looking at the graph theory. Determining the centrality of the node according to the degrees of tops (numbers of relations built on the entry and the exit by a given organization) often also means the assessment of the popularity or influentiality of nodes.

The centrality according to the degrees of tops is useful for determining which nodes are the key ones from the point of view of spreading information or affecting the nodes situated in the immediate vicinity. Another indicator of the role of a node in a network is mediation. Mediation shows which nodes are the most important from the perspective of communication between nodes. Large mediation nodes are potential points of loss of cohesion of the network. Lin, Yang and Arga (2009) notice that the position of a node in the relational sense means authority essential for exerting efficient influence on other participants of the network. Taking into account the social networks theory in characterizing the network it can be noticed that the social status of the node reflects its authority in the form of one-sidedly directed emotional ties - respect, liking, recognition. Hagedoorn, Roijakkers, Van Kranenburg (2006) remark that the centrality and the popularity of nodes in a network creates a potential for exerting influence on other members of the network. The central link in the network, fulfilling the above-mentioned conditions, is defined in the paper as the flagship enterprise.

During the life of a flagship enterprise networks have features which predispose them to create new relationships (Kramarz M., 2012). Consequently, these nodes more often than others decide about adding new nodes to the network. The phenomenon of preferential addition of results when creating a network in which a small number of nodes has a very high degree of networkness. The remaining nodes of such a network have a considerably lower degree of networkness. Preferential adding usually results in the phenomenon of small worlds (cliques).

The resistance of a supply chain is understood as a property (an attribute) of the organization / system involving rules, procedures, methods and management techniques as well as strategies protecting the organization against the negative results of deviations occurring under the influence of disruptions. Christopher and Peck (2004) define the resistance of a supply chain as an ability of the supply chain to the return to the original state (flexibility) or transition to a new and more suitable state under the influence of the occurring changes (adaptability).

Therefore, the flagship enterprise, which is supposed to strengthen the resistance of a supply chain, can use three approaches: elimination of disruptions, compensation of disruptions, smoothing of deviations. The research presented in the paper focused on strengthening the resistance through the system reaching the state of the original system (compensation of disruptions).

Fig. 1 shows the relationship between the strategies of strengthening the resistance, mentioned in the literature, indicating that certain strategic activities help to obtain the aims of the superior strategy.

Modularity and designing the product from the logistic perspective is a way for realization of the postponed production strategy and one of possible strategies of product differentiation. Virtual production can help both the flexibility of the organization and its adaptability. Postponed production can be realized via complex network relations between the base enterprise and the subcontractors, and the organization manner can take into account virtual production. Moreover, the

flexibility can be shaped in different phases of the value chain, including on the supply, production or distribution level through network relations. Network relations and the redundance of resources are shown not only as tools for building the flexibility and the adaptability of the supply chain. The adaptability uses `the possibility of reconfiguration of networks constructed in each phase of the supply chain in order to achieve a new level of system equilibrium.

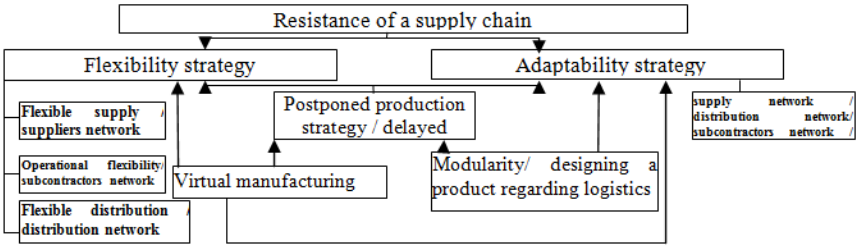

Fig. 1 The resistance strategy. Source: The authors' study

To sum up, the resistance in network supply chains requires describing the structure of a network supply chain, characterizing the enterprises which control the flows as well as defining risk factors and zones of strengthening disruptions.

3. THE CONCEPT OF GATHERING AND ACCUMULATION KNOWLEDGE FOR STRENGTHENING THE RESISTANCE

The main objective of the research was the construction of the model of strengthening the resistance of the network supply chain from the perspective of the flagship enterprise. This model presents the stage of accumulation and gathering knowledge and the stage of decision support of the flagship enterprise of a distribution network.

Problems indicated by managers, occurring as a result of including subcontractors into the structure of flows, and the analysis of IT tools in material flow management, induced to channel the research in such a way as to allow working out tools permitting identification and assessment of disruptions as well as an analysis of decision-making variants connected with compensation of disruptions, through considering two options depending on the frequency of the appearing disruptions (Machado et al, 2007), (Chopra et al, 2007):

- flexibility allowing compensation of disruptions via designed mechanisms (e.g. the flexibility of resources, the supplies surplus, the redundance of subcontractors, suppliers, logistic co-operators),
- adaptability involving a change of procedures or network structures.

In the research the author used secondary data accumulation for analysing a network supply chain of metallurgic products concerning formation of supplies as well as initial data in the area of the identification of disruptions and assessment of their influence on material flows.

Gathering and accumulation the initial data were conducted by means of the diary method (Dohn, Gumiński, Matusek & Zoleński, 2013), (Di Caprio & Santos-Arteaga, 2009). The measurement tool was a questionnaire called the "the disruption measurement card". The questionnaire contained both closed as open questions. The research conducted by means of disruption measurement card aim at:

- determining which disruptions are not caught by the IT systems supporting material flows in the investigated organizations,
- limitation of potential disrupting factors, selected on the basis of the literature research, to the ones essential for the investigated supply chain.

The process of the analysis of disruptions is a multi-staged one (Blackhurst, Craighead, Elkins & Handfield, 2005). At the first stage the authors suggested using the cause and effect analysis for identifying the relationship between disruptions and deviations. Thanks to this, this stage of research was conducted according to the following steps:

- identifying deviations in material flows,
- indicating the relationship: a deviation in material flows – a result of the disruption (organizational results, e.g.: difficulty in functioning of the process, lack of workers, equipments, lack of materials, lack of information, financial results, including costs connected with extraordinary transport, costs of lost sales),
- identifying the place where the disrupting factor occurs (the base enterprise, the supplier, the subcontractor, transport processes),
- identifying factors strengthening the disruption,
- assessment of the total of losses connected with the appearance of the deviation.

The classification of disruptions is based on the system approach which allows dividing disruptions according to the following phases: entry, inside the system, which involves processes of transformation and exit. The cause and effect analysis allows sorting out the investigated variables in the following sets: deviations in material flows, factors causing disruptions, chain links of the supply chain generating disruptions, factors strengthening disruptions. Thanks to such an approach it is possible to assess the power of their influence on deviations in the realized processes. The set of factors causing disruptions was categorised into endogenous factors connected with the characterization of the order, with the characterization of the base enterprise and with the characterization of the partner, and exogenous actors connected with the environment of the process of order completion.

In the disruption measurement card factors causing disruptions were left in the form of an open question, allowing workers who filled the questionnaire every day to name freely the event which caused deviations in material flows. It was a

conscious approach to the manner of measurement which aimed at catching all possible events, and not only those which were known to the author of the questionnaire while creating it. The mentioned disruptions were characterized descriptively in respect of the reasons of occurrence and the results, the subject responsible for the occurrence of a disruption, and they were assessed according to the power of the influence on the organization according to the organizational and financial criterion. The manner of rating the power of the influence of disruptive factors was provided in the table. Factors strengthening disruptions in material flows were also assessed every day. Respondents marked if a given event took place on that day and, if the they rated (in the event of a positive response) what power of influence it had a on disruptions in material flows.

The obtained results were compared with the knowledge on disruptions, identified through practical IT solutions (ERP class systems), which are used currently.

The integrated ERP system allows simulation of various activities and their analysis, and consequently better planning and management of processes in an enterprise. The ERP system is supplemented by the SCOR reference model. It combines perfectly the business knowledge with the knowledge on possibilities of the implemented IT systems.

All the processes inside the supply chain can be divided into three areas: processes situated above the enterprise, processes connected with the enterprise and processes situated below the enterprise. These areas create the following relationships (Szymanowski 2006), (Chopra & Meindl, 2004): Customer Relationship Management – CRM, Internal Supply Chain Management – ISCM, Supplier Relationship Management – SRM.

Internal Supply Chain Management (ISCM) involves the internal activity of an enterprise, beginning from task planning to completion of customers' orders, and is characterized with a strong integration with CRM and SRM systems.

Supplier Relationship Management (SRM) refers to cooperation between producers and their suppliers, their joint construction of strategic plans, negotiations, monitoring and assessment of the organization of supply processes.

Summing up, it can be stated that present IT technologies involve most of logistic areas, enabling decision support of an enterprise, inventory control, organization of transport routes and any types of tactical and operational logistic activities. The identified gap of the mentioned IT tools is their difficulty in identifying and analysing disruptions at the stage of creating network relations.

In connection with the above, the authors developed an IT tool compatible with the ERP system, aimed at recording disruptions and analysing deviations in material flows. It is a tool from the area of management information systems (MIS). The tool involves a module for gathering knowledge regarding disruptions in a network supply chain (Fig. 2).

The proposed procedure is universal and can be applied in different supply chains. However, the tool for gathering and accumulation knowledge requires adaptation to the specificity of a given industry through conducting research based

on disruptions measurement cards, selection of risk factors in respect of frequencies and results, and defining the zones of strengthening disruptions.

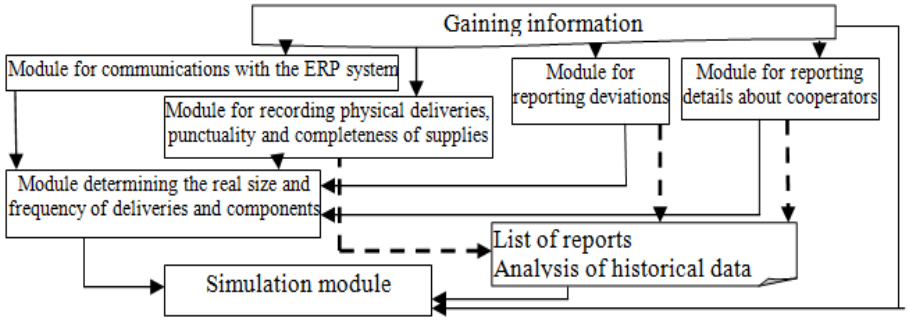

Fig. 2 Modules of the tool Planning supplies of components and controlling the level of material supplies. Source: The authors' study

The developed tool was enriched with a simulation model to support management decisions. The simulation model, in compliance with the adopted assumptions, was developed for all three variants of strengthening the resistance of a network supply chain in the technique of the management systems dynamics.

4. Variants of strengthening resistance

The stages of creating and analysing risk factors, the zones of amplification of disruptions as well as designing the IT tool and simulation models (Can & Chan, 2006), (Celik, Lee, Vasudevan & Son, 2010), (Harrison, Lin, Carroll & Carley, 2007), all indicated strategic variants strengthening the resistance to flagship enterprises of the network supply chain of metallurgic products.

The flagship enterprise which is a material decoupling point can strengthen the resistance of the supply chain using one of the options: supplies surplus, flexible resources, network cooperation.

The general model of amplification of the resistance of a network supply chain from the perspective of the material decoupling point consists of three models which provided the basis for simulation models. The assumptions which are common and differentiating the proposed models were shown in the table 1.

The proposed strategic variants should be investigated in respect of their sensitivity to fluctuations of demand. The conceptual simulation models allow determining the thresholds of the efficiency of each variant.

In the assessment of the efficiency of the accepted strategy by the material decoupling point, both the logistic customer service and logistic costs must be taken into account. The determined deviations in material flows correspond to

elements of the logistic customer service. Consequently, striving to reduce deviations in material flows, at the same time one strives to improve the level of the customer service. The costs consist of both the costs of transport, storage, non-utilization of production capacities and the costs of lost sale.

Table 1 The characterization of strategic variants of amplification of the resistance of a supply chain. Source: The authors' study

	The supplies model	**The flexible resources model**	**The cooperation model**
Common assumptions	Material decoupling point realizing the postponed production tasks differentiating the base product to orders placed by recipients of the automotive industry		
	The transport cycle between MPR and the recipients		
	The supplies of the finished (diversified) products		
	The supplies of the base product (supplies on the entry to the system)		
	The unit costs of supplies		
	The unit costs of transport		
Assessment criteria:	The logistic customer service and logistic costs (it was assumed that the logistic customer service could not be smaller than 0.90 and with such an assumption the authors searched for a solution with the lowest logistic costs)		
The characteristic assumptions for the model			
The characterization of demand	A multivariant product, differentiated on a large scale with a relatively stable demand for each variant	Differentiation of the product dependent from orders for particular variants of the product, large deviations from the forecast demand	Differentiation of the product dependent from orders for particular variants of the product or resulting from the specification presented in the project of the variant of the product, very strong deviations from the forecast demand
The prevailing model of the process	BTF Build to forecast	BTO Build to order	CTO/BTO Configure to order / Build to order
Attributes of resources	Dedicated resources in MPR	Flexible supply in MPR, dedicated substitutional supply at the subcontractor's	Flexible supply in MPR, several subcontractors having at their disposal dedicated substitution and complementary resources
Cooperation	Limited, only refers to substitution resources, irregular relations (loose relations between MPR and the subcontractor)	Limited , refers to the substitution supply, cooperative agreements (strong relations between MPR and the subcontractor)	Strong , refers to substitution and complementary resources, Diversified relations between MPR and the subcontractors

Each of the investigated strategic variants of amplification of the resistance has its consequences in the approach to material flow management. The material decoupling point, when choosing a model of flow management, should have data within concerning the frequency of disruptions, the influencing power of zones amplifying disruptions, the required level of individualisation of the product. The key stage of the making-decision process is to identify the value of the zone of amplification of disruptions in the area of the market. It is because this group includes factors characterizing the demand and the attributes of placed orders. It is fluctuations of demand, apart from the power of internal disruptions, that most strongly determine the efficiency of each variant of the strategy of amplification of the resistance of a network supply chain.

5. CONCLUSION

The network structure of the supply chain enlarges the flexibility through the redundance of production and logistic resources. Flexibility, however, increases the resistance of the entire supply chain on disruptions

In such structures it is extremely essential to gather knowledge on disruptions. The proposed methodology of measuring disruptions including identification of disruptions, indication of the risk factors and zones of amplification of disruptions aims at adjustment of the designed IT tool which allows knowledge gathering under the specificity of a given industry.

The modules designed in the tool, i.e. the modules for tracking disruptions and for tracking real material flows, compatible with the ERP system, allow undertaking activities to correct the size and the frequency of deliveries and the volume of buffer reserves according to the developed real-time strategies of amplification of the resistance.

The system also allows recording deviations in the past periods and making a list of historic data. These provides the basis for estimating the trends connected with disruptions and referring them to the cooperators' attributes.

The system takes into account the stochastic aspect of cooperation. Through historic analyses it is in a position to assess the variability of demand and deliveries on the part of cooperators as well as the sizes and the reasons of deviations and use this knowledge for material flow management.

Essential modules of the tool are simulation models which, using the data gathered in the system, permit developing and evaluating variants of amplification by the material decoupling point the resistance of the network supply chain.

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BIOGRAPHICAL NOTES

Włodzimierz Kramarz – the assistant professor in the Management and Administration Institute at the Department Organization and Management of the Silesian University of Technology. He is the author of publications from the field of supply chain, IT systems supporting logistic management, simulation modelling. He has practical experience in the management and realization of information technology projects. The realized projects in the industry refer to technical preparation of production and logistics. In the methodological aspect the author's main interest is simulation modelling and its utilization to decision support.