MODELS OF PRODUCT DIFFERENTIATION IN THE CONTEXT OF THE SUPPLY CHAIN RESISTANCE

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Abstract

Network supply chains include key chain links for building the resistance. These chain links (Material Decoupling Point - assembly to order and production to order, concern products differentiated according to orders placed by the customer) affect material flows of the whole supply chain through silencing disruptions. Logistic and production processes in this type of supply chains can be organized according to the model of early or delayed product differentiation. The issue of strengthening the resistance in the supply chain discussed in the study was aimed at the product differentiation strategy. The research analyzed both strategic variants: early and delayed differentiation. The study aims at presenting a research into strategies of strengthening the resistance in a network supply chain of metallurgic products. The research was carried out in the years 2011-2014.

Keywords: Material decoupling point, network supply chain, differentiation, resistance

1. INTRODUCTION

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 [10, 13]. Consequently, the first step in the research into the resistance of a supply chain is to identify disruptions and factors amplifying them. Deviations in the anticipated and real level of customer service is the most important measure showing the results of disruptions in material flows.

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. Moreover, the study discussed the problem of different distribution network configurations including two variants of central links: the flagship enterprise of a production network (early differentiation) and distribution network (delayed differentiation).

The first part of the study introduces several approaches to building the resistance of a supply chain and product differentiation which have been presented for the past years in the literature. The second part described the author's idea and the resulting methodology of the identification, the measurement and analysis of disruptions in material flows, in reference to contemporary solutions in this field. The elaborated methodology was applied in a network supply chain of metallurgic products. The obtained findings were used for developing standard strategies of amplification of the resistance. A strategy of the early differentiation and the delayed differentiation was being analyzed. At the next stage the authors carried out simulation experiments based on four models built in the management system dynamics technique (VensimDSS).

2. NETWORK SUPPLY CHAIN RESISTANCE IN THE CONTEXT OF EARLY AND DELAYED DIFFERENTIATION

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 [4, 7]. This model presents the stage of

strengthening the resistance of a network supply chain 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 [12, 13]:

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

The accepted decision range of the central chain link was shown in **Fig. 1**.

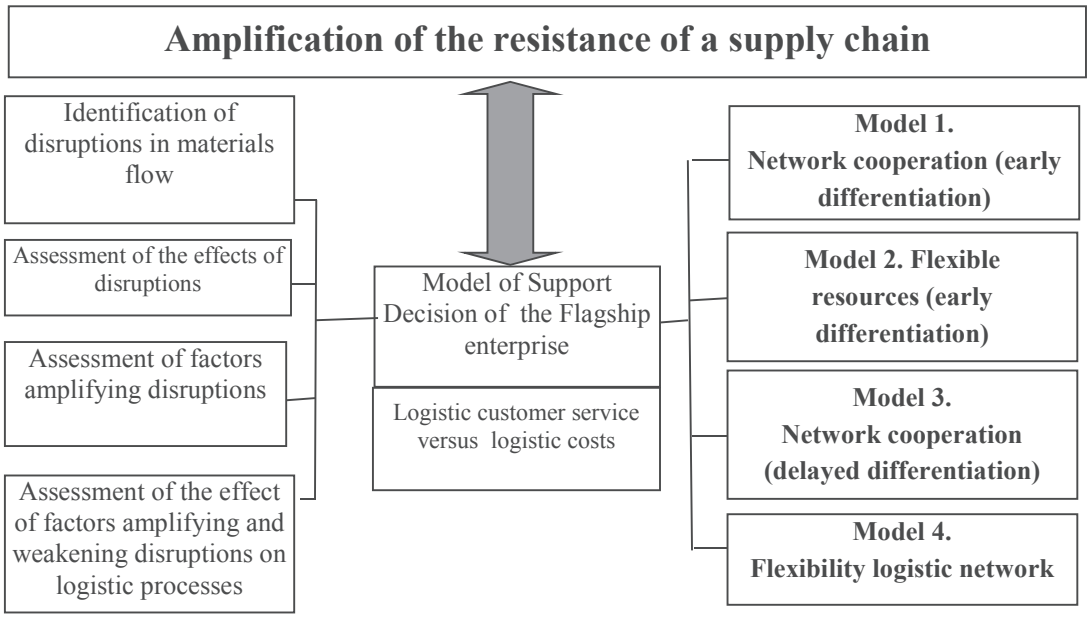

Fig. 1 Strategic decision support system of the flagship enterprise

Source: The authors' study

Summing up the findings of literature research [6, 9, 10, 13] concerning the supply chain resistance one can indicate four models which allow strengthening the resistance through compensation of disruptions at the level of the flagship enterprise, which are adequate to the problem of product differentiation.

Model 1: Network cooperation in distribution network (early differentiation)

Network relations built at the distribution enterprise level (delayed differentiation, mass customization).

Model 2. Flexible resources (early differentiation)

The surplus of production resources in the flagship enterprise and/or the surplus of supplies of the base product.

Model 3: Network cooperation in distribution network (delayed differentiation)

Network relations with subcontractors of postponed production tasks built at the distribution enterprise level (delayed differentiation).

Model 4. Flexibility logistic network (delayed differentiation)

The reduction of limitations at the level of realization of transport tasks through cooperation with the integrator of the transport network and realization of extraordinary transport of any size of loads commissioned for transport.

Models of strengthening the resistance, defined in this manner, are aimed at two variants of early product differentiation in a supply chain and delayed differentiation. In the literature "postponed production" (postponement of the last stage of production process until the order comes in) tends to be identified with "delayed differentiation" [3]. Such approach is presented by Aviv, Federgruen [2]. They define delayed differentiation as the strategy which allows reducing the risk connected with offering multivariant products through seeking the common base for products and designing products and distribution processes in such a manner that it will allow beginning the process of their differentiation possibly at the latest. In practice it is stressed that the strategy of delayed differentiation of products requires conducting production and distribution processes in several stages each of which is characterized with a specific cycle. The findings of the research into postponed production presented in the literature indicate that the advantages of delayed differentiation come down to the following factors: economy of scale, drawing from the pool of risk (put together in the research with a strategic bonus), the learning effect.

In the early studies into product differentiation researchers focused on the aspects of cost minimization or profit maximization for a single enterprise. Therefore, for example Anand and Mendelson [1] considered a model taking into account: the base product manufacturer, the distribution center and two different markets where final goods are directed, obtained through differentiation of the base product as a result of postponed production. The model analyzed two configurations of such a supply chain: earlier and delayed differentiation. Continuing these investigations, Anand and Girotra [1] consider delayed differentiation as the decisive variant in competitive scenarios. In the model worked out by Anand and Girotra, every enterprise also chooses between two different configurations of the supply chain: early and delayed differentiation, but compared to the earlier model, the decision model includes an additional factor affecting the choice of the strategic option - the competitor's decision regarding the configuration of the supply chain. Early differentiation is drawing profits from the reaction time to the customer's needs (the strategic pool which is subordinated only from the size of the market in which both enterprises compete), yet delayed differentiation draws profits from the risk pool. Anand and Girotra construct the basic model for two enterprises each of which manufactures two products. Each enterprise has one product and supplies it to the captive market (M) and one product is situated on the market where the analyzed enterprises compete with one another (C). The supply chain of every enterprise consists of the production area (P), the distribution center (CD), and two retail outlets, one per each market. The authors suggest two stages of the decision problem: in the first one (the production one) the enterprise decides about the quantity of production and transports it to the distribution center. At the second stage (the distribution one) the enterprise allocates these quantities for sale. At the distribution stage the enterprise observes the realization of needs. Therefore, the uncertainty is reduced at the second stage. Such a model is justified for products with relatively long logistic and production time (the cycle: supply - production - distribution) compared to the lead time accepted by the customer. In the fashion industry, together with the growth of the demand uncertainty, with large deviations of demand forecasts from the actual sale for individual products, the production and logistic reaction must be based on reducing supply cycles of both differentiated batches of products and forms of products (variants) aimed at individual markets. Hence it is essential to determine the level of the supply chain which is accountable for product differentiation. In order for enterprises to use early differentiation, products are differentiated on the production stage (the industrial enterprise plays the role of the materials decoupling point). Then the distribution center receives products specialized in final markets and customers. Therefore, the second stage, realized by the distribution center, involves only quantitative allocation of products according to the needs of individual markets. According to delayed differentiation, the basis of both products are indirect goods (simplified, modular construction of products). According to this concept, at the production stage the enterprise can decide about the general amount of indirect good (the base product), common for the good A and B. At the distribution stage (CD), according to

responses to particular orders coming from markets, every unit of indirect good is converted into product A or B.

These two variants were analyzed in this study. The discussed issues included the problem of reliability of realized orders at different demand fluctuations and additional disruptions in the system. While analyzing the problem of resistance of the supply chain the authors considered both the possibility of shaping network relations (Model 1), flexible resources and the surplus of supplies as well as the option of high flexibility of transport processes thanks to co-operation with the logistic network.

3. THE CONCEPT OF STRENGTHENING THE RESISTANCE OF A NETWORK SUPPLY CHAIN OF STEEL PRODUCTS

In the research the authors used secondary data gathered for analyzing 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 [8].

Gathering the initial data was conducted by means of the diary method. 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.

Disruption measurement cards were made available in three research objects which are different stages of the supply chain of metallurgic products. The cards were filled every day for 6 months by workers of different organizational units. The obtained data were converted in the STATISTICA software. The set of factors causing disruptions was categorized 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. Factors strengthening disruptions as well as risk factors were distinguished by means of the factor analysis. The elaboration of variants of strengthening the resistance was preceded by research into the influence of zones of strengthening disruptions on separated risk factors.

At the stage of identification of disruptions in material flows in a network supply chain the authors also distinguished key deviations (as a results of disruptions): unpunctual order realization, incomplete order realization, unrealized order, deviations from the determined stock levels, extraordinary transport. The correlation analysis showed that the increase in the frequency of disruptions generated by suppliers is accompanied by an increase in the frequency of unpunctual orders and extraordinary transports. However, the growth of factors from the wastage group (muda) is accompanied by an increases in the frequency of deviations from the determined stock levels. The growth of disruptions generated by the subcontractor causes an increase in the frequency of deviations from the determined stock levels. The canonical analysis, where deviations in material flows were the dependent variable and risk factors were the independent variable, confirmed the influence of the frequency of disruptions on deviations (the canonical correlation coefficient R^2= 0.74 at the relevance level p = 0.004).

The strategic variants (early and delayed differentiation) were examined in respect of their sensitivity to demand fluctuations. The proposed simulation models allow determining the thresholds of the efficiency of each variant. The assessment of the efficiency of the accepted flagship enterprise strategy took into account both logistic customer service and logistic costs. 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.

The sensitivity of models for strengthening the resistance of the supply chain was investigated in two variants: early differentiation and delayed differentiation. In the first strategic variant the material flow management is based on forecasts of demand for variants of the product. This is the basis for shaping the combination of supplies of the base product and finished products. The control system is programmed so as to make up supplies up to the alarm level and consequently to maximize the level of the logistic customer service through limitation of incomplete, unpunctual and unrealized deliveries. The supplies of the base product are created on the basis of a summary demand for variants of products and the norms of the reserve. This model corresponds to the model of production-to-stock, taking into account the postponed production for needs of the differentiation of the product. The level of alarm reserve in the base product stock and in the finished products stock (for each variant of the product) is variable in the control system. The variability of the level of the alarm reserve depends on changes in demand. Controlling involves tracking this variability and compensating the shortage of supplies in each stock. The system performs well in the conditions of a slight variability of demand and slight disruptions. Both the growth of fluctuations of demand and the growth of internal disruptions cause that the system to become not resistant and no configuration of supplies is in a position to ensure the required level of the logistic customer service.

In the second variant of amplification of the resistance (through flexible resources), the process of the flow management involves maintaining comparatively high production powers on the level of the materials decoupling point and supplementing them with dedicated power at the cooperator's. The material decoupling point has a flexible supply allowing differentiation of the base product according to the recipients' diversified needs. In the event of an increase in demand, part of operations connected with production of one variant of the product is directed to the subcontractor, and then the flexible supply realizes orders for the second variant. In this way the designed system is able to react to changes in both the summary demand and the demand for particular variants of the product as well as disruptions in material flows only slightly amplified by cooperation with the subcontractor. Disruptions in this model occur on a lower level than in model 3 because strictly limited numbers of subcontractors allow building strong and formalized relations, based on strictly designed procedures limiting the possibility of generating disruptions. Controlling involves tracking the demand for finished products, shaping the level of the reserve of base products based on summary forecasts, encompassing all variants of the product, and starting production in the material decoupling point and at the cooperator's depending on real demand for particular variants. It is a management model based on the pull system, in which an impulse for realization of the operation of differentiation of the product (delayed differentiation) are the recipients' real needs. Any excess of production power and the flexibility of the system cause a possibility of a quick reaction to the variability of the demand. The system shows a high resistance to the average disruption level.

In the third variant of amplification of the resistance (creating a surplus of network relations) the system is controlled by conducting (orchestration) the subcontracting of the operations of the postponed production and building relations in the network or through flexible resources and the surplus of supplies in the material decoupling point, which the central enterprise of the distribution network is. The production and logistic system designed in this way is both flexible and adaptive. The management process involves an estimation of the summary demand for variants of the product, adjusting on this basis the stock level of the base product, receiving orders for variants of the finished product and distributing them between the production powers and partners in the network. The considerable differentiation of a product affects assumptions concerning extensions of the entire time of the production and logistic cycle but simultaneously requires high standards as regards punctuality and plenaries of deliveries. Considerable fluctuations of demand entail establishing additional relations with cooperators. These relations increase production capacities of the entire system. The system is efficient to a certain level of the variability of demand in connection with the fact that building additional relations increases internal disruptions which after exceeding the threshold value reduce the

resistance of the entire system. Internal disruptions increase together with the growth of the number of cooperators. Due to the dynamic system of relations between the material decoupling point and subcontractors, relations are weaker, less formalized and more susceptible to the influence of endogenous factors.

The mentioned three variants of the configuration of a supply chain in compliance with the accepted strategy of the central enterprise of a distribution network were broadened by Variant 4. Search for an additional solution was undertaken in connection with the obtained results of simulation experiments. None of the proposed variants turned out to be effective enough for the determinants: product differentiation, strong demand fluctuations, the strong influence of zones of strengthening disruptions. Given the assumption of a high level of logistic customer service, Variant 3 generates too high logistic costs and Variants 1 and 2 do not allow obtaining a high level of logistic customer service in such conditions. Flexible transport networks are the proposed fourth variant.

This variant is realized similarly for early and delayed differentiation. Flexible transport networks in the proposed variant are organized in the form of a logistic cluster. The network of cooperation in the form of a cluster, understood as spatial concentration of enterprises, institutions and organizations mutually related by an extensive network of formal and informal relations, based on a common trajectory of development (e.g. technological, common target markets), simultaneously competing and cooperating in certain operational aspects, is a form of cooperation with a high degree of innovativeness, knowledge transfer and technology transfer [5, 10]. The initiative of creating a cluster in a given area arises most often on the regional level and a system of this type includes not only enterprises but also municipal organizations, city councils, colleges, science and research units. Organizations forming a cluster focus on operational objectives connected with fulfilment of orders using the resource base of organizations included into cooperation, and they set superior goals, including especially the economic development of a given region and attracting new investors. Such a concept of the form of organization of a transport network improves the flexibility of the entire supply chain and ensures a higher degree of adaptation to changes of the environment. This variant requires organizing measurement of disturbances and a new definition of key nodes managing material flows, in another manner than in the three previous variants. The different configuration of such a supply chain results from the competence of chain links coordinating the structure of a distribution network and the structure of a cluster

The developed simulation models for the network supply chain of metallurgic products allowed carrying out experiments within the sensitivity of each of the three proposed strategies of resistance to disruptions.

Each of the investigated strategic variants of amplification of the resistance has its consequences in the approach to material flow management. When selecting the management flow model, the central enterprise should have data concerning the type and the frequency of disruptions, the power of the influences of the zones strengthening the disruptions, the required level of product individualization.

4. CONCLUSIONS

The network structure of the supply chain enlarges the flexibility through the redundancy 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. Knowledge on disruptions in supply chains is gathered in central nodes which, while converting it, are searching for solutions to allow increasing the resistance of the supply chain. The analyzed variants of strengthening the resistance indicate not only a different configuration of the supply chain but also a different role and authorizations of the central links. The obtained findings became the basis for constructing an IT tool to support knowledge acquisition on disruptions in flows of materials.

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