THE WAYS OF CREATING RESILIENT SUPPLY CHAINS

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Abstract
This article deals with the different means of achieving resilience in supply chains. The concept of resilient supply chain was created as a reaction to problems arising from the application of lean principle into unstable conditions of today's business environment. The disruption of flows (material, informational and financial) is the main problem in supply chain, which is not prepared for arisen risks. Nowadays, the suggestions of resilience principles implementation are unsystematic and incomplete; which is why this article focuses on their detailed characteristics, analysis and consequent systematization.

Key words:
Supply chain, resilience, risk management

1. INTRODUCTION
At the beginning of the twenty-first century, the human society is witnessing a period sharp scientific, technological and economic development in many areas. The areas of management and logistics, which represent the focus of this article, are no exceptions. The development is closely related to the instability of the environment, which provokes a number of changes and risk situations. These changes and the risks appear more and more frequently and they have greater financial impact on the studied objects. At the same time, these areas show increasing commitment to integration. This trend arises from the fundamental principles of logistics which are based on the idea of optimizing the entire system as a whole. In the past, a company was considered to be the highest unit studied during optimization. At present, this view is insufficient, the definition of the system is wider, and it is now represented by supply chain.

These essential facts increase the importance of the topic that examines the risks in supply chains in the field of logistics. Dealing with this issue in a proactive manner is a desirable approach that reduces or eliminates the possibility of risk situations arising in a supply chain. It also quickly and efficiently solves the existing risks and minimizes their impact. This approach is called creating resilient supply chains, which is the theme of this article.

The basic definitions in the article are initially followed by characteristics of the individual options of building resilient supply chains. This characteristic is based on a literature search of the current scientific literature, combined with the practical knowledge of the authors. It is followed by a design of a uniform system of classification of approaches and tools used for building resilient supply chains, whose creation is the main objective of this article.

2. DEFINITIONS
The concept of resilient supply chain is divided into two basic sections in this chapter, and it is also analyzed in parts. The general understanding of supply chains is explained first, followed by characteristics of the term
of resilience, and, after that, the two parts are put together and defined as a whole. Apart from the general definition of resilient supply chains, the article also includes a view examining the optimal level of resilience in relation to costs that are always important for practical application.

2.1. Definition of Supply Chain

The concept of a “supply chain” has recently been defined by many authors, which led to several different viewpoints. One the crucial ones defines a supply chain as a group of activities which fall within a few different companies. The closest definition to the above presented understanding of resilient supply chain was presented by the European Committee for Standardization [1] “supply chain is a sequence of processes to add value to the product during its flow and processing of raw materials, through all the intermediate forms, to form in line with end customer requirements”.

Other respected definitions include, for example, a definition by R. Ganeshan and T. Harrison [2], who define supply chain as “a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of finished products to customers”. A much respected and well known definition is the one by M. Christopher [3] “the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer”. Similar definition is presented by P. K. Bagchi [4] saying that „a supply chain consists of a network of companies and carriers supplying raw materials and components and, later, they transform them into semi-finished products and final products designed to be consumed by the ultimate consumers”. The simplest and shortest definition is by D. Lambert, J. Stock and L. Ellram [5] „a supply chain is the alignment of firms that bring products or services to market”. There are many more definitions of a supply chain; however, despite a great number of various interpretations, they are all quite uniform in terms of their content.

The characteristics of each supply chain include: modified on the basis of [6]

- supply chain is a complete process in order to provide products and services to ultimate consumers,
- supply chain includes all logistic operations, from sourcing to distribution,
- the scope of activities includes production and distribution,
- supply chain management extends beyond the boundaries of individual organizations to plan and control processes in other organizations,
- supply chain allows the realization of individual goals of the organization,
- supply chain elements include suppliers, production equipment, warehouses, carriers, consumers and customers,
- the flows among these elements can be divided into information, material and financial.

2.2. Definition of resilience

Resilience is a noun commonly used in the language. According to the Oxford dictionary, it has two basic meanings: (1) ability of a substance or object to spring back into shape; elasticity, (2) capacity to recover quickly from difficulties; toughness. As an adjective, which also appears in books focused on supply chains, it is divided into two groups, according to whether it describes animate or inanimate object: (1) resilient substance or object - able to recoil or spring back into shape after bending, stretching, or being compressed, (2) resilient person or animal - able to withstand or recover quickly from difficult conditions. The basic definition of resilience, which is used in this article, comes from the area of science of ecosystems, where resilience is defined as “the ability of a system to return to its original state or move to a new, more desirable state after being disturbed.”

2.3. Definition of resilient supply chain

Many more definitions of resilient supply chains have already been created. The most respected author in this area is M. Christopher [7], who emphasize two basic cornerstones in his general definition, flexibility and
adaptability of the system. According to Fiksel’s [8] economic definition, resilience is “the capacity of an enterprise to survive, adapt, and grow in the face of turbulent change”. Sheffi and Rice [9] define resilience as “the ability to bounce back from a disruption”. The main idea of these definitions is to create such a supply chain that is not vulnerable to risks.

Building a resilient supply chain is not an easy or short-term goal. It is a strategic decision that requires a lot of effort and financial resources from all parties involved. A natural question then is: how resilient a supply chain should be? The optimal degree of resilience is, according to the authors of this article, closely associated with efficiency and cost. The logistic costs, according to C. Schulte, include [10]: (1) costs of the system and its management, (2) costs of maintaining inventory, (3) transportation costs, (4) handling costs.

Nowadays, however, the considerations must also include the fifth category of costs, which can be named “costs of risks.” This category partially penetrates into all four original categories and it can be divided into three basic groups: (1) losses that arise during disruptions in the supply chain caused by risk factors, (2) costs necessary to eliminate disruptions in the supply chain, (3) costs of proactive measures against disruptions in the supply chain. Graphical description of this set of logistic costs is shown in Figure 1.

![Figure 1 System of logistic costs. Source: own.](image)

If this system of logistics cost breakdown is adopted, an optimal level of resilience in the supply chain as such can be defined, where the total logistics costs in the supply chain in a long period of time are minimal. For monitoring and subsequent analysis of costs in the supply chain can be used many methods. For the high quality output is appropriate unification of methods across the supply chain. Example of a suitable method can be analysis based on ABC [11].

### 3. BUILDING A RESILIENT SUPPLY CHAIN

The term of resilient supply chain has already been defined, as well as the degree of resilience considered to be effective. Now, it is important to show the ways, approaches and tools leading to the construction of such a chain. According to M. Christopher and H. Peck [12], there are four basic principles how to create a resilient supply chain that are described in more details in their article. They are Supply Chain Reengineering, Supply Chain Collaboration, Agility and Supply Chain Risk Management Culture. Other important authors from this field are Y. Sheffi and J. Rice [9], who describe two ways how to achieve resilience; building in redundancy or building in flexibility. In a different book [13], Y. Sheffi et. al. recommend the following principles of building resilience: developing the ability to move production among plants, using concurrent processes of product development, designing products and processes for maximum postponement of as many operations and decisions as possible in the supply chain, aligning procurement strategy with supplier relationships. Iakovou, Vlachos, and Xanthopoulos [14] refer to the following ways of creating resilience: flexible sourcing, demand-based management, strategic safety stock, total SC visibility.
and process and knowledge back-up. Falasca et al. [15] focus on the methods associated with supply chain design and they examine the influence of supply chain density, supply chain complexity and supply chain node criticality on the degree of resilience. Tang [16] proposes the following SC design strategies to create a resilient supply chain: postponement, strategic stock, flexible supply base, make-and-buy trade-off, economic supply incentives, flexible transportation, revenue management, dynamic assortment planning and silent product rollover. H. Carvalho and V. C. Machado [17] describe SC characteristic features that can be modified to increase SC resilience: Chain configuration, Chain control structure, Information system, Organization structure. C. I. Enyinda and J. Szmerekovsky [18] stress the links between sharing information and using new technologies.

Aggregation of the above described options for achieving resilience in supply chains enabled us to create a set of approaches and tools. After closer examination and analysis, three basic categories were selected, in which the degree of resilience of supply chain can be intentionally increased by means of managerial decisions. These categories include: Design of Supply Chain, Design of Processes and Design of Relationships. A set of sub-areas that can be addressed was also designed in each category (see Figure 2).

**Figure 2** Building the Resilient Supply Chain. Source: own.

### 3.1. Design of Supply Chain

Basic description of the individual approaches and tools used to achieve resilience in the area of Design of Supply Chain. *Match between design and requirements* – Supply chain is in compliance with demand. In ideal case, it copies its main characteristics, for example: capacity requirements, delivery terms, variability, and seasonality. *Multiple sourcing* – More suppliers of the same material and service increases direct purchasing cost, but decreases the risk of production disruptions. Losses caused by production disruptions may be many times higher than costs of multi-sourcing. That is why it is desirable to subject this issue to analyses, which will determine an optimal procurement system in a supply chain. *Length of supply chain* – Supply chains with less serially linked partners and shorter distances have major advantage in lower cost of transportation and shorter delivery times. At the same time, they are more flexible and have shorter delays and lower losses. *Shape of supply chain* – There are many variables that need to be analysed in this sphere. The basic characteristic is represented by the number of partners within the chain, their geographic density, the complexity of mutual links or importance of the individual partners. *Agility* – A supply chain that is capable of reacting quickly and precisely to market changes or to changes and disruptions will, naturally, be more resident in its structure than a chain that is not capable of adjusting.
3.2. Design of Processes

The basic description of the individual approaches and tools used to achieve resilience in the sphere of Design of Processes. Redundancy of stocks – Higher buffer stock may, to a certain degree, provide protection against possible disruptions of the supply chain. However, this measure is often expensive and can cause other risks, such as: damage or obsolescence of inventory. Spare capacity – Processes within the supply chain have these unused capacities in order to be efficient and flexible at the same time. Process convergence – Partners in the supply chain share technologies and methods in such a way to achieve smooth and efficient material flow. Decoupling point – The best policy is to move the decoupling point as far downstream as possible. This reduces the total amount of stock, makes the response time faster and reduces vulnerability. Velocity – A supply chain with fast material flow between the partners as well as in its internal processes doesn’t waste time. The resulting advantages are especially in shorter waiting time, higher flexibility and faster reaction to market requirements. Flexibility – Internal and external flexibility of processes of the individual partners in the supply chain is one of the fundamental characteristics that are necessary to build a resilient supply chain. To increase flexibility, companies can, for example: standardize the processes, use standardized materials and intermediate products, cut delivery times or use process simultaneity.

3.3. Design of Relationships

The basic description of the individual approaches and tools used to achieve resilience in the sphere of Design of Relationships. Collaboration – The whole concept of supply chain is built on the cooperation among the partners. If the partners want to increase their resilience and thus the resilience of the supply chain as a whole, they work together with a common goal and common efforts. Data and information sharing – There is a free distribution of information related to potential risks in the supply chains. The ideal situation is to share the information databases and to unify the used information technologies. Trusted networks – There is a certain degree of trust within the supply chain in the fact that none of the partners conceals their problems and, vice versa, they actively work on their risk management thus eliminating the risks of the entire chain. Forecast and planning – Supply chain creates forecasts of the development and plans as a whole. They are available to all partners who implement them into their internal plans.

4. CONCLUSION AND FURTHER RESEARCH

Creating resilient supply chains in practice can cause many problems and difficult decisions. If you want to get them under control, the applications of quality management decision-making and logistic approaches are the key factors. It is not necessary to create supply chains that will be absolutely resilient. Supply chains that are optimally built, set up, and managed should have the desired ratio of cost-effectiveness and resilience with regard to the conditions of the environment in which they are located. This article proposes a number of tools and approaches to be used in order to increase the degree of resilience in supply chains. The application of the individual proposed options in a specific supply chain can be both complicated and beneficial. The authors of the article therefore recommend a detailed analysis on the basis of which a classification of possible complications, costs and benefits of selected options can be created. First of all, it is also advisable to put into practice the tools and approaches that are currently most cost effective, easiest to apply and that will bring the highest overall benefit.

Further research will focus on the development of a simulation model of a supply chain in the automotive industry, which will be used to test various tools and approaches in order to increase the degree of resilience. A simulation, as a suitable tool to analyze logistical problems, is described by D. Malindzak and M. Straka [19] or M. Kramarz and V. Kramarz [20]. The main benefit of simulation is finding the information necessary to create the proposed analysis.
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