

## UNCERTAINTY FACTORS IN SUPPLY CHAINS

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**Abstract:** Increasingly diversified consumer needs force market players into a competitive situation where the optimal design and operation of the entire supply chain becomes essential for survival and economic efficiency. This can only be achieved if the elements of the supply chain can respond to changing environmental conditions as quickly as possible. One of the biggest challenges to the optimal operation of supply chains, as a consequence of globalization, is uncertainty. In recent years, we have witnessed how a natural disaster or a pandemic can cause significant disruptions in the operation of supply chains, compelling companies to recognize the importance of stable supply chains. This article examines the impact of these uncertainty factors on the operation of supply chains and aims to explore the possibilities for identifying and managing risks.

**Keywords:** supply chain, logistics, supply chain uncertainty, operational disruptions, flexibility

### 1. INTRODUCTION

These days, in the context of growing global competition, one of the most important tasks of companies is to meet diversifying consumer demands, an important condition for which is the ability to ensure the flawless operation of the supply chain in order to maintain a competitive position. In order to satisfy the demand for low costs, high quality and agility, companies are expanding their reach beyond their national borders with the aim of minimizing the risk factors affecting the supply chain.

Companies must constantly adapt to the changing market environment, which is influenced by both technological development and economic changes. In a globalised economic system, even a single disruption in the supply chain is capable of causing significant problems. Digitalization and automation offer companies the opportunity to respond to such challenges faster and more efficiently, however, these new technologies also present new risk factors. The growing vulnerability of increasingly complex supply chains requires companies to develop new strategies to ensure flexibility and sustainability [1, 2].

Large multinational companies are increasingly striving to ensure both rapid responsiveness and global integration, creating complex, differentiated supply chains, and thereby increasing the likelihood of disruption. The complex and dynamic interactions among supply chain actors lead to significant risks that can adversely affect the operation of the supply chain. Such risks can significantly reduce operating performance and profitability in the long term. It follows from the above that factors related to uncertainty and disruption are becoming increasingly important aspects in corporate operations.

Companies are placing increasing emphasis on strengthening local and regional supply chains as these offer opportunities to reduce the impact of risks and market uncertainties. The diversification of supply sources has become crucial for companies, enabling them to respond

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flexibly to global economic and logistical challenges. Swift adaptability and agility have become essential factors in maintaining competitive advantage, as changes in market demand and supply chain disruptions require rapid intervention.

Managing uncertainties and supply disruptions is not just a matter of competitiveness, but also a key factor in ensuring long-term business stability and sustainability. Companies that are capable of managing risks and developing effective strategies to protect their supply chain can gain a significant advantage in the market [3, 4]. This article seeks to provide a detailed insight into the main uncertainty factors affecting the operation of supply chains and the strategies that can help minimise risks.

## 2. UNCERTAINTY FACTORS IN SUPPLY CHAINS

The number of research studies on supply chain resilience has increased significantly over the past two decades, as demonstrated by papers published in the field. Supply chain resilience can be defined as the ability of a system or chain to respond to unexpected and unpredictable changes arising from an uncertain environment in order to meet different customer needs, while maintaining customer satisfaction without significant additional costs. Such changes may include wars, epidemics, natural disasters, and strikes, which today are referred to as "disruptions."

When studying the literature on resilience, we can conclude that research in the 1990s focused on examining the resilience of manufacturing systems and set the objective of developing a system for measuring resilience. The decade saw many researchers develop various models and frameworks designed to increase the adaptability and efficiency of manufacturing processes, taking into account changes in market demands. In the course of such research, the different dimensions of resilience were also analyzed in detail, which contributed to the optimization of production systems and the improvement of competitiveness [5, 6].

After the turn of the millennium, the increasing market competition forced companies to shift their focus from internal corporate operations to improving the efficiency of the supply chain. During this period, research on flexibility focused on developing flexibility metrics and defining the relationships between various flexibility dimensions, as well as extending them to the supply chain [7, 8]. The objective of the researchers was to determine the relationship between factors influencing supply chain resilience and resilience dimensions.

The analysis of the literature suggests that many authors have examined the relationships between resilience dimensions and corporate performance, however, relatively few of them have addressed the strategies aimed at achieving the appropriate level of resilience in the supply chain [9, 10].

The functioning of supply chains depends on a number of external and internal factors affecting efficiency and stability in a constantly changing environment. Globalisation and technological development are making supply processes increasingly complex, while also increasing the risk of uncertainties. A well-functioning supply chain is not only crucial in terms of cost efficiency and speed, but also determines the competitiveness and long-term survival of companies.

Uncertainty regarding supply chains is driven by the growing degree of globalisation, the increasing complexity of products, outsourcing, e-business, the shortening of product and technology life cycles, and the increasing and changing expectations of clients. Future

changes in customer demand, the reliability of suppliers in fulfilling their commitments, and the quality of the materials supplied may also create uncertainty [11].

The sources of uncertainty in supply chains are explored in the literature by means of various models. The first model is attributed to Davis, who identified three sources of uncertainty: demand, manufacturing process and supply uncertainty [12]. According to his model, demand and supply uncertainty have an effect on the uncertainty of the manufacturing process, which ultimately affects the timely fulfilment of orders.

- **Supply uncertainty:** This is related to the uncertainty concerning the supply of materials. Supply uncertainty can manifest itself in the form of uncertainty related to materials, which primarily depends on the reliability of the suppliers and the availability of raw materials. A natural disaster or a transportation disruption may cause serious problems in the supply of raw materials. If supply is uncertain, greater flexibility is required to deliver a higher level of customer service.
- **Process uncertainty:** The uncertainty of the manufacturing process is related to the inherently probabilistic nature of machine availability, quality, and processing time, which may be influenced by labour, unstable availability, or IT issues. If a company lacks sufficient flexibility and alternative solutions, internal disruptions can easily slow down the entire supply chain, meaning that the more uncertain the internal processes are, the greater the amount of flexibility required.
- **Demand Uncertainty:** This refers to the inherently probabilistic nature of the quantity, type, timing, and location of the demand. Demand uncertainty may arise as the result of demand forecasting errors, changes concerning customer orders or uncertainties regarding the specifications of the products ordered by the clients. Manufacturing companies, especially those producing innovative products, have to face a shrinkage of product life cycles and escalating market competition, which generate demand uncertainty. The flexibility of the supply chain is inevitable to ensure that it can cope with the dynamic nature of demand.

The uncertainty model of Mason-Jones and Towill (Fig. 1) introduced another source of uncertainty in addition to the ones outlined in Davis's model – that is control uncertainty [13]. This refers to the capability of an organization to transform customer orders into a production plan and raw material requirements by means of information flow and decisions. Companies need to monitor and control the various processes within the supply chain to be able to identify emerging problems and potential risks [14]. Control allows companies to respond to changes quickly and minimise uncertainties.

Companies shall measure supply chain performance using various metrics such as delivery time, inventory levels and customer satisfaction. This helps identify weak points and enables the continuous improvement of processes.

Managing change is an important task, in the framework of which companies must be able to adjust supply chain operations in response to internal and external factors, such as demand fluctuations or supplier problems.

To reduce the uncertainty of supply chains, it is inevitable to use appropriate information systems that enable the monitoring of supply chain processes and support the real-time collection and analysis of data. Such information is essential for decision-making and effective management [15].

The model shown in Fig. 1 highlights the importance of proper information flow in the efficient operation of the supply chain, as well as the importance of information sharing

among supply chain actors. The improvement of transparency and the availability of real-time data help reduce uncertainties and improve response times. Peck developed the model further, and supplemented it with some external factors such as politics and natural disasters [16].

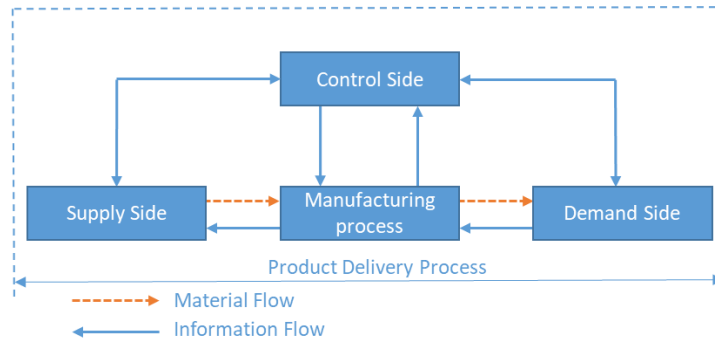


Figure 1. The supply chain uncertainty circle. Source [13]

Based on the above, we can conclude that the flexibility of the supply chain is made inevitable by the uncertainty of the environment and the possible disruptions that may arise. To ensure competitiveness, the supply chain must be capable of responding to the disruptions caused by such uncertainties. Recent crises, such as the COVID-19 pandemic, have shown how widespread and drastic the impact of such disruptions can be on all aspects of our lives, causing immense damage, including to the functioning of supply chains. The supply chain can only respond well to such disruptions, if it is prepared and possesses the appropriate flexibility and resilience.

The resilience of a supply chain lies in its preparedness for unexpected events and in its ability to respond quickly and specifically to such disruptions. The enhancement of supply chain resilience is an important task for all the members of the chain. To achieve this goal, companies must continuously assess the risks and proactively address potential problems. Technological innovations can help predict disruptions and respond more effectively. Additionally, closer cooperation and communication among supply chain members is essential for increasing flexibility and minimising disruptions, thereby ensuring the seamless operation of the chain in the future.

### 3. ENHANCING THE FLEXIBILITY OF SUPPLY CHAINS

Ensuring supply chain flexibility is costly, but for companies operating in uncertain environments, achieving the right level of flexibility pays off. When increasing supply chain flexibility, companies may set the following objectives (Fig. 2):

- Higher service level: Service level is a metric that measures a company's ability to meet customer needs. When both demand and supply are uncertain, a flexible supply chain is required to maintain high service levels [17].
- Resource utilization: Supply chain activities usually involve a variety of resources, such as those used for production, warehousing, material handling, transportation, and administrative activities. Resource utilization generally measures the extent to which available resource capacity is used to achieve production results. In an

uncertain operating environment, it is often difficult to achieve high levels of resource utilization. However, if the supply chain has sufficient flexibility, there is an opportunity to better utilize resources along the supply chain [18].

- **Responsiveness:** Responsiveness is a very important capability that companies are expected to have when engaging in business activities. In an uncertain environment, responsiveness can only be achieved if the supply chain maintains an appropriate level of flexibility. A flexible response to the changes concerning demand reflects the ability to respond to evolving customer needs and requirements [19]. Improved supply chain responsiveness can be achieved by reducing uncertainties and improving chain flexibility.

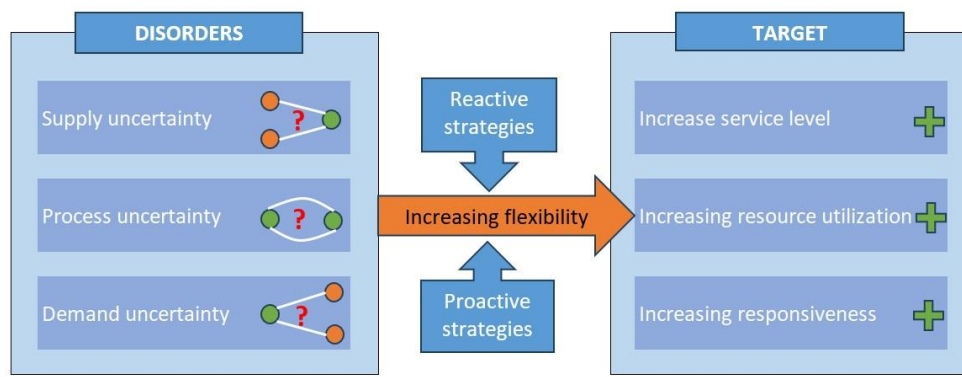


Figure 2. Increasing supply chain flexibility

Flexibility is a strategy for managing uncertainties threatening the supply chain. It can be reactive or proactive in nature [20]. The reactive nature of flexibility addresses the external and internal environmental uncertainties affecting the organization, while its proactive nature allows the organization to define market uncertainties.

In the case of reactive strategies, companies essentially do not seek to influence the level of uncertainty, but they rather react to it, striving to maintain the service level they provide to their clients or increasing their efficiency, for example by means of better capacity utilization. The following strategies fall into this group:

- **Safety stock:** The use of safety stock is one of the most common approaches to improving flexibility amid demand and supply uncertainty. The use of safety stocks enables a company to reduce the likelihood of inventory shortages to an acceptable level. A safety stock can be considered a reactive strategy, as it merely responds to the current level of uncertainty without taking proactive measures to reduce it.
- **Relying on multiple suppliers:** It is risky to work with a single supplier. Companies often rely on multiple suppliers, which guarantees availability but can increase costs.
- **Safety lead times:** To manage uncertainty, companies often add safety lead time to the actual cycle time. While safety lead time increases stock and costs, it enhances material availability, allowing companies to respond more flexibly to demand.

In the case of proactive strategies, companies try to increase supply chain flexibility by proactively redesigning products, processes, and the supply chain, as well as by holding proactive negotiations with trading partners on making relationships more effective.

The following strategies fall into this group:

- **Outsourcing:** Using external capacities through subcontracting and outsourcing is also a strategy that serves the flexible management of uncertainty. Outsourcing is a tactic that can be used to obtain purchasing flexibility as it can reduce the risks of capacity utilization and amortization, especially when demand is uncertain, irregular, low, and/or temporary.
- **Postponement:** The design or redesign of processes, both in terms of production and administrative processes, can significantly improve flexibility. Manufacturing or logistics postponement is a good example of process design improving supply chain flexibility.
- **Risk pooling:** When demand is highly uncertain and affects multiple sales regions, the supply chain often designs a network to pool risk. Centralizing stock to fewer facilities reduces risk and enhances flexibility in terms of distributing stocks to multiple destinations or sales regions.
- **Flexible supply contract:** Strategies to enhance supply chain flexibility include the proactive negotiation of supply contracts to alleviate minimum order quantities and the commitment of suppliers to provide the necessary raw materials in the event of a significant increase in demand. Flexible purchasing contracts allow for the provision of adequate levels of supply and provide stability.
- **Lead time reduction:** With shorter lead times, companies can better respond to demand uncertainty. The proactive reduction of lead time can be achieved by redesigning procurement processes, changing supplier selection criteria, or the development of suppliers to help them better manage lead time.

Enhancing supply chain flexibility is essential for the success and sustainability of companies. Proactive and reactive strategies play a key role in ensuring flexibility, allowing companies to deal with unexpected situations. Proactive strategies aim to anticipate potential disruptions, with companies conducting risk analyses to identify weak points. In addition, the diversification of the supplier network also contributes to reducing risks by minimising dependence on a single source. In contrast, reactive strategies require an immediate response to emerging problems, such as unexpected demand shifts or delivery delays.

Flexibility allows companies to quickly adapt to the dynamic market environment, thereby increasing operational efficiency. Technological innovations such as data analytics and real-time information sharing further enhance flexibility, enabling rapid and informed decision-making. In addition, maintaining flexibility helps companies sustain their competitive advantage by being able to respond to the constantly changing needs of the market.

The integrated application of proactive and reactive strategies enables more effective crisis management, focusing not only on managing risks but also on exploiting opportunities. Finally, flexibility enables companies to sustain their operations in the long term, adapting to challenges and ensuring their success in the future. Flexibility is therefore not just an advantage, but a fundamental requirement of the modern supply chain.

By applying the appropriate strategy, it is possible to enhance the flexibility of the supply chain and thereby ensure proper operation even in the event of disruptions in the economic environment.

#### 4. SUMMARY

Today, increasing global challenges are pushing companies to be agile and make informed decisions quickly despite an uncertain economic environment. Constantly changing market conditions, geopolitical tensions, and natural disasters can all have a significant impact on business operations. For companies to remain competitive, it is essential to ensure efficient and sustainable operations, one of the key elements of which is supply chain flexibility.

A flexible supply chain allows companies to quickly adapt to changing demand, minimise risks, and optimize resource utilization.

Increasing supply chain flexibility can be achieved by applying different strategies. This includes a multi-supplier model that reduces dependence on a single source, and the development of alternative logistics routes that ensure the continuous availability of goods. In addition, restructuring inventory strategies, such as increasing safety stocks or reviewing just-in-time systems, can also contribute to supply chain stability. Besides choosing the right strategy, digitalisation is essential, as it enables real-time data collection and analysis, ensuring fast and informed decision-making. The use of artificial intelligence and predictive analytics may offer additional benefits in supply chain optimisation by helping to predict and manage potential disruptions.

In the study, we described in detail the most common disruptions affecting supply chains, including raw material shortages, delivery delays, and other risks. In addition, we reviewed the strategies that can be applied to enhance the flexibility of supply chains, making companies more resilient to unexpected challenges. Effective supply chain management not only provides a competitive advantage, but also contributes to sustainable and long-term stable operations, which is crucial in today's dynamically changing business environment.

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