# A CONCEPTUAL FRAMEWORK FOR BUILDING CAR MANUFACTURER SUPPLY CHAIN RESILIENCE

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**Abstract**

Supply chain resilience is a general capability of a supply chain to return to its original performance after serious disruptions such as natural disasters, economic crises, political conflicts, or pandemic crises. The paper presents a conceptual framework for building supply chain resilience in the automotive industry. The framework is based on identifying specific capabilities leading to increased car manufacturer's supply chain resilience. The resilience capabilities were identified using a systematic literature review and verified based on in-depth semi-structured interviews with logistics experts in Škoda Auto company. The framework consists of two pillars (Efficient management and Supplier collaboration) that are laid on the foundation of Process digitization capability. Each pillar contains three additional resilience capabilities. The capabilities are described and justified on the example of Škoda Auto's best practices.

**Keywords:** Supply chain, resilience, capability, automotive industry, conceptual framework

## 1. INTRODUCTION

Today's supply chains face an increasing number of major and often hardly predictable disruptions. Examples include natural disasters (e.g. large-scale fires or floods), economic crises (e.g. energy or semiconductor crises), political conflicts (e.g. war in Ukraine or terrorist attacks in Israel) or pandemic crises (Covid 19). A managerial response to these disruptions is the concept of supply chain resilience that can be defined as "the capacity of an supply chain to survive, adapt, and grow in the face of turbulent change" [1] or "the ability to bounce back from a disruption" [2]. This research defines supply chain resilience as a general capability of a supply chain to return to its original performance after serious disruptions. Achieving this general capability requires building specific resilience capabilities. The aim of the paper is to find the key capabilities leading to increased car manufacturer's supply chain resilience and on this basis develop a conceptual framework for building supply chain resilience in the automotive industry. The capabilities were identified using a systematic literature review and verified based on in-depth semi-structured interviews with logistics experts in Škoda Auto company. The result of the synthesis of the findings is a conceptual framework based on seven key resilience capabilities represented in the form of a temple. The identified capabilities as well as the developed conceptual framework are discussed in detail in the paper.

## 2. METHODOLOGY

The fulfilment of the research aim was carried out in two phases. First, a systematic literature review was conducted to identify resilience capabilities potentially suitable for a conceptual framework for building resilience in a car manufacturer's supply chain. Second, the results thus obtained were verified through in-depth semi-structured interviews with logistics experts in Škoda Auto company.

The Scopus database of scientific articles was used for the systematic literature review. A combination of keywords focused on resilience capabilities/strategies/practices and supply chain/logistics were searched to find the most relevant scientific articles (articles, conference papers, book chapters, and reviews). In the first

phase, article titles, abstracts and keywords were searched. A total of 323 articles were identified, but a significant proportion of these dealt with resilience capabilities only marginally. For this reason, only article titles were searched in the second step. The following query string was used to get the initial database: (TITLE ("resilien* practice") OR TITLE ("resilien* capabilit*") OR TITLE ("resilien* strateg*")) AND (TITLE ("supply chain") OR TITLE ("logistic*")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE, "re")).

In this way, 49 articles were identified, and their content was analysed. The list of capabilities recommended for building supply chain resilience included 37 articles. The aim was to focus on articles that conducted primary research on the resilience capabilities in supply chains. Thus, 23 articles identifying these capabilities based only on a literature review were excluded from further examination (this group also included 10 optimization-oriented articles, which examines only a very limited set of resilience capabilities such as facilities fortification, backup suppliers or safety stock).

Another criterion for the selection of articles was the year of publication. An analysis of the articles showed a rather significant shift in the understanding of resilience capabilities after 2019, which was the beginning of new large-scale disruptions (the Covid 19 pandemic, the war in Ukraine, the semiconductor shortage or the energy crisis). Therefore, 5 articles published before 2019 were also excluded from the original set. The final set of articles for the detailed analysis of resilience capabilities thus contained 9 articles (see **Table 1**).

Resilience capabilities identified through a systematic literature review became the basis for in-depth semi-structured interviews with logistics experts at Škoda Auto. In the first phase, those capabilities that do not match the car manufacturer's supply chain were excluded. The automotive industry is a typical example of a supply chain with multiple suppliers ("Λ" type) [3]. For this reason, it is the supply side of the chain (inbound and internal logistics) and not the demand side (outbound logistics) that is key for car manufacturers. Thus, resilience capabilities such as flexibility in order fulfilment, flexibility in distribution and transportation, flexibility in customer base, dynamic revenue and demand management or promotional activity are on the verge of being of interest.

In the second phase, the remaining resilience capabilities have been discussed in several rounds, especially those with higher frequencies. Specific cases of their application were searched for and the impacts on the overall resilience of the company's supply chain were assessed.

## 3. RESULTS AND DISCUSSION

The systematic literature review resulted in the identification of 172 resilience capabilities. Some of them overlapped either completely or partially. Based on the synthesis, 34 unique capabilities were identified. **Table 1** summarizes their list and frequency. The identified resilience capabilities are ranked from highest frequency to lowest.

**Table 1** List of identified resilience capabilities

| **Resilience capability / Author(s)** | **Michel-Villarreal, (2023) [4]** | **Nagariya et al. (2023) [5]** | **Sun et al. (2023) [6]** | **Carissimi et al. (2023) [7]** | **Vann Yaroson et al. (2023) [8]** | **Silva and Ruel (2022) [9]** | **Furstenau et al. (2022) [10]** | **Malik et al. (2022) [11]** | **Vanany et al. (2021) [12]** | **Frequency** |
|---|---|---|---|---|---|---|---|---|---|---|
| Information sharing | x | x | x | | x | x | x | x | x | 8 |
| Flexibility in order fulfilment | x | x | x | x | | x | | x | x | 7 |
| Flexibility in product and production | x | x | | x | x | x | | x | x | 7 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Information digitalisation and visibility | x | x | | x | x | x | x | x | | 7 |
| Inventory management | x | | x | x | x | | x | x | x | 7 |
| Redundancy facilities and technologies | x | x | x | x | | x | x | x | | 7 |
| Awareness towards potential risks | x | x | x | | | x | x | x | | 6 |
| Collaboration and partnership | x | x | x | x | | x | | | x | 6 |
| Collaborative planning, forecasting and replenishment | | x | | x | | x | x | x | x | 6 |
| Flexibility in distribution and transportation | | x | x | x | | x | | x | x | 6 |
| Flexibility in sourcing | x | x | x | | x | | | | x | 5 |
| Multiple sourcing | x | | x | x | | | x | x | | 5 |
| Resource and risk sharing | x | x | | | x | x | x | | | 5 |
| Back-up suppliers | x | x | x | | | | x | | | 4 |
| Communication | x | | | | | x | | x | x | 4 |
| Learning from experience | | x | | | | x | x | x | | 4 |
| Process improvement | | x | | x | | x | | x | | 4 |
| Quick response | x | x | | | | | x | | x | 4 |
| Risk management team | | | x | | | x | x | | x | 4 |
| Strategic aliances | x | x | x | | | | x | | | 4 |
| Financial strength | x | | | | | x | | | x | 3 |
| Flexibility in workforce | x | | | x | | | | | x | 3 |
| Joint decision making | x | | | x | x | | | | | 3 |
| Process management and technological innovation | | x | | x | | | | x | | 3 |
| Business continuity planning | | x | | | | | | x | | 2 |
| Capabilities for integration | | x | | | | | | | x | 2 |
| Flexibility in customer base | x | | | | | x | | | | 2 |
| Supply chain re-design | x | x | | | | | | | | 2 |
| Training | | | | | | | | x | x | 2 |
| Adaptability of members | x | | | | | | | | | 1 |
| Coordination capabilities | | x | | | | | | | | 1 |
| Dynamic revenue and demand management | | x | | | | | | | | 1 |
| Personal security with a Covid-19 pandemic protocol | | | | | | | | | x | 1 |
| Promotional activity | | | | x | | | | | | 1 |

Based on in-depth semi-structured interviews with logistics experts in Škoda Auto company, seven capabilities were identified that play a crucial role in the resilience of a car manufacturer's supply chain: (1) Flexible management, (2) Crisis management, (3) Paradigm shift, (4) Enhanced communication, (5) Support and assistance, (6) Manufacturing relocation, and (7) Process digitalization.

Flexible management includes, in particular, increased flexibility in production programme planning and control and parts transport planning and control. An example of this resilience capability at Škoda Auto is the ability to move from a stable planning period of several months to a dynamic period of seven to 14 days in the event

of a major supply chain disruption. A second example is the ability to quickly and efficiently execute emergency parts transports. At the time of the Covid 19 pandemic, this enabled the company to cope with an enormous increase in critical parts whose inventory was unable to cover even one day of production (more than 100 parts in 2021) and fluctuations in demand in individual markets.

Crisis management involves, in particular, very close teamwork across the company, delegation of authority from higher to lower levels of management and the dynamic establishment of crisis teams with clear responsibilities. At the time of the pandemic crisis, Škoda Auto organised more than 100 crisis team meetings per month, involving more than 50 experts from the departments of logistics, production, purchasing, sales, quality, controlling and R&D. At the same time, a two-level structure of crisis teams was used. At the higher level was the "Task Force Teams, which met on a regular basis to address the most serious issues. Subordinate to these teams was the "Fast Reaction Force" with 24/7 availability designed to respond immediately to emerging issues.

The paradigm shift means moving away from previously successful long-term logistics principles and concepts that can significantly decrease the performance of the entire supply chain when disruptions occur. A typical example of such a concept in the automotive industry is JIT/JIS, the aim of which is to reduce lead times and maintain a minimum stock of products. Before the pandemic, but especially the semiconductor crisis (global chip shortage), car manufacturers immediately distributed finished cars to their customers, thus keeping their stocks at a minimum level. However, if the JIT/JIS concept is respected, the shortage of parts will cause the stoppage of production and large losses from unproduced cars that are hardly possible to make up in the future. Škoda Auto has therefore come up with a new concept of "Incomplete car production". This means producing cars to stock without shortage parts, which will be installed in the cars only when they are available. This concept is successful if the losses from unproduced production are significantly higher than the increase in the cost of car storage and additional assembly. However, the implementation of the “Incomplete car production” concept requires the search for technical and technological solutions that allow the additional assembly of the missing part. An example of such a solution is the production of a dummy of the missing part, its assembly in the car and subsequent replacement with the original part. At Skoda Auto, this solution has been successfully implemented, for example, in the case of a shortage of ESP/ABS control unit or automatic gearbox shifter. 3D printing is also used today for the rapid production of dummy parts.

Enhanced communication should be based on the following principles: (1) openness, (2) standardization, and (3) setting up an effective escalation process. In particular, respecting these principles allows for mutual awareness of changes in production plans, joint and timely problem solving, and sharing of best practices. During the pandemic crisis, Škoda Auto communicated with critical suppliers (suppliers that threaten the continuity of the car manufacturer's production) once a week and shared more than 80 best practices.

Support and assistance means process, technical and personnel support for critical suppliers as soon as possible after a supply chain disruption occurs. Personnel support is based on the deployment of in-house experts and staff, as well as external experts and agency staff, to help recover a supplier's disrupted processes. During the pandemic crisis, Skoda Auto supported 40 suppliers from seven European countries in this way. Its staff spent almost 1 300 man-days with the suppliers. Another example is the Slovenian supplier's shutdown due to flooding, when Škoda Auto, as well as other Volkswagen Group companies, sent teams of its maintenance staff to put flooded machinery and equipment back into operation.

Manufacturing relocation means working with a supplier to quickly relocate production (including necessary personnel, production technology or materials) to a manufacturing facility not affected by the disruption. An example of this resilience capability at Škoda Auto is the relocation of part of the production of cable harnesses by a Ukrainian supplier due to the war in Ukraine. It took only 5 weeks to relocate staff and equipment directly to the Škoda Auto production facility. Just as quickly, Škoda Auto and its supplier were able to relocate the production of parts from the Slovakian plant affected by the fire to another supplier's plant in Spain.

Process digitization enhances supply chain resilience through real-time availability, visualization and sharing of information, early warning systems, decision support during supply chain disruptions, and supply process recovery management. At Škoda Auto, the digitization of supplier processes is supported by business intelligence tools. An example is an application for tracking the logistics flows of parts and components from the dispatch centre located in the Czech Republic to the company's foreign plants (e.g. in India).

## 4. CONCLUSION

The research results were used to design a conceptual framework that will enable companies in the automotive and related industries to effectively manage their supply chains when disruptions occur that unpredictably and significantly threaten their standard performance. The conceptual framework was formed as a temple (see **Figure 1**).

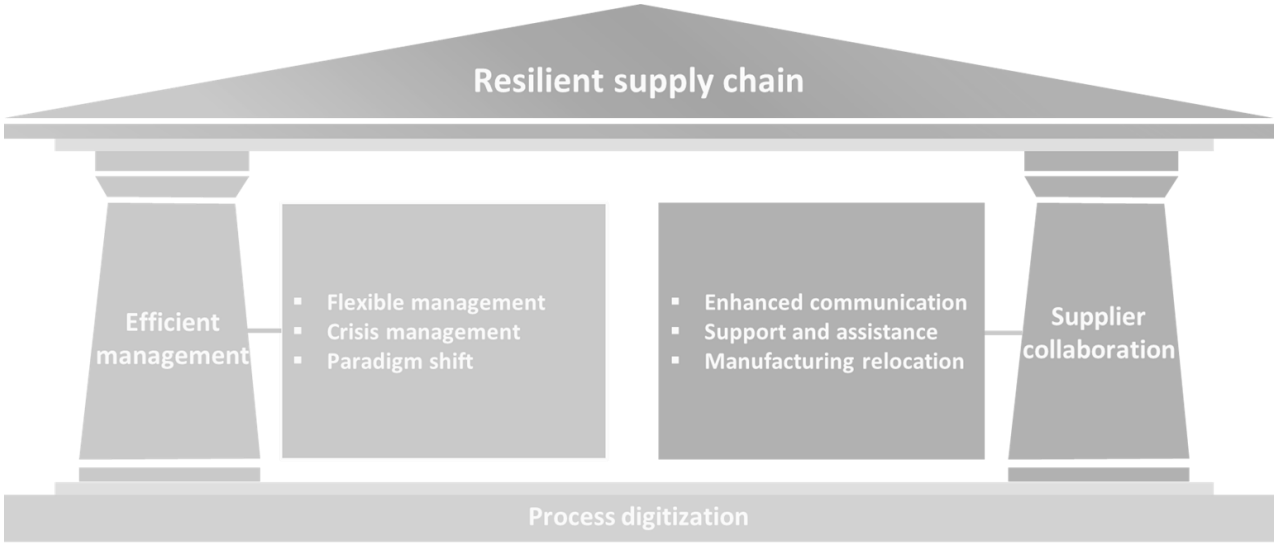


**Figure 1** Conceptual framework for building car manufacturer supply chain resilience

The temple roof represents the long-term goal of the conceptual framework, i.e. building a resilient supply chain. To achieve this goal, a manufacturer should use two pillars of resilience capabilities: (1) Efficient management and (2) Supplier collaboration. Efficient management includes three resilience capabilities: (1) Flexible management, (2) Crisis management, and (3) Paradigm shift. Supplier collaboration includes also three resilient capabilities: (1) Enhanced communication, (2) Support and assistance, and (3) Manufacturing relocation. The last resilience capability, Process digitization, forms the basis of the developed conceptual framework. This is due to the fact that a given capability helps to improve all other capabilities in a cross-cutting manner.

Further research will focus on creating a model for implementing the developed conceptual framework or building the identified key resilience capabilities in the form of a maturity model.

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