Analysis of Theoretical Aspects of Supply Chain Resilience Determinants and Strategies

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Abstract. Today, you can find quite many various paper on the topic of supply chain resilience. Although the topic of supply chain resilience is fully covered, the rapid development of humanity creates new opportunities and obstacles for supply systems and thereby affects their sustainability, and therefore there is a need for its further research from the point of view of today. The emergence of new technologies, such as AI, increasing popularity of certain concepts, such as the concept of sustainability, can shake the current understanding of the concept of supply chain resilience and become challenges for the resilience of existing systems and enterprises. Such novelties lead to changes in company activities, national legislation, and trade relations. These externalities and related issues may have relevance over the next few years and possibly the next decade, so it is worth investigating them and countermeasures to ensure sustainability now to minimize future negative risks and their impact. The main objective of this paper is supply chain disruptions and resilience strategies. The paper seeks to provide a theoretical overview of the concept of supply chain resilience, identify all possible challenges for supply chain resilience, and uncover the main strategies intended at preventing disruptions in the supply chains.

Keywords: Supply chain · Supply chain resilience · Supply chain disruptions · Supply chain uncertainty

1 Introduction

Today, the concept of globalization is raging in the world. Elements of the same product are produced and assembled into finished products in different countries and transported to the final consumer anywhere in the world. The final products contain foreign and domestic resources added at various stages of production and delivered through international supply chains. Supply chains enable global production and international trade. However, the further the concept of the global economy develops, the more complex and multifaceted the chains become.

Looking at statistics on the global supply chain system and some chains of international companies, we can see a trend that production capacity is more concentrated in Asia, but innovation and new technologies tend to originate in Europe and North America. This means that in most cases other countries have a close relationship with the

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regions mentioned above. In addition, supply chain costs are one of the largest groups of elements in the total cost of the product. Supply chain logistics accounts for 5% to 50% of the total cost of a product. This category of costs may include costs for transportation, storage, packaging, and other services. The more complex the product, the more chains it needs, which accordingly increases the cost and complicates the implementation process.

Understanding the above, we conclude that the supply chain plays an important role in the world economy. Supply chain issues can cause production interruptions, temporary shortages of products or materials, an increase in the final price, a stop or slowdown in trade, social or environmental problems, and a slowdown in the pace of development of the world economy.

Disruptions in supply chains have a negative impact not only on the company but also on other stakeholders.

In the literature, there is a classification of uncertainties. There are two categories: low chance causing high impact and high chance causing low impact [6]. The second type occurs more often and can be a result of demand fluctuation, error in planning or minor issues during production or distribution processes, etc. The damage is small and can be resolved quickly. The first type (low chance but high impact) is quite a rare uncertainty, but when it appears, it results in negative output and requires a longer time to solve it and restore the company's activities to the previous or better level. The damage caused by such events is greater than from usual operational risks.

To deal with uncertainty, managers use different strategies and techniques of strategic risk management. Nevertheless, each uncertainty needs its own strategy to solve it, but traditional methods cannot deal with modern issues, so we need to find new solutions. Today in the literature and practice, the concept of supply chain resilience has become popular and appeared to be an effective tool to overcome challenges in the supply chain. This concept involves not only managing uncertainty but also improving the efficiency of supply chain networks and competitive advantage for companies.

2 Concept of Supply Chain Resilience

The first mentions of the concept of supply chain resilience can be found in the early 2000s. However, the concept of "resilience" was used earlier in other sciences, such as psychology, ecology, sociology, and others. The concept of resilience is of Latin origin and means "bounce back". In the Middle Ages it had a more negative meaning, in the Middle French (résiler) it meant "to retract" or "cellar" [1].

In social sciences, resilience refers to the ability of individuals, communities, or societies to cope with and recover from various challenges, such as natural disasters, economic crises, or social unrest. It includes the ability to mobilize necessary resources in optimal time, adapt, rebuild social systems for better effectiveness, and maintain social cohesion. Social resilience is more related to the resilience of society, rather than specific individuals or groups. This means the distinct values and traditions of societies: their customs, languages, religions, and spiritual heritage, ethnic distinctions, and much more.

Economic resilience includes the capability to lessen possible weaknesses, to encourage more robust and inclusive growth, to improve the macro-economy's ability to resist shocks, and to reallocate resources in order to take advantage of new growth possibilities.

The type, amount, and direction of these connections, as well as the degree of diversity in the scope and geography of its commerce and the scale of its external imbalances, all affect a country's ability to withstand economic shocks.

Scientists highlighted resilience of an organization in the management field. The ability of an organization to foresee potential dangers, to successfully deal with unfavorable occurrences, and to adapt to changing conditions should be understood as organizational resilience. S. Duchek argued that in the scientific literature organizational resilience is defined using 3 different approaches or a combination of 2 of them [3]. She mentioned such perspectives:

- defensive, from this point of view, resilience is the ability to resist adverse situations and/or the ability to recover after disturbances and return to a normal state;
- improving, focused on the need to adjust any changes to come out of the crisis stronger than before;
- anticipation (notion); resilience involves activities of identifying possible risks and taking prevention steps.

Supply chain resilience refers to the supply chain's ability to withstand disruptions and other issues and recover from them while maintaining its core functions and meeting customer needs. This involves the ability to anticipate, adapt, and effectively respond to various changes that may affect the flow of goods, services, and information in the supply chain.

The term "resilience" suggests that, despite the "outrage", the supply chain system keeps unchanged those properties and characteristics that make it a given system. The resilience of the supply chain system can also be understood as the ability of the system to maintain a dynamic balance with the environment, or as the ability of the system to compensate for the influence of external environmental factors.

We have collected several definitions of supply chain resilience, which scientists have given in their works, in Fig. 1. Placing the publications in chronological order, it is possible to trace how the scientists' opinions about the phenomenon changed. The range of years of the taken literature is 17 years (2005–2022). Examining the works of scientists, we observed that their opinion was influenced not only by the literature studied by them, but also by the specifics of their field of activity and their background.

In these definitions, it is possible to trace the changes in approaches that Stephanie Duchek noted in her works. Indeed, in the early definitions, the use of a defensive approach is observed, since 2013, we can observe that scientists began to think not only about restoring the system to the previous state, but also about the growth of indicators to the new desired state (improving perspective). Closer to 2020, the opinion shifts to anticipation approach and in definitions we can notice relation to risk management.

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Authors	Definition of Supply chain resilience	Decade
Estrada, 2005	SCR implies the ability of a system to return to its original or desired state after being disturbed.	2001-2010
Shaffi, 2005	In the corporate world, resilience refers to the ability of a company to bounce back from a large disruption—this includes, for instance, the speed with which it returns to normal performance levels (production, services, fill rate, etc.).	
Datta, Christopher and Allen, 2007	SCR is the ability of the production–distribution system to meet each customer demand for each product on time and to quantity.	
Datta, 2007	SCR is defined as not only the ability to maintain control over performance variability in the face of disturbance, but also a property of being adaptive and capable of sustained response to sudden and significant shifts in the environment in the form of uncertain demands	
Barroso et al., 2010	SCR is the supply chain's ability to react to the negative effects caused by disturbances that occur at a given moment in order to maintain the supply chain's objectives	
Li and Zhao, 2010	SCR is self-adaption and self-recovery abilities.	
Ponis and Koronis, 2012	SRC is the ability to proactively plan and design the Supply Chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage	2011-2020
Pettit et al., 2013	SCR is the ability to survive, adapt, and grow in the face of turbulent change	
Hohenstein et al, 2015	SCR is the supply chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state.	
Li et al., 2017	SCR refers to a supply chain's capability to cope with changes, which is formed through being prepared to endure future changes, being alert to changes and being agile in response to changes.	
Sangari and Dashtpeyma. 2019	SCR is the capability of being responsive to unplanned changes and disruptions.	
Dormady et al., 2019	SCR is able to endure the crisis and able to adjust flexibility to retrieve back to its sustainable state as soon as possible.	
Dixit et al., 2020	SCR is an adaptive potential of a SC to prepare and get ready for unpredictable future events and correspondingly retaliate quickly towards disruptions and recuperate back by sustaining continuity of SC processes at the desired level of excellence.	
Um and Han, 2021	SCR is the ability to tolerate supply chain risks in sourcing, manufacturing and delivery.	2021-
Grzybowska and Tubis, 2022	SRC is the capability to anticipate crises, identify risks, increase their impacts, adapt and respond quickly to threatening disruptions or vulnerabilities in the supply chain, and return to normal	

Fig. 1. Definition of supply chain resilience.

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3 Factors of Resilience

Before going to the factors of resilience, it is necessary to look closer to the resilience triangle (see Fig. 2). By looking at R-triangle, we can understand what resilience is and how it works. A visual concept of resilience is based on two criteria (time and performance) and illustrates the fluctuation of performance after disruption and the time needed to recover to the previous state. When a crash event occurs, you may see a dramatic drop in performance, and after that it takes time for SC to restore its profit or other performance indicators. The main aim of supply chain managers is to reduce the area of the R-triangle to minimum. The larger the area of this figure, the lower the resilience ability of the enterprise or system. Different resilience mechanisms can adjust the dimensions of the figure to the optimal and help maintain performance indicators.

In the literature, several approaches can be found to determine the factors (elements) of supply chain sustainability. First, we suggest considering the approach of division into elements in the work of Petit et al. [7]. They offer to look at such elements as vulnerabilities and capabilities; further authors develop concept of zone of resilience which occurs as a balance between those two factors. Both vulnerabilities and capabilities—attributes that provide a company with the ability to foresee and overcome disruptions—are important elements that make an enterprise sensitive to disruptions. The increase of one of them will lead to an increase of negative outcomes (see Fig. 3). Not having sufficient capabilities given the vulnerabilities a firm faces exposes the firm to risk, but investing in capabilities that are not needed can reduce profits. The company should find the optimal ratio between those two factors to obtain resilience.

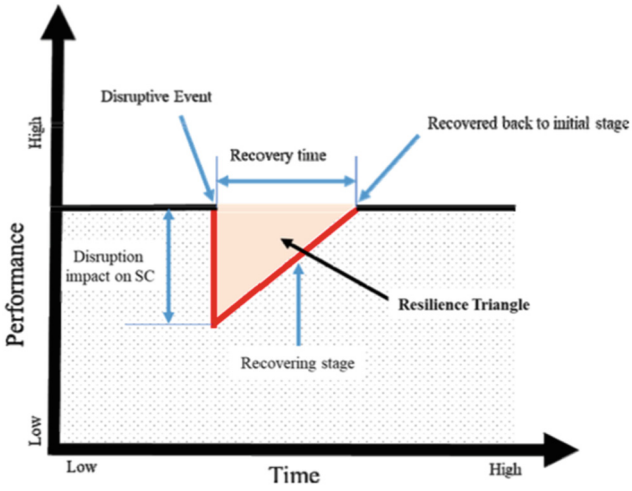

Fig. 2. Resilience triangle [4].

Petit et al. divide these two factors into 21 sub-factors, which in turn are divided into an even greater number of smaller sub-factors. We suggest that you familiarize yourself with the grouping in Fig. 4. The division into sub-factors was created to subjectively

measure factor. Later, in their next work in 2013, they developed a measurement tool and conducted an experiment that revealed critical linkages between factors and suggests a correlation between increased resilience and improved supply chain performance.

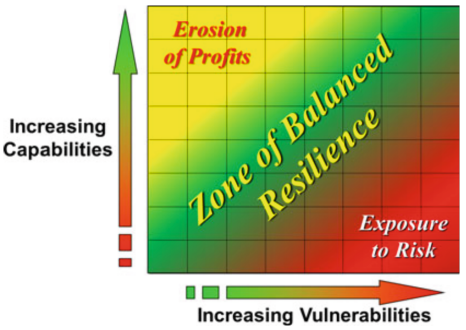

Fig. 3. Resilience fitness space [7].

Let us consider another approach to determining the factors of supply chain resilience. Juttner and Maklan offered their vision of factors which they called 'formative elements' [5]. According to the authors, formative factors are important from a supply chain management viewpoint because they explain how the preparation, reaction, and recovery of supply chain event can be ensured. They also mentioned that they used the capability approach to identify key elements. Due to their study, there are 4 formative elements of SCR: flexibility, velocity, visibility, and collaboration.

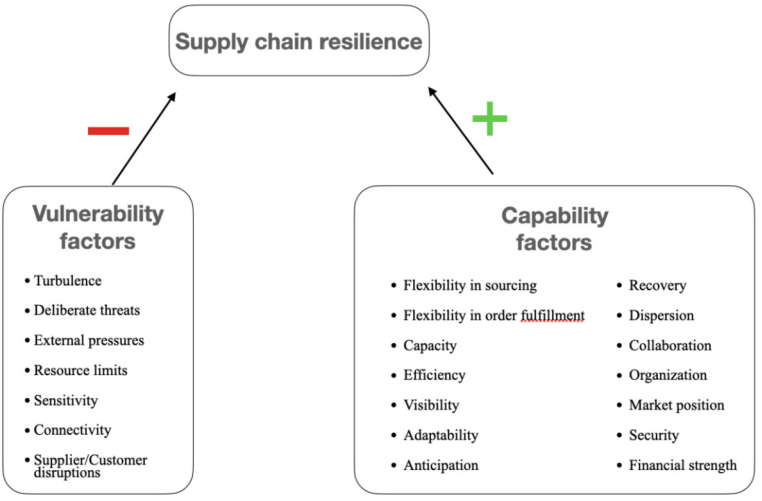

Fig. 4. Supply chain resilience factors [5].

Flexibility is defined as "being able to bend easily without breaking". Velocity is described as the "speed of motion, action, or operation, rapidity and swiftness" and is measured as a function of time and distance.

Visibility refers to the capability of "being perceived by the eye or mind". Collaboration means "working with another or others on a joint project".

4 Supply Chain Resilience Strategies

In the literature, we can find quite a wide range of supply chain resilience strategies. All of them are divided into proactive and reactive groups of strategies. Both types of product are developed to combat disruption. The difference between those two groups is the approaches and timing of the actions taken. Proactive strategies are applied before the disruption event occurs; usually they are used during the planning stage. In such strategies, optimum supply chain network structures are considered. Reactive strategies are applied when a collapse has happened. In such strategies, the optimum control policies are managed. Joshi and Huynh showed the previously mentioned division (see Fig. 5).

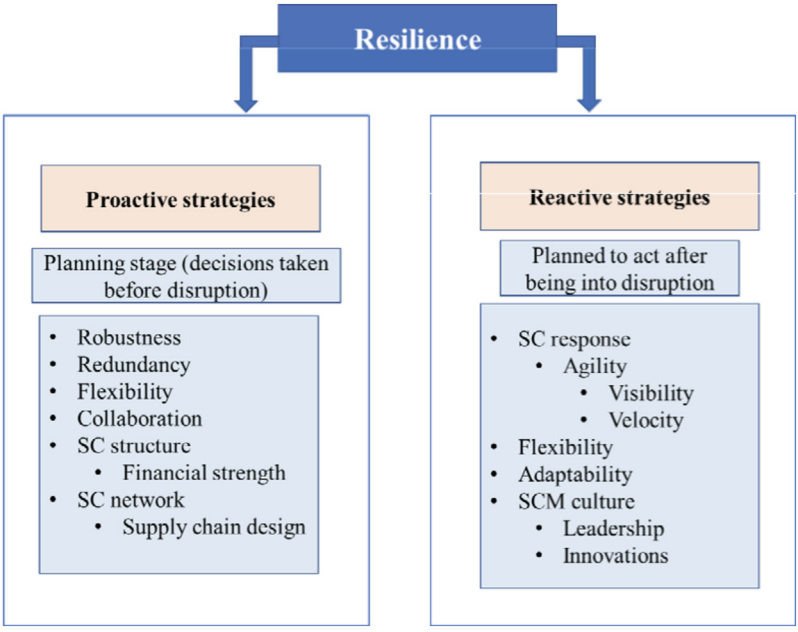

Fig. 5. Categories of supply chain resilience strategies [4].

Visibility refers to the capability of "being perceived by the eye or mind".

It is worth noting that the division is conditional, as some of the strategies can move from one category to another. Attribution of the strategy to a certain category in this case will depend on the purpose and time of its application.

However, both types of strategy are often used together. Scientists mentioned that there is an interrelation between some of the strategies and few of them support or/and reinforce each other.

Tukamuhabwa et al. made a table of 24 strategies [8]. They divided them into 2 categories mentioned above. In the work, Tukamuhabwa et al. highlights four key strategies: flexibility, redundancy, supply chain collaboration, and supply chain agility.

The flexibility strategy aimed to increase the ability to response effectively to changes caused by external and internal circumstances.

The redundancy strategy aims to ensure the usual activity of the company with the help of additional resources (inventories). Redundancy is the deliberate and selective use of inventory and spare capacity that can be used during a crisis to deal with, for example, supply shortages or demand spikes [2]. This strategy needs to be applied carefully, as extra capacity means extra expense.

The agility strategy aims to improve the reaction of the supply chain network to disruption. Supply chain agility, according to Christopher and Peck, is the capacity to react quickly to unexpected changes in demand or supply [2].

The collaboration strategy aims to use relationships with other stakeholders to combat disruption. Supply chain cooperation, according to Pettit et al., is the capacity to collaborate successfully with other organizations for mutual gain in areas like forecasting, postponement, and risk sharing. The collaboration strategy is an effective tool in complex structures supply chain networks [7].

5 Conclusions

Supply chain resilience can be described as a recovery process after the failure that is measured by performance and time indicators. The definition of resilience has developed through different spheres. Each sphere brought novelty to understanding and created the possibility to look at the term from other points of view. Moreover, we can see the positive impact of different spheres, such as the effect of risk management on supply chain management. Three core aspects of SCR (defense, recovery and improvement, anticipation) should be taken into consideration today when building or improving the supply chain network.

Today, there is no agreement between scientists on the list of factors (elements) that form resilience. Some authors said that resilience refers to the balance between capability and vulnerability of the company, others suggested that resilience consists of ‘formative elements’: flexibility, velocity, visibility, and collaboration. In the literature, 13 formative elements are mentioned by different scientists. From our point of view, the list of factors will change in further years as we are a new real knowledge and the development of civilization provokes us to develop our vision of various phenomena. Therefore, further research and discussions of this topic will be of relevance.

Supply chain resilience strategies are sets of ideas and actions that aim to improve the resilience of the supply chain network or company. Strategies are categorized into two groups: proactive and reactive. Although scientists pay more attention to reactive strategies, in practice managers use a combination of several different strategies. The ability of SCR strategies to enforce each other stimulates managers to use a mix of such measures.

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