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# Conceptual Model of Managing Resilience in Supply Chain

Matija Kovačić*, Maja Mutavdžija, Krešimir Buntak

**Abstract:** The supply chain is the basis for the functioning of today's society because it ensures the timely supply of all the resources needed to produce products or provide services offered in the market. Due to changes in the environments in which the supply chain exists, new risks arise that could jeopardize its functioning. Interruption in the normal functioning of the chain may result in the risk of inability to meet the requirements of stakeholders. Given this, the aim of this paper is to define a conceptual model of supply chain resilience management. The paper is based on the conducted secondary research and analysis of the achievements of other researchers in this field. The model described in this paper is based on the principles of the quality management system and provides a systematic approach to the analysis of supply chain threats, defining measures to reduce the threat, and testing and improving the established system.

**Keywords:** quality management; resilience; supply chain; supply chain risk management

## 1 INTRODUCTION

The supply chain is a set of stakeholders that enable the movement of raw materials, production, storage and delivery of products and services from the place of production to the place of consumption and disposal of used products in a harmless way for the environment. [1] In other words, a supply chain consists of several different organizations that are interconnected in a chain.

Despite the connectivity, each organization is a system unto itself and is different from other organizations. Changes in one organization may result in changes in other organizations. Changes can result in a crisis, i.e. a break in the normal functioning of the entire chain.

Each stakeholder in the supply chain functions within its own context. The stakeholder context in the chain is determined by the general environment, the industrial environment and the internal environment of the stakeholder [2]. The general environment of the stakeholder refers to economic trends, political environment, technological trends and social trends within the system in which the stakeholder exists. The industrial environment is determined by competition, customers and general trends within the industry of the organization. Finally, the internal environment is determined by organizational structure, culture, and resources. [3] Due to the different contexts in which each stakeholder exists, there are different risks that can jeopardize the business continuity of each stakeholder. An example of such a risk is the global crisis caused by the SARS CoV-2 virus pandemic that has led to reduced throughput in global supply chains. In addition to a pandemic, an economic crisis that can affect the economic system in which a stakeholder in the supply chain operates can also affect disruptions, wars and political instabilities can disrupt or affect a slowdown in the supply chain.

## 2 GENERAL SYSTEM THEORY AND SUPPLY CHAIN

General system theory can be used for the description of relations within the supply chain as it clarifies the interrelationship between system components. [4] In other words, the basic premise of general system theory emphasizes how each system consists of multiple subsystems and how each subsystem interacts with other subsystems. Changes in one of the subsystems may affect changes in other subsystems. If such settings are generalized to a supply chain that is a complex system by design, changes in one of the stakeholders involved in the chain may imply changes in other stakeholders [5].

On the other hand, following the general theory of the system, the performance of the entire system is determined by the performance of individual components within the system. The overall efficiency of the supply chain, i.e. the overall performance of the supply chain is determined by the partial performance of the stakeholders within the supply chain.

Since the stakeholders in the supply chain are in most cases interconnected in series, the total performance of the supply chain represents the product of the performance of each of the stakeholders involved in the chain.

One of the fundamental characteristics of serially connected elements relates to the creation of bottlenecks that can affect the slowing down of the flow of resources through the chain. Bottlenecks may be components in which the efficiency is known to be less than the efficiency of the other components. [6] In the end, they can result in increased costs, i.e. the risk of breaking the chain.

On the other hand, designing a supply chain using a parallel connection can also mean the risk of creating stocks or redundant activities. Such activities can also mean an increase in costs in the overall chain. However, in cases where stakeholders are involved in a parallel relationship and can deliver the same quality of service or service of the same quality (which is crucial to maintain the same level of quality of the final product), they can be included in a chain with half their capacity which will reduce costs and increase the reliability of the entire chain. This approach opens the possibility for organizations to direct part of their business to one supply chain, and the other part of their business to another part of the chain.

## 3 SUPPLY CHAIN RESISTANCE

Supply chain resilience can be defined as the ability of organizations involved in the supply chain to identify and respond promptly to a risk that may jeopardize the normal functioning of the chain or reduce its performance. [7] Several factors, which depends primarily on the needs of organizations in the chain, or the needs of customers and users for whom the supply chain was created can determine resistance of the supply chain. Due to the development of competitive advantage and the need to increase efficiency, i.e. reduce costs in the chain, organizations seek to implement various solutions in the supply chain that can make it vulnerable to risks. In other words, the elimination of certain activities such as controls, the development of mechanisms and procedures in the event of the risk of chain breakage, can result in the appearance of places in the chain that have reduced resistance. With the appearance of variability from the environment, there may be a risk that will affect the breaking of the chain or a decline in its performance, which will affect the functioning of organizations involved in the chain and society in general. In other words, the design of the supply chain according to the Lean principle brings with it advantages in terms of reducing costs and increasing the efficiency of the chain, but also increasing the risk associated with a decline in resilience.

If there is an interruption in the supply chain, the supply chain goes through several phases: the phase of initial impact, interruption of function, preparation for recovery, recovery and ultimately long-term consequences due to interruption in functioning. It should be emphasized that the downtime of the supply chain should be as short as possible as longer downtime can result in greater long-term consequences. [8] Two interruptions can be identified in the supply chain, sudden (Fig. 1) and gradual (Fig. 2). The fundamental difference relates to the time it takes for the supply chain to consolidate and continue to function, that is, the speed at which the flow or function of the chain is interrupted. Fig. 1 shows an example of a sudden break in chain functionality. The performance drops sharply after the appearance of variability in the chain and it starts to grow again with time and the measures are taken. The greater the time that the chain spent in the break, the greater the consequences, i.e. the costs that occur, and vice versa.

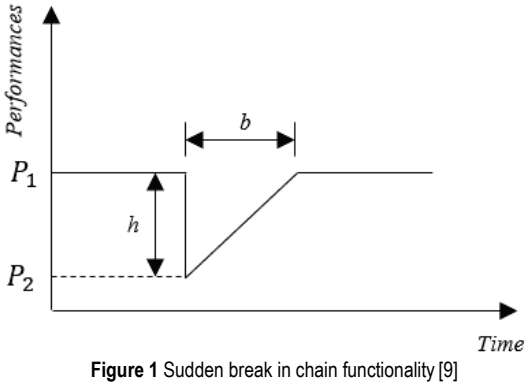


**Figure 1** Sudden break in chain functionality [9]

Fig. 2 shows a situation in which variability in the chain occurs gradually and in parallel with this, there is a gradual decline in performance in the chain. The reason for the gradual decline may be the developed partial resistance of the chain, i.e. the lack of indicators that would record the decline and prevent its continuation.

When it comes to the place in the supply chain that is exposed to special risks associated with the rupture of the chain, or interruption of its functionality, in practice, most of the problems were recorded on the part of the supplier. Resource suppliers are the foundation of the normal functioning of the chain as they provide all the necessary resources that are necessary for the manufacturer to carry out the production process. Interruption in the functioning of the supplier may result in an interruption in the functioning of the manufacturer who cannot deliver the required quantity of products or services to the customer or user. Therefore, the interruption of supply leads to a lack of capacity, i.e. a lack of capacity of the supplier who is affected by some risk results in a decrease in capacity in the entire supply chain

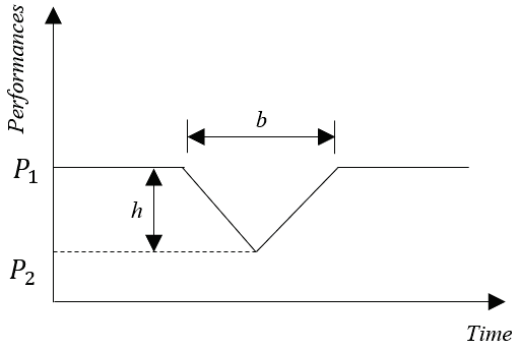


**Figure 2** Gradually break in chain functionality [9]

A study by Carvalh, Azevedo and Cruz-Machado on the example of Japan and the earthquake that hit Japan in 2014 identified how the earthquake largely affected resource suppliers, followed by a reduction in available energy, damage to infrastructure, and only end damage to the products themselves that are stored. [10] Thus, although all stakeholders in the chain are equally important for its functioning, without the existence of adequate suppliers it is not possible to ensure the normal functioning of other stakeholders involved in the chain.

### 3.1 Risks in the Supply Chain

Risks in the supply chain are determined by the context of the supply chain, i.e. the context of the organizations involved in the supply chain. Since the supply chain consists of several interconnected organizations, when analysing the risk, it is necessary to consider the communication of all stakeholders with each other in the chain to identify what is a common weakness, or common risk. [11] In addition to identifying common risks, it is necessary for each stakeholder in the chain to identify for himself, which risks he faces, i.e. which risks characteristic of him could affect the entire supply chain and its functionality. The risks that may

occur in the supply chain can be divided into infrastructure risks, political risks (which include risks of political instability, wars and related events), supply risks, demand risks. [8] It should be emphasized that these risks are just some of the risks that may arise in the supply chain and that the emergence of new risks is primarily determined by the requirements of stakeholders [12]. This is due to the requirements that stakeholders place on the supply chain, and failure to meet such requirements for the organization can mean the risk that may be associated with financial losses, loss of reputation, etc. The impact that risk may have on the organization or supply chain depends on resilience. The greater the resilience, the lower the effect that the risk can have. [13]

All identified risks should be treated, and the treatment of risk depends on the significance of the risk, i.e. on the possible negative impact that the risk may have on the supply chain or the individual organization involved in the supply chain.

All identified risks can be classified into three basic categories, depending on how they will be treated. Risks characteristic of the organization are classified as internal risks of the organization. Risks that are external risks to the organization represent internal risks to the supply chain while risks that are specific to the supply chain environment are classified as external risks to the entire supply chain as a system. Despite the different risk categories, all stakeholders in the supply chain should strive to reduce risk as a different approach may result in the risk being extended to other stakeholders in the chain. In other words, chain stakeholders should share their risk-related experiences and create mitigation plans with other stakeholders who have similar or the same risks.

### 3.2 Resilience Development Capabilities and Strategies

When it comes to supply chain capabilities in response to threats, there are five basic capabilities that a supply chain needs to have, or that needs to be developed in the supply chain to be resilient:

1) Preventive measures - include activities aimed at reducing the likelihood of risk. They are usually defined for activities that are high risk or are of importance to the functioning of the supply chain.
2) Resistance to consequences - means defining plans and measures that will enable the continuation of the supply chain without the risk of loss of controllability and function.
3) Response plan - means defining plans that will be activated after an event occurs that jeopardizes the functioning of the supply chain.
4) Recovery plan - refers to the actions that will be taken to recover the supply chain after a threat has occurred, i.e. after its performance has fallen due to an adverse event.
5) Continuous improvement - the supply chain and all organizations involved in the supply chain need to constantly improve their system to constantly develop new mechanisms to increase their resilience. [8]

It should be emphasized that resilience in the supply chain can be viewed through three basic levels, the operational level, the tactical level and the strategic level. The operational level emphasizes flexibility, agility and robustness. The tactical level refers to the development of redundancy and system integration while the strategic level refers to cooperation and risk management in the entire supply chain. [14]

## 4 AN OVERVIEW OF EXISTING RESISTANCE MANAGEMENT MODELS IN THE SUPPLY CHAIN

Research has identified that there are several proposals for resistance management models. Zavala-Alcívar, Verdecho and Alfaro-Saiz base their model on three blocks: the performance management block, the risk management block and, as the last block, they cite resilience itself. They describe how stakeholders and their requirements form the basis for defining the very goal that the supply chain seeks to meet. They talk about risks through the prism of internal and external risks and emphasize the importance of timely identification and development of mitigation plans. [8]

On the other hand, Aguila et.al. in his model describes the resilience index and views resilience through the economic aspect and emphasize that the resilience of the supply chain depends on the economic situation in the system. He also emphasizes that for resistance testing, it is necessary to conduct a simulation using the created model to identify how the supply chain will react if a threat occurs. [15] Vargas and González do not talk about the model of resistance management in the supply chain but describe the indicators that can be used to measure the existing level of resistance. They emphasize that the resilience of the supply chain can be seen through the resilience of the workforce, i.e. employees, the resilience of the business model and finally the resilience of the organization with all components within it. [16] Furthermore, Ouabouch describes only the characteristics that a resistant supply chain should have and emphasizes the redundancy of components as one of the characteristics, ie flexibility. [17]

Ivanov explains that all identified risks related to the supply chain should be adequately treated through risk mitigation measures. However, it does not specify the methodology by which the supply chain could be made resilient, nor does it describe how to manage the supply chain to ensure its resilience. [18]

Thus, it is evident that the authors in their research talk about the importance of developing supply chain resilience but do not define a clear methodology by which organizations could approach the analysis of the current situation and define measures by which the supply chain could be made more resilient. There is a visible need to develop a conceptual model that would enable organizations to design the supply chain based on the principles of resilience or evaluation of the existing level of resilience to increase it.

## 5 CONCEPTUAL MODEL OF RESISTANCE MANAGEMENT

The conceptual model of supply chain resistance management is shown in Fig. 3.

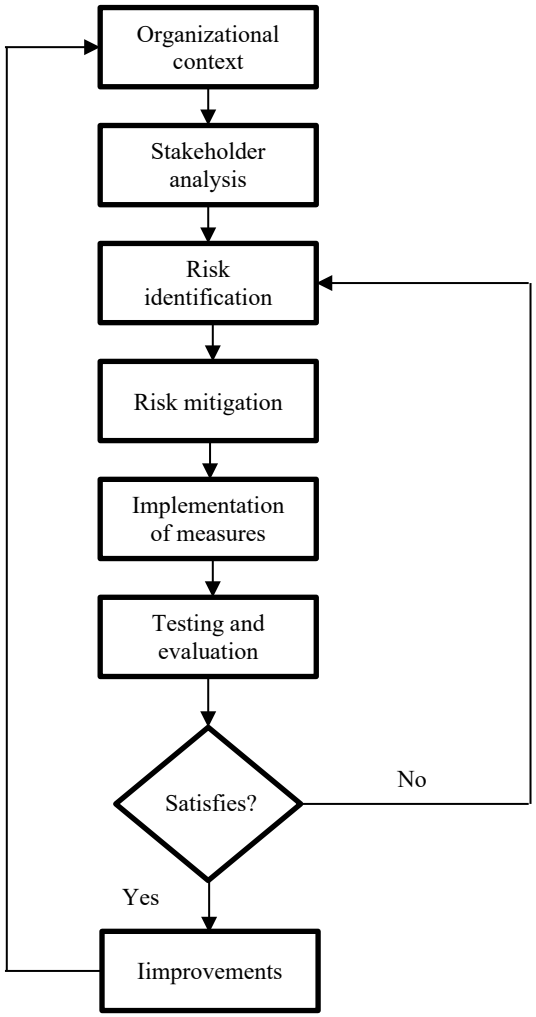


**Figure 3** Conceptual model of supply chain resistance

As shown in Fig. 3, the first step in supply chain resilience analysis or management is to determine the context of the supply chain. The supply chain context refers to the general environment in which the supply chain operates, the industrial environment, i.e. the internal environment of the chain itself. Thus, the supply chain should be viewed, i.e. a system consisting of several organizations. However, in addition to this approach, the supply chain can be viewed through the prism of the context of each organization for itself, after which each context of the organization is taken and viewed. In addition to determining the context of the supply chain, it is necessary to analyse the requirements of all stakeholders. Stakeholder requirements are of importance for the supply chain as the supply chain is formed precisely because of the requirements of the stakeholders. Likewise, a change in stakeholder requirements can also result in the emergence of risks, especially in the case of stakeholders with great power.

The next step is to identify the risk. The risks to be identified relate to risks within the supply chain itself, risks related to the general environment, i.e. risks related to the requirements of stakeholders and the possibility for the supply chain to meet such risks. Identifiable risks can be categorized into categories of economic risks, environmental risks and social risks. All identified risks should be analysed and evaluated to identify their impact on the supply chain, i.e. on individual organizations. It is important to note that risk analysis must look at all risks through a partnership approach and that all organizations involved in the supply chain should share their knowledge with others regarding risk analysis and mitigation.

For risks that turn out to be dangerous or critical risks that may jeopardize the functioning of the supply chain, it is necessary to define measures by which they will be reduced or eliminated. All defined measures must be clearly communicated in the supply chain and all organizations must be familiar with the defined measures. Likewise, all defined measures must be implemented in organizations that are affected by risk or may become affected by risk in the future. The implementation of defined measures must be systematic, which means that employee education, infrastructure renovation, implementation of techniques and technology that will be used to monitor risk must be carried out.

To identify the appropriateness of the measures, it is necessary to conduct tests of the appropriateness of the defined measures. Tests should include a simulation of an adverse event and the effectiveness of each organization in responding to the threat. If testing identifies that there is room for improvement, i.e. that the defined measures are not adequate or that not all risks have been identified, it is necessary to re-identify the risks to identify possible risks that were not noticed for the first time.

It should be emphasized that it is necessary to continuously improve the supply chain resilience management system given that the environment in which the supply chain exists is changing and that new risks may arise that will jeopardize the functioning of the chain. Improvements can also relate to the risk analysis process itself, ie determining the context of the supply chain, or to a particular partial part of resilience management.

When it comes to the tools and methods available, Tab. 1 shows some of the tools that can be used to manage supply chain resilience.

**Table 1** Tools for managing resistance of supply chain

| Phase | Tools |
|---|---|
| Organizational context | PEST(LE), VRIO, Porter's Five Forces, SWOT/TOWS, ETOP, Vulnerability Assessment, Four Angles Analysis, Resources Analysis |
| Stakeholder analysis | Stakeholder matrix Salience model, Stakeholder attitude and knowledge map, Influence and Interest stakeholder matrix. |
| Risk identification | FMEA, 2×2 risk matrix, Monte Carlo, bowtie, HAZOP, Cause Consequence analysis, Consequence/probability matrix, Event tree analysis |
| Risk mitigation | |
| Improvement | Pareto diagram, Ishikawa diagram, brainstorming, benchmarking, etc. |

Tab. 1 shows only some of the tools that can be used. In practice, there are many more, and their application depends on the needs of the organization.

## 6 DISCUSSION

The research identified that there are not enough models in the professional and scientific literature that would solve the problem of supply chain resilience. Likewise, it has been identified that the resistance of the supply chain is determined by various factors, primarily the risks that lie within the supply chain itself. In addition to the lack of adequate models, it was identified that the authors emphasize the importance of establishing security stocks that can represent a significant cost to the organization but are a necessary measure to reduce the impact of adverse events or chain disruptions on organizations. In addition to security stocks, the authors stress the importance of selecting multiple vendors of the same resource to disperse risk [19]. However, the selection of several different suppliers in the case of an exclusive supplier of a resource in each area is not possible, which is why there is a need to develop mechanisms to ensure the smooth supply of all resources needed in the supply chain.

A significant risk associated with the functioning of the supply chain is associated with global chains that extend across multiple countries or continents, given that each country has its own context, or each organization involved in the chain may face different risks. [20] It is especially important to note that in such cases organizations can increase their resilience, and thus the resilience of the entire supply chain through the implementation of a security management system consisting of risk management system, quality management system as a core process, business continuity management system, etc., i.e. the integration of the mentioned control systems can significantly increase the resilience. However, since all the mentioned management systems are exclusively intended for organizations and not for the supply chain, the lack of a management system was identified, and then the norms that would cover the area of resistance of the supply chain.

One of the fundamental challenges that organizations may face is a trade-off between efficiency and chain resilience as greater efficiency often requires the elimination or reduction in the number of mechanisms by which efforts are made to increase chain resilience. However, one of the solutions to this problem may be the development of indicators, i.e. the creation of a system based on technologies such as artificial intelligence that can monitor many indicators and signal in time the emergence of risks that may jeopardize the business. So, through the implementation of Industry 4.0 technologies. The supply chain can still be efficient enough but on the other hand, it can also be resilient enough. [21]

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## 7 CONCLUSION

In this paper, a supply chain resistance management model is described and proposed. The model is based on the principles of quality management, i.e. risk-based approach, evidence-based decision-making, relationship management. This is evident through the emphasis on the need for risk analysis, the involvement of all stakeholders in the supply chain in the adoption of risk reduction measures, and the final decision on the implementation based on analysis using tools and methods. Likewise, the proposed model is in line with the PDCA principle and emphasizes the importance of continuous improvement.

However, a fundamental limitation of this research, and thus of the model, is the insufficient number of professional

and scientific papers covering the area of supply chain resilience. Given this, there is a possibility of upgrading the model based on future research since the proposed model contains within itself the achievements described in other papers that have been improved and converted into a methodology.

The recommendation to future researchers is to upgrade the model by defining indicators that will be selected by the stakeholders in the chain, and which will be used to identify potential risks.

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**Authors' contacts:**

**Matija Kovačić**, dr. sc., mag. ing. traff.
University North,
Trg dr. Žarka Doinara 1, 48000 Koprivnica, Croatia
matkovacic@unin.hr

**Maja Mutavdžija**, dr. sc., mag. ing. traff.
University North,
Trg dr. Žarka Doinara 1, 48000 Koprivnica, Croatia
mamutavdzija@unin.hr

**Krešimir Buntak**, prof. dr. sc.
University North,
Trg dr. Žarka Doinara 1, 48000 Koprivnica, Croatia
krbuntak@unin.hr