Resilience Measures in Global Production Networks: A Literature Review and Conceptual Framework




Martin Benfer, Bastian Verhaelen, Sina Peukert, Gisela Lanza

Summary: The resilience of globally interconnected production networks to changes in their environment and internal disruptions is an important research object in business and production science. While many different measures to improve resilience have been suggested in academic literature, effectively choosing measures to improve production networks remains challenging. This contribution analyzes measures to improve the resilience of production networks proposed in the existing body of literature. The most commonly suggested measures are discussed in detail. These measures are structured in a conceptual framework to enable increased clarity regarding the mechanics by which measures improve resilience and to choose specific measures for a production network.

Keywords: Resilience, Robustness, Global Production, Production Network, Supply Chain, Production Management

Resilienzsteigernde Massnahmen in Globalen Produktionsnetzwerken: Ein Literaturüberblick und konzeptioneller Gestaltungsrahmen

Zusammenfassung: Die Resilienz von global vernetzten Produktionsnetzwerken gegenüber Veränderungen in ihrer Umwelt und internen Störungen ist ein wichtiger Forschungsgegenstand in der Wirtschafts- und Produktionswissenschaft. Während in der wissenschaftlichen Literatur viele verschiedene Massnahmen zur Verbesserung der Resilienz vorgeschlagen wurden, bleibt die effektive Auswahl von Massnahmen zur Verbesserung von Produktionsnetzwerken eine Herausforderung. Dieser Beitrag analysiert die in der wissenschaftlichen Literatur vorgeschlagenen Massnahmen zur Verbesserung der Resilienz von Produktionsnetzwerken. Die am häufigsten vorgeschlagenen Massnahmen werden im Detail diskutiert. Diese Massnahmen werden in einem konzeptionellen Rahmen strukturiert, um mehr Klarheit über die Mechanismen zu schaffen, mit denen Massnahmen die Resilienz verbessern und um spezifische Massnahmen für ein Produktionsnetzwerk auszuwählen.

Stichwörter: Resilienz, Robustheit, Globale Produktion, Produktionsnetzwerk, Wertschöpfungskette, Produktionsmanagement

1 Motivation and Aim of Research

Disruptions in global production networks arise from a "combination of an unintended and unexpected triggering event that occurs somewhere in the upstream supply chain […], the inbound logistics […], or the purchasing (sourcing) environment, and a consequential situation, which presents a serious threat to the normal course of business operations of the focal firm" (*Bode/Macdonald* 2017). For the management of production networks, disruptions of any kind pose a serious threat to the profitability and survivability of the business. They may be caused by natural disasters such as volcanic eruptions (*Lund/Benediktsson* 2011) or fires (*Filkov et al.* 2020), but also due to human-caused events such as logistics disruptions or even economic crises (*Jüttner/Maklan* 2011). Besides disruptions, other rapid changes in the environment present a challenge to the management of global production networks. These changes may be caused by dramatic changes in trade conditions such as Brexit or the recent trade conflict between the People's Republic of China and the United States of America (*Itakura* 2020). Furthermore, sudden changes in demand or changing legal conditions as well as supply shortages (*Lohr* 2011) may threaten the well-balanced setup of production. Finally, common disruptions in supply chains are a constant challenge for production network management (*Peukert et al.* 2020). As these examples show, producing companies are highly vulnerable to changes in their environment and need to navigate those challenges while maintaining profitability.

The ability of production networks to absorb, adapt to, and recover from disruptions and changes of different lengths and magnitudes of impact is essential for the respective companies' existence (*Golan et al.* 2020). Global production networks are particularly vulnerable to disruptions due to their high interconnectedness worldwide and complexity (*Lanza et al.* 2019). The vulnerability of a system, such as, in this case, a production network, is composed of the potential impact and likelihood of disruptions (*Sheffi/Rice Jr.* 2005). Knowledge and understanding of activities, measures, and tasks to improve resilience provide insights into a company's strengths and deficits and help focus future planning activities on lowering the vulnerability of the production network.

While the topic of resilience has been discussed in depth by literature on supply chains, contributions with a production science background have not yet examined this aspect in detail. To remedy this seeming negligence, this contribution examines the following research question: Which measures exist, that increase the resilience of production networks and how do they work? To answer the former half, a quantitative literature review is conducted, analyzing resilience measures commonly discussed in scientific literature. Building upon the literature review findings, the contribution conceptualizes a framework to aid the understanding and classification of resilience measures, addressing the later half of the question. Additional measures to improve resilience not yet discussed as much, specifically in the context of production network research, are then proposed.

The remainder proceeds as follows: Section 2 gives an overview of the relevant fundamentals and state of the art on resilience in production networks. In particular, global production networks and supply chains, influencing factors, and the terms resilience and robustness of production networks are defined. Furthermore, existing literature reviews on these subjects are examined. Section 3 describes the quantitative literature review as the used research method in detail. Section 4 presents the findings of the literature research. Section 5 proposes a novel conceptual framework to classify resilience measures and categorizes the measures found in the body of literature accordingly. Furthermore, additional measures that have not seen as much attention in the literature are proposed. Section 6 provides a summary, shows the research limitations, and gives an outlook on future research fields.

2 Fundamentals and State of the Art

Research on global production combines a multitude of fields and scientific streams of discourse. Management theory, operations research, manufacturing engineering, and logistics are represented in global production management. The contemporary definition of a global production network is a set "… of geographically dispersed production entities, which are interlinked by material, information and financial flows." (*Lanza et al.* 2019) Typically, the distinction is made between internal production networks, which legally belong to one company, and external production networks, which also incorporate legally independent stakeholders involved in the value creation process, such as suppliers, logistics providers, distributors, collectors, and recovery plants (*Váncza* 2014).

The concept of production networks has a significant overlap with the term supply chain, originating from a more logistics-focused perspective. Research on supply chains typically considers multiple companies, whereas production networks often take the perspective of a focal company. While research on supply chains is more focused on aspects of the flow of goods between nodes, i.e., production and distribution facilities, production network literature focuses on the nodes or actors themselves (*Coe/Yeung* 2015, 2; *Schönsleben* 2016, 11). Thus, a supply chain resilience perspective is typically focused on the resilience of the entire supply chain with all its connected entities. A production network perspective, on the contrary, is typically concentrated on a focal company and considers others in the supply chain outside the core concern. Whereas the supply chain view is often limited to a single product and has to manage all disruptions within that system a production network perspective can consider multiple products to offset some types of disruption. Nevertheless, both streams of research have significant overlap, so this contribution considers both of them as valuable inputs for the discussion of resilience in global production networks.

The management of global production networks involves various decisions interlinked with different company functions, time horizons, decision objects, and management levels. According to *Friedli et al.* (2014), there are three core tasks of designing and operating global production networks. *Production strategy* decisions include long-term decisions regarding the interactions between markets, product portfolio, technological capabilities, and business strategy. *Network footprint* decisions define the physical shape of the production network, the location and overall capacities of different sites, and the allocation of value creation processes. *Network management* is concerned with operative and coordinative production planning and order management, and supplier and logistics management.

Today's production networks exist in a complex environment that constantly interacts with them. *Lanza et al.* (2019) identify six distinct types of influencing factors, which shape production networks. *Markets and market developments* describe the interaction of producers and consumers of products, including competitive pressures and technological changes. Location-specific *cost factors* such as labor and capital costs, material and energy costs, and coordination and communications cost significantly influence global production networks. *Logistics*, describing the costs, availability, and lead times of transportation also shape global production networks. Furthermore, *cultural factors* like the employees' qualification level and staff turnover also play an essential role. *Legal factors*, such as the prevalence of corruption, the protection of intellectual property, and the importance of the rule of law can shape production management decision-making. Finally, *political factors*, such as taxes, subsidies, standards, political stability, environmental regulations, and trade barriers, can significantly alter the shape of production networks.

Resilience and robustness are two terms commonly discussed in the context of supply chains. Both are sometimes used interchangeably, yet the terms contain significant differences (*Datta* 2017). In the context of this paper, robustness will be understood as a system's ability to deliver high performance under varying inputs (*Stricker et al.* 2015). A production network that is robust against demand fluctuations could, for example, produce at costs below the market price irrespective of the capacity fluctuation. In this sense, the robustness of a system refers to its *passive* ability to tolerate different environmental conditions at high system performance. The resilience of a system, in contrast, describes its ability to maintain a high level of performance through changes of its state (*Tukamuhabwa et al.* 2015). It must be able to adapt *actively* to a changing environment. An example of a resilient production system regarding demand fluctuation would be one that could add or retract production capacity depending on current capacity utilization. In the remainder of this work, robust systems are subsumed under resilient systems since making a system more robust would improve its resilience.

Several contributions have offered an overview of resilience measures in supply chains. *Rist et al.* (2014) provide an overview of resilience measures, primarily focusing on the ecological resilience of production and sustainability. *Li/Zobel* (2020) model supply chains as infection chains and conclude insights regarding supply chain length and diversification. *Datta* (2017) discusses several intervention types and mechanisms that enable improved outcomes based on a systematic literature review. Several general interrelations are discussed, and suggestions to improve resilience are given. *Ponis/Koronis* (2012) identify nine supply chain capabilities that support resilience. *Ali et al.* (2017a) present a detailed analysis of the state of the art regarding supply chain resilience. The authors also conclude with a mapping framework, but do not implement production-related knowledge. Other authors like *Ivanov et al.* (2017a) analyze the state of the art of tools to support disruption management in supply chains but lack a managerial overview of measures for achieving resilience in production networks. While several reviews of resilience measures exist, they primarily focus on the supply chain perspective and cannot provide a more production-focused categorization of approaches.

3 Research Process

This research uses a systematic literature review to determine existing measures to improve robustness and resilience (see *Figure 1*). The method adapted from *Moher et al.* (2009) was focused on obtaining a broad range of proposed measures, so the reasons for exclusion were tailored towards that goal. The initial set of contributions was identified based on a keyword search on Scopus. The keyword combination required either "robustness" or "resilience" and either "supply chain," "production network," or "global production." This combination of keywords was selected to incorporate a wide range of perspectives on resilience in global production networks. Only journal contributions in English published between January 2010 and February 2021 were included to limit the scope. To further reduce the search and eliminate entries not relevant for the management of global production networks, the subject area was limited to "Business, Management, and Accounting." This search yielded 758 results. The list of results was further reduced in a title-based screening to 471 relevant contributions. Thirty-five contributions were added through a backward search in that selection. Of the resulting 506, 260 were available for download and further investigated in this study. All 260 were screened according to whether they provided insights into potential measures to increase resilience in production networks. 143 were found applicable and are the basis for this literature review.

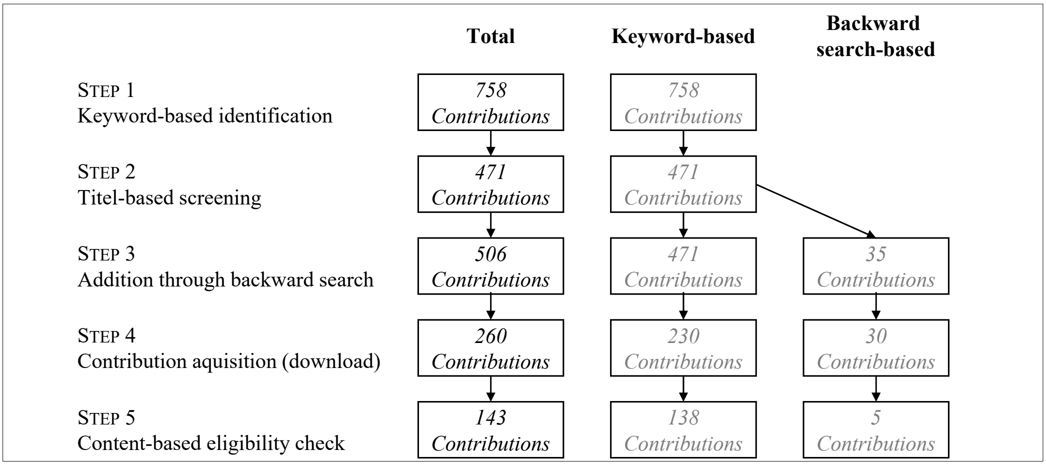

Figure 1: Selection and review process adapted from (Moher et al. 2009)

The results of this literature review are displayed in the subsequent section. The contributions were examined regarding their general characteristics and whether they proposed measures to increase resilience. In a first part of the research, distinct measures were collected. Subsequently, measures proposed in other contributions were examined, whether they aligned with already defined measures or whether new categories were necessary. This way, the list of measures was continuously updated and refined throughout the measure screening process. The identified measures are described in section 4. A conceptual framework was developed to structure the measures, sorting them based on existing conceptual models for production network management and resilience. The framework is based on existing structuring of influencing factors in global production networks and relevant management tasks. Furthermore, a structure to describe how different measures fundamentally influence a production networks resilience was developed based on theoretical modeling. The resulting framework was subsequently used to identify potential measures underrepresented in literature to enhance further production network resilience based on open expert interviews.

4 Results

4.1 Publication Characteristics

In this section, an overview of the body of literature examined here is given. For comparability, only contributions found through keyword-based identification are used. *Figure 2* shows the year-wise distribution of publications for steps two, four, and five of the literature review process presented in *Figure 1*. The resulting distribution shows an increasing interest in the topic of resilience in supply chains and production networks, which concurs with findings of other reviews on the subject (*Kamalahmadi/Parast* 2016; *Ali et al.* 2017a). The recent surge in publications is not entirely reflected in the final selection due to the limited availability of more current contributions for download.

One can conclude from the publication characteristics, that the importance of resilience measure contributions increased from 2010 to 2019. After this initial slow increase, there is a significant surge in contributions more recently. This may be a result of the on-going COVID-19 pandemic which shows the need for resilience supply chain structures and global production networks. The drop in 2021 can be explained by the short time horizon which was analyzed in the year 2021. Supposedly, there will be more contributions coming 2021 with a focus on resilience due to the pandemic and its impacts on industry.

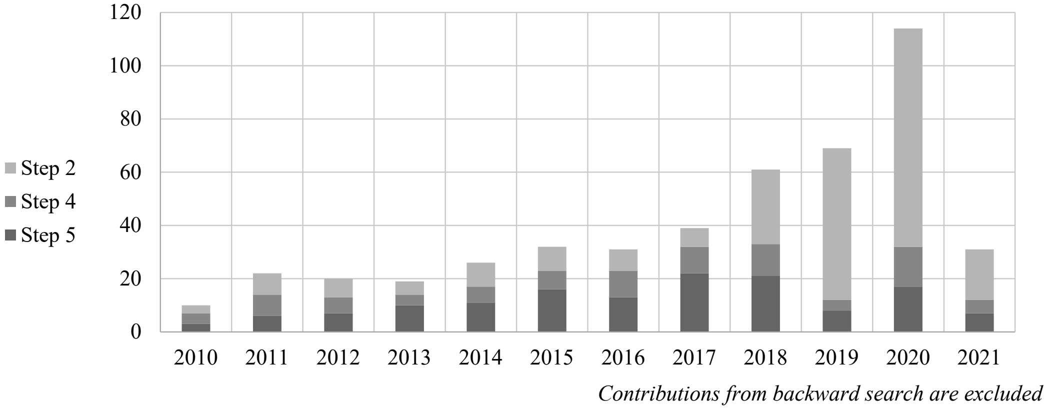

Figure 2: Year-wise distribution of contributions after the title-based screening (step 2), downloadable status (step 4) and content-based eligibility check (step 5)

4.1.1 Applied Methods

Figure 3 reflects the methods applied in the examined contributions in total and separated in three time periods. Practice-focused methods like conceptual modeling, case studies, and surveys play an essential role, while more theoretical and quantitative approaches are not prevalent. It lays in the nature of these more qualitative approaches to develop and propose dedicated resilience measures, as these approaches are often frameworks or generic models. More quantitative approaches, like optimizations, quantitative modellings or simulations, focus on the mathematical optimum of resilience in supply chains or other structure and neglect the proposal of dedicated resilience measures. Therefore, the number of these references is relatively low. Figure 3 shows that as the topic of resilience has matured, the share of case studies has declined while the share of conceptual models and reviews has grown. This is a typical development to be expected as more and more research on a topic appears.

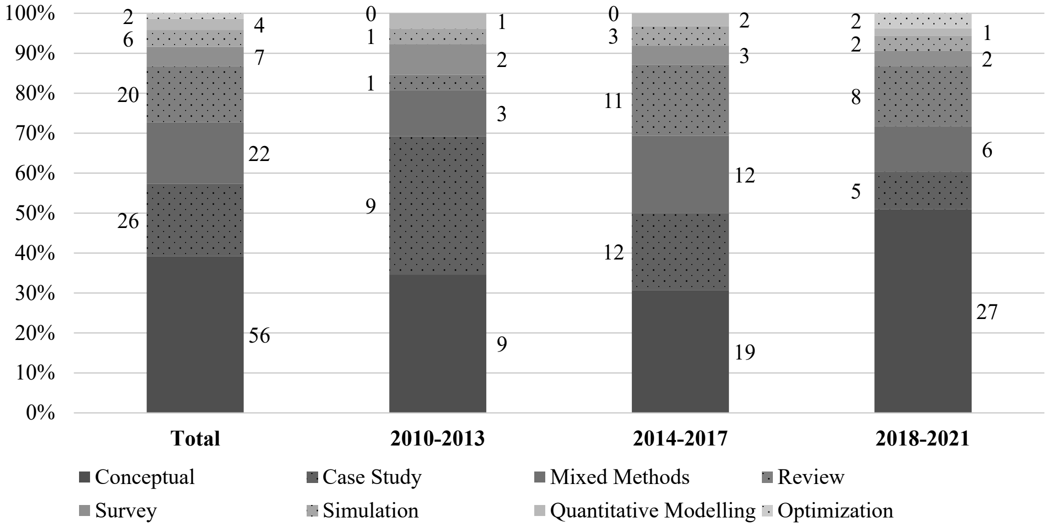

Figure 3: Applied methods of selected contributions in total and per time period.

One can conclude from the overview of the methods that qualitative approaches and contributions are more suitable for deriving measures in the topic of resilience management. Therefore, also the present approach builds upon a quantitative literature review to obtain qualitative measures.

4.1.2 Types of Disruptions / Environment Changes

Upon scrutiny, it becomes clear that the disruptions and environmental changes the contributions consider differ significantly. The types of issues can be broadly categorized into supply-side, demand-side, and internal challenges. This categorization is based on the view of a production network as an input-output model, which attains components from suppliers and orders from their customers. The origin of any unplanned occurrences can then be attributed to one of those three. As *Figure 4* shows, a majority of the contributions focuses on supply-side issues while only a smaller subset concentrates on demand-driven challenges. Even fewer articles consider internal disruptions and changes. Due to their perspective, the supply chain focused contributions foremost consider issues on the supply-side as these issues can be resolved through logistic solutions and better information exchange between supply chain partners as the subsequent sections will show. The apparent lower priority of demand-side and internal issues could also be explained by the nature of issues that arise there. They are typically less dynamic like changes in demand or do not affect as many supply chain partners like internal machine. Concluding, the reason behind less attention to internal and demand side issues is not clear while more attention to those types of issues may be beneficial.

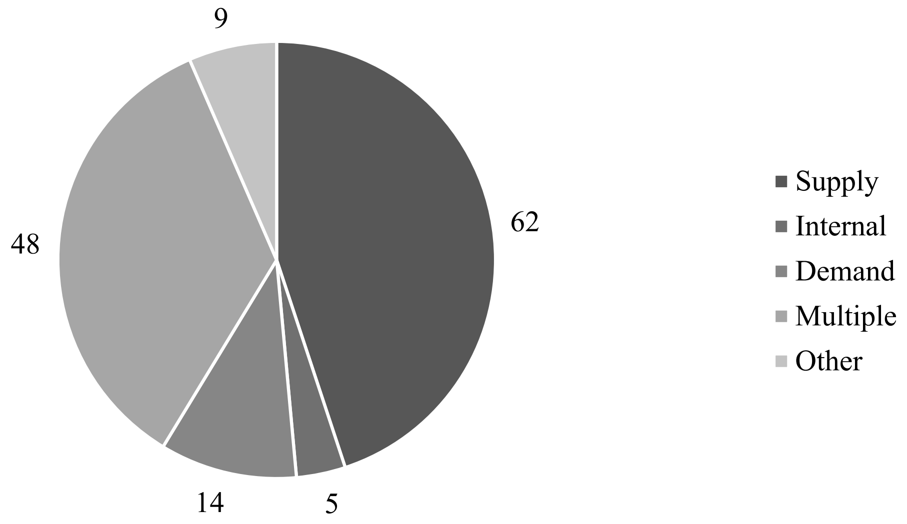

Figure 4: Considered types of disruptions or environmental changes by point of origin in the value stream

4.2 Identified Measures

In this section, the identified measures are discussed. As *Table 1* shows, a broad range of measures is proposed in the body of literature. These measures are not all understood uniformly in the literature, and significant overlap exists. Therefore the measures found in the body of literature are described using the most suitable descriptors, which may not be used in all sources describing the measures.

The most commonly mentioned measure is *supply chain collaboration*. In contrast to *supply chain coordination*, which focuses on operational issues, collaboration refers to the integrated work of multiple parties under consideration of different strengths and weaknesses. However, establishing a collaborative supply chain culture remains challenging as companies seek to protect their competitive interests (*Duong/Chong* 2020).

The interaction of multiple supply chain parties is also a theme of some other measures. A common one is *multiple sourcing*. Here, more than one supplier is available for each item, decoupling downstream processes from the issues at suppliers (*Lücker/Seifert* 2017). Often, suppliers with very different risk and performance profiles are combined to reduce vulnerability to supply chain disruptions (*Namdar et al.* 2018). S*calable production volume* refers to the ability to change the capacity of the production systems to accommodate higher volumes (*Scavarda et al.* 2015). *Flexible routing* is the ability to allocate orders to different factories or suppliers in a production network, allowing for swift reactions to fluctuating demand profiles or disruptions in the network (*Khalili et al.* 2017). In combination with *diversification and redundancy*, flexible routing shows an even higher potential to circumvent disruption and stabilize the production network (*Chowdhury/Quaddus* 2016; *Han et al.* 2020).

An approach to limit the exposure to failure points in the supply chain is to create *short supply chains* in terms of the number of suppliers and the lead times (*Chang/Lin* 2019). This is achieved through high degrees of vertical integration either of the focal company or its direct suppliers. However, this can increase the risks associated with technological shifts and changes in the market's competitive landscape. *Strategic stocks* are another option to limit supply-side problems. However, they may also negatively affect the ability to adapt to new market conditions quickly (*Xu et al.* 2014).

Some technical approaches to increase the speed of adaptions to changing conditions, as well as the span of possible states, also exist. *Agile factory* concepts promote factories that are quicker to raise, expand and shrink than typical factories. Hence the sluggishness typically associated with production networks can be remedied (*Fujimoto/Park* 2014). *Technological manufacturing flexibility* allows the creation of parts at several sites using location and production volume-adapted technologies, such as more generalist or specific production equipment (*Chowdhury et al.* 2021). *Product modularity* can also facilitate a reduction in exposure to market shifts and enable a reduction in stocks by sharing components between products (*Khan et al.* 2012).

Measure	Description	#	Sources
Short Supply Chains	*Short supply chains* shorten previously very long supply chains to reduce complexity. Thus, the situation for relevant suppliers is easier to monitor, and fewer points of failure exist. Short supply chains can be achieved by maintaining a high-value creation share in-house and partnering with strong suppliers offering complex components.	7	1, 14, 18, 26, 32, 55, 137
Diversification/ Redundancy	*Diversification* minimizes the dependency on a specific market, a single supplier, or an industry. Accordingly, susceptibility is strengthened since, in the event of a market or supplier disruption, only parts of the production and company are affected. Complete pandemics or worldwide sales crises can be better managed, but the appropriate diversification is difficult to assess in advance as a tradeoff with costs exists.	44	1, 2, 6, 9, 12, 18, 26, 27, 30, 31, 33, 41, 47, 53, 54, 55, 57, 60, 61, 62, 64, 65, 67, 68, 73, 74, 78, 81, 91, 95, 100, 101, 103, 105, 113, 116, 126, 129, 130, 132, 133, 135, 137, 140
Product Modularity	*Product Modularity* supports stability by allowing modules to be flexibly allocated between products. Thus, less demanded products are not manufactured, but products in demand can be manufactured using the same modules. An increase in modularity is a strategic issue.	5	29, 47, 65, 76, 137
Strategic Stocks	*Strategic Stocks* can buffer critical products to cushion fluctuations in demand or avoid increased factor costs. Accordingly, the stability of the system is increased.	41	6, 13, 14, 17, 22, 26, 29, 30, 32, 34, 36, 47, 52, 54, 55, 57, 61, 63, 65, 67, 68, 70, 75, 80, 88, 89, 96, 97, 100, 101, 104, 105, 110, 114, 116, 123, 127, 129, 135, 137, 140, 142
Contingency Plans	A *contingency plan*'s mere definition facilitates a quick response to unexpected disruptions. For example, teams prepare to deal with disruptions and, if necessary, shift capacities in the network or use the mobility of resources. This management-oriented approach allows to react to influences from politics or legal factors and propose targeted solutions.	35	1, 6, 9, 16, 20, 22, 30, 35, 47, 49, 52, 53, 63, 66, 68, 82, 86, 87, 92, 93, 97, 102, 104, 105, 106, 107, 118, 124, 125, 126, 127, 131, 132, 133, 137
Flexible Routing	*Flexible Routing* enables the shifting of production volumes across different sites. This measure requires a high degree of standardization. Production sites can thus absorb market disruptions such as the COVID-19 pandemic occurring elsewhere.	33	2, 3, 6, 8, 12, 13, 14, 17, 25, 27, 29, 30, 31, 34, 35, 52, 57, 60, 63, 75, 80, 85, 86, 97, 101, 110, 114, 120, 123, 127, 130, 135, 137

Measure	Description	#	Sources
Supply Chain Collaboration	*Supply Chain Collaboration* describes the close interrelations between different parties in the supply chain, extending beyond simple buyer-supplier relations. It enables the rapid detection of faults at any point in the supply chain. Through open communication, problems are communicated promptly through the network, which supports all collaborating partners. Resources and knowledge can be shared effectively, supporting the success of all participants.	86	1, 3, 4, 5, 6, 7, 8, 10, 12, 13, 14, 16, 18, 19, 20, 21, 22, 24, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 42, 43, 44, 45, 46, 50, 51, 53, 57, 58, 59, 69, 71, 72, 74, 76, 78, 81, 82, 83, 85, 86, 87, 91, 94, 95, 97, 99, 101, 102, 103, 104, 105, 106, 107, 108, 109, 111, 112, 115, 116, 117, 118, 119, 120, 122, 124, 125, 126, 133, 135, 136, 137, 138, 140, 141, 143
Agile Factory	*Agile Factories* are characterized by quick setup and change times for local production. The manufacturing technologies used for these factories are optimized for quick implementation, standardization, and low employee requirements. They allow companies to quickly change the structure of their production network and serve local markets.	8	7, 47, 53, 78, 84, 109, 122, 138
Technological Manufacturing Flexibility	*Technological Manufacturing Flexibility* refers to the ability to produce at several different locations. This ability can be achieved through the standardization of production equipment and the utilization of different production technologies appropriate for different locations.	7	9, 32, 46, 47, 57, 85, 137
Scalable Production Volume	*Scalable Production Volume* allows production systems to adapt to higher and lower volumes and corresponding product variance degrees. For example, production lines can be automated using converters as soon as customer demand increases or decreases. The corresponding change enablers must be planned and implemented.	13	6, 8, 20, 29, 31, 46, 51, 58, 59, 85, 88, 102, 115
Traceability/ Transparency	*Traceability and Transparency*, also referred to as visibility, denote the ability to describe the processes in a specific product lifecycle using data and make that data available to many applications. Traceability can increase the transparency regarding proceedings in the supply chain and enable better decision-making.	7	1, 6, 8, 23, 101, 123, 136, 137
Supply Chain Coordination	*Supply Chain Coordination* improves the overall performance of the entire supply chain by coordinating production planning activities between partners. The supply chain from the first supplier to the customer is analyzed and optimized holistically. A common focus is on inventory management, quality management, and technical change management.	24	6, 7, 13, 25, 29, 32, 46, 55, 56, 65, 69, 75, 85, 101, 104, 114, 116, 121, 132, 133, 136, 137, 140
Predictive Analytics	*Predictive Analytics* exploits historical data to predict future events. Historical data on suppliers, markets, or factor costs can be used to predict future developments. The predictions allow the definition of management actions to counter these developments.	6	6, 18, 29, 42, 87, 137
Proactive Disturbance & Risk Management	*Proactive Disturbance Management* can also be used on the network management level to anticipate disturbances. Through suitable scenario management and the provision of, e.g., jumpers for the loss of employees in a production line, the impact of disturbances may be reduced. These actions require comprehensive knowledge of the different challenges that may occur and suitable options to lessen their impact.	45	1, 4, 6, 9, 11, 18, 20, 23, 29, 32, 33, 36, 38, 45, 46, 49, 53, 58, 59, 64, 71, 74, 77, 81, 83, 90, 92, 93, 102, 104, 105, 106, 109, 112, 119, 120, 122, 123, 124, 125, 126, 131, 137, 138, 139

Measure	Description	#	Sources
Multiple Sourcing	*Multiple sourcing* reduces the dependence on single suppliers by buying one type of item from more than one supplier.	19	1, 6, 7, 14, 29, 30, 32, 33, 51, 54, 65, 67, 80, 84, 88, 95, 102, 110, 125
Software Solutions	*Software solutions* enable the digitally assisted detection of disturbances. Furthermore, it fosters collaboration between production plants and value stream partners.	12	6, 11, 16, 32, 42, 47, 69, 81, 86, 99, 100, 108
Supply Chain Risk Management (SCRM) Culture	*SCRM culture* may make the consciousness for change and risks more transparent in the employees' minds and everyday lives. It describes a comprehensive culture that takes risks along the whole supply chain into account and encourages thinking about the impact of individual actions on the entire chain.	32	4, 9, 10, 11, 18, 19, 20, 22, 23, 30, 40, 41, 43, 45, 52, 57, 58, 74, 78, 84, 90, 97, 105, 108, 112, 118, 119, 120, 125, 126, 133, 139

Authors: 1: Abe/Ye (2013); 2: Adenso-Diaz et al. (2012); 3: Adenso-Díaz et al. (2018); 4: Adobor (2019); 5: Adobor/McMullen (2018); 6: Ali A. et al. (2017); 7: Ali I. et al. (2017); 8: Alvarenga et al. (2018); 9: Amalnick/Saffar (2017); 10: Andersson et al. (2014); 11: Annarelli/Nonino (2016); 12: Azadeh et al. (2014); 13: Azevedo et al. (2013); 14: Azevedo et al. (2016); 15: Bailey/De Propris (2014); 16: Belhadi et al. (2021); 17: Berle et al. (2013); 18: Bevilacqua et al. (2020); 19: Bhattacharjya (2018); 20: Birkie et al. (2017); 21: Brandon-Jon et al. (2014); 22: Brusset/Teller (2017); 23: Bühler et al. (2016); 24: Cainelli et al. (2012); 25: Cardoso et al. (2015); 26: Chang/Lin (2019); 27: Chauhan et al. (2021); 28: Cheng/Lu (2017); 29: Chowdhury/Quaddus (2015); 30: Chowdhury/Quaddus (2016); 31: Chowdhury/Quaddus (2017); 32: Chowdhury et al. (2021); 33: Christoph et al. (2004); 34: Christopher/Holweg (2017); 35: Colicchia et al. (2010); 36: Das (2018); 37: Das (2019); 38: Datta (2017); 39: de Sá et al. (2018); 40: De Sanctis et al. (2018); 41: Dolgui et al. (2018); 42: Dubey et al. (2021); 43: Duong/Chong (2020); 44: Durach/Machuca (2018); 45: Durach et al. (2015); 46: Ekanayake et al. (2021); 47: Fujimoto/Park (2014); 48: Gimenez-Escalante et al. (2020); 49: Golgeci/Ponomarov (2013); 50: Golicic et al. (2017); 51: Gunasekaran et al. (2015); 52: Gunessee et al. (2018); 53: Han et al. (2020); 54: Hasani/Khosrojerdi (2016); 55: Hearnshaw/Wilson (2013); 56: Heckmann et al. (2015); 57: Hohenstein et al. (2015); 58: Huang/Farboudi Jahromi (2021); 59: Huatuco et al. (2010); 60: Ishfaq (2012); 61: Ivanov (2017); 62: Ivanov (2018); 63: Ivanov (2020); 64: Ivanov/Das (2020); 65: Ivanov/Dolgui (2019); 66: Ivanov et al. (2016); 67: Ivanov et al. (2017); 68: Ivanov et al. (2019); 69: Iyer (2011); 70: Jabilles et al. (2019); 71: Johnson et al. (2013); 72: Jüttner/Maklan (2011); 73: Kahiluoto et al. (2020); 74: Kamalahmadi/Parast (2016); 75: Khalili et al. (2017); 76: Khan et al. (2012); 77: Khemiri et al. (2017); 78: Kochan/Nowicki (2018); 79: Komoto et al. (2011); 80: Kumar et al. (2013); 81: Kwak et al. (2018); 82: Lam/Bai (2016); 83: Leat/Revoredo-Giha (2013); 84: Li et al. (2011); 85: Li et al. (2017); 86: Loh/Van Thai (2014); 87: Lotfi/Saghiri (2018); 88: Lücker/Seifert (2017); 89: Macdonald et al. (2018); 90: Mandal (2017); 91: Mandal/Sarathy (2018); 92: Mangla et al. (2014); 93: Manning/Soon (2016); 94: Matsuo (2015); 95: Namdar et al. (2018); 96: Nejad/Kuzgunkaya (2015); 97: Norrman/Wieland (2020); 98: Pal/Torstensson (2011); 99: Papadopoulos et al. (2017); 100: Park et al. (2020); 101: Pereira et al. (2014); 102: Pett et al. (2010); 103: Ponis/Koronis (2012); 104: Purvis et al. (2016); 105: Rajesh (2016); 106: Rajesh/Ravi (2015); 107: Rajesh et al. (2015); 108: Ralston/Blackhurst (2020); 109: Sabahi/Parast (2020); 110: Sabouhi et al. (2020); 111: Sahu et al. (2016); 112: Sahu et al. (2017); 113: Salehi Sadghiani et al. (2015); 114: Saw et al. (2013); 115: Scavarda et al. (2015); 116: Schmitt/Singh (2012); 117: Scholten/Schilder (2015); 118: Scholten et al. (2014); 119: Scholten et al. (2019); 120: Sharma/George (2018); 121: Shi et al. (2020); 122: Shin/Park (2021); 123: Shqairat/Sundarakani (2018); 124: Singh et al. (2018); 125: Siva Kumar/Anbanandam (2020); 126: Stone/Rahimifard (2018); 127: Ta et al. (2006); 128: Tan et al. (2016); 129: Tan et al. (2019); 130: Tan et al. (2020); 131: Thun/Hoenig (2011); 132: Torabi et al. (2015); 133: Tukamuhabwa et al. (2015); 134: Tukamuhabwa et al. (2017); 135: Urciuoli et al. (2014); 136: Valipour Parkouhi/Safaei Ghadikolaei (2017); 137: Vlajic et al. (2012); 138: Wieland/Wallenburg (2013); 139: Wieteska (2020); 140: Xu et al. (2014); 141: Yuan et al. (2015); 142: Zamanian et al. (2020); 143: Zeng/Yen (2017)

Table 1: Overview of measures to increase resilience proposed in the body of literature

In addition to structural adaptions, *software solutions* can also enable quicker responses to changes in the production network (*Iyer* 2011). Those solutions reduce the dependence on manual detection of issues. *Traceability and transparency* in the supply chain allow for an overview of current stock levels and production statuses and can both trigger and guide decision-making in case of disruptions (*Pereira et al.* 2014). *Predictive analytics* can be used to integrate external information and identify demand- and supply-side changes more quickly (*Ali et al.* 2017a).

The final set of measures addresses company culture and management. Fostering a holistic *supply chain risk management culture* that encourages employees to incorporate risk in their decision-making can significantly impact the susceptibility of the production network (*Norrman/Wieland* 2020). Central *proactive risk management* also helps to create more resilient structures (*Vlajic et al.* 2012). *Contingency plans* are an important reactive measure, increasing the speed of companies adjusting to changes (*Scholten et al.* 2014).

Overall a broad range of measures is discussed in the body of literature. However, all these measures come with specific tradeoffs in terms of production efficiency and cannot address all types of challenges a production network is faced with. Many measures focus on proactive disruption management by means of strategic stocks, proactive risk management, flexible routing or, more generic, supply chain collaboration. Furthermore, the identified measures help to react to disruptions without making big changes in the configuration of the supply chain. Therefore, the changes are only minor. All these aspects culminate in the fact that there is, so far, no common overview or framework which summarizes relevant measures on all relevant levels in a production network. Concluding, an overview of the available measures and their effects can help companies to design more resilient production networks.

5 Conceptual Framework and Additional Measures

5.1 General Framework of Resilience Measures in Global Production Networks

As the previous sections have shown, several measures to improve resilience have been proposed and studied. However, most contributions to this field of research come from a supply chain background. Thus, while the measures are applicable in production network management, they leverage supply chain-specific aspects to improve resilience, potentially forgoing adaptions to production. Furthermore, it remains difficult for practitioners and researchers to structure the measures to gauge which measures fit which types of issues best and where potentials for improved resilience lie. Therefore, this contribution proposes a framework to structure the measures in production networks to increase resilience. This framework was derived using models commonly used to describe production networks as well as a systematic understanding of mechanisms at play to increase resilience. They are used to enable better understanding of the functionality of different measures with respect to production networks.

The proposed framework uses the three production management tasks discussed by *Friedli et al.* (2014) to define the enactment level at which measures are implemented. Hence, measures can be assigned to either the *production strategy*, *network footprint,* or *network management* level.

Additionally, different types of issues measures address can be distinguished. A differentiation can thereby be done by discerning between supply-side, demand-side, and internal challenges. However, a more detailed distinction is possible using the influencing factors described by *Lanza et al.* (2019). Any type of disrupting event or change in the production networks acts upon the network through these influencing factors. Thus, different measures can increase resilience concerning the influencing factors. As described above, the six influencing factors for production networks include *markets and market development*, *cost factors*, *logistics*, *political and governmental factors*, *legal factors*, and *people and culture*. While other classification schemes for challenges and disruptions are also possible, as, for example, discussed by *Kochan/Nowicki* (2018), this categorization ensures applicability to the research on production networks.

To further distinguish measures, the mechanisms that make systems more or less capable of successfully withstanding outside disruptions are captured. As discussed in section 2, other contributions have proposed similar concepts but often lack generality as they focus on one or several aspects of production systems. Here, production networks are considered as a system subjected to outside influences originating in their environment. Systems can use mechanisms that improve performance in case of changing requirements to become more robust and resilient. Several mechanisms are described in the existing literature (*Ponis/Koronis* 2012; *Tukamuhabwa et al.* 2015; *Kamalahmadi/Parast* 2016), but those mechanisms sometimes overlap each other and are already focused in the supply chain as the object of interest, hence losing a more generalist perspective. Thus, this contribution proposes to distinguish five mechanisms that support the resilience and robustness of an abstracted system and uses that abstract categorization for specific measures in the context of production networks. These mechanisms are derived from general system properties that contribute to its resilience. *Figure 5* shows a system under varying requirements over time. These requirements include the general condition a system is expected to perform in as well as the desired results. In reality, the requirements are multidimensional but for simplicity they are shown as one-dimensional here. Disruption or longer term changes in the requirements challenge the resilience of the system. The system can either tolerate changes passively or actively adapt corresponding to its robustness and resilience. Considering the example of *Figure 5*, five fundamental properties that influence the systems robustness and resilience were identified. These properties align with observations other contributions have made concerning important features of resilient systems.

- *Susceptibility*: This characteristic describes the degree to which outside influences affect the system. Systems can lower their susceptibility or vulnerability by decreasing the volatile and possibly disruptive influences they are subject to (*Sheffi/Rice Jr.* 2005). Less susceptible systems consequently behave more robust.
- *Stability*: The stability of a system describes whether the system can balance outside influences through inner mechanisms such as flexibility. Stable systems may be subject to changes, but they can tolerate these inputs without changing their state. (*Stricker et al.* 2015)
- *Speed*: This describes the system's capability to quickly reach another state once a decision for change has been made (*Klibi/Martel* 2013).
- *Span*: The span of possible states a system can adapt to describes how far a system can change in the face of disruptions. It describes the limits of a system's state space (*Lanza et al.* 2019).
- *Sensitivity*: The sensitivity describes the system's ability to perceive environmental changes that it needs to quickly adapt to and define the direction of its own change.

> Sensitive systems perceive threats long before they have disruptive effects on it. (*Schuh et al.* 2018)

A resilience measure can increase the resilience through five corresponding mechanisms, which are decreasing the *susceptibility* to changes, increasing the *stability* of the system facilitated by flexibility with regards to tolerated inputs, increasing the *speed* a system can change its state to adapt to new situations, increasing the *span* of states a system can adapt to, and increasing the *sensitivity* of the system to perceive outside changes and initiate reactions.

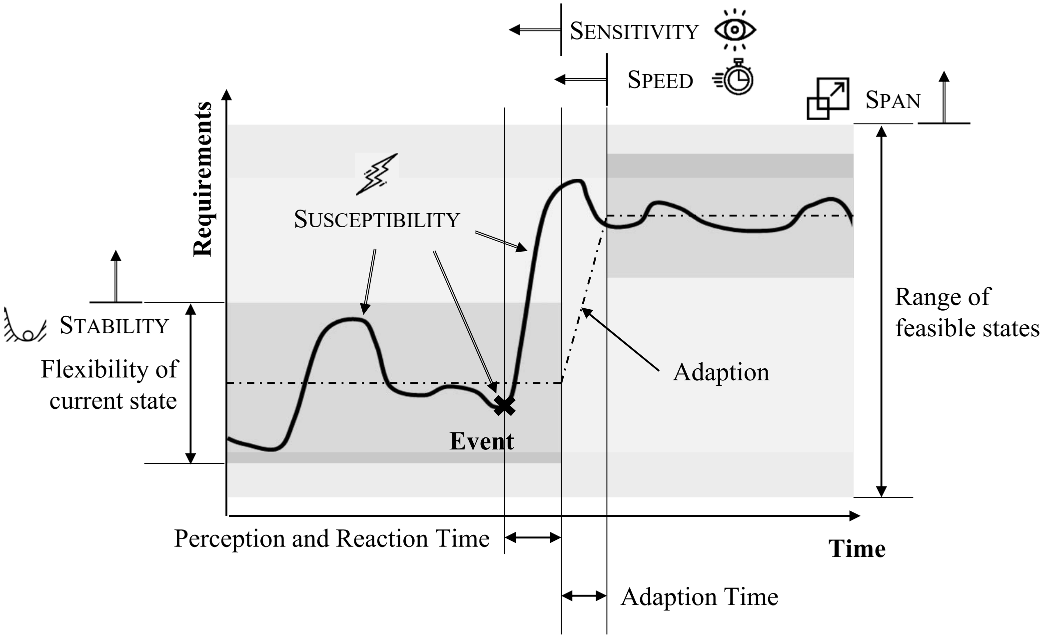

Figure 5: Mechanisms to improve system resilience shown in a visualization adapted from (Lanza et al. 2019)

Figure 5 shows how these mechanisms can lead to improved robustness and resilience. As long as the requirements are within the flexibility range of the system, the system behaves robustly. As soon as the change exceeds this limit, the system needs to adapt and does so with the delay of perception, reaction, and adaption time (*Lanza et al.* 2019). The visualization also demonstrates that mechanisms might interact. A lower susceptibility, for example, may lead to lower requirements for the other characteristics, whereas a higher speed might enable a system to make use of its entire adaption span. Improving any of the production networks mechanisms can lead to better resilience. However, the different mechanisms may address different types of challenges better or worse. Decreasing susceptibility may be suited to relieve the necessity of other mechanics as a less susceptible production network will be subject to fewer issues to overcome. Stability increase should focus on compensating issues that occur regularly and require fast changes that would exceed the ability of the system to change. Sensitivity and speed increase should go hand in hand as excessively optimizing one without the other would show diminishing returns.

The span finally should be optimized for the relatively slow but sweeping changes the production network needs to adapt too and serve as a last line of "defense".

The overall framework depicted in *Figure 6* categorizes measures by their level of enactment, their addressed influencing factors, and the utilized mechanism to improve resilience. A measure such as traceability and transparency is implemented at the operative network management level. It helps to address challenges from logistic influences and disruptions and to legal challenges in the case of product recalls, for example, and improves the resilience of the production network. This improvement is achieved by increasing the sensitivity with which challenges are recognized, and appropriate responses are designated. The measures identified in the review are characterized in this way in *Table 2*. Here, every measure is linked with influencing factors it addresses, its enactment level and the mechanisms it uses. In several cases, a measure that addresses multiple influences is implemented on more than one level and utilizes more than one resilience mechanism. For example, supply chain collaboration is implemented first at a strategic level, where companies agree to work together closely for mutual benefits and operationalized on the network management level. Such collaboration can then increase stability, as collaborative supply chains are subject to fewer late discovered disruptions and span and speed as the collaboration enables coordinated reaction to problems and a broader range of configuration by organizing all partners in the network.

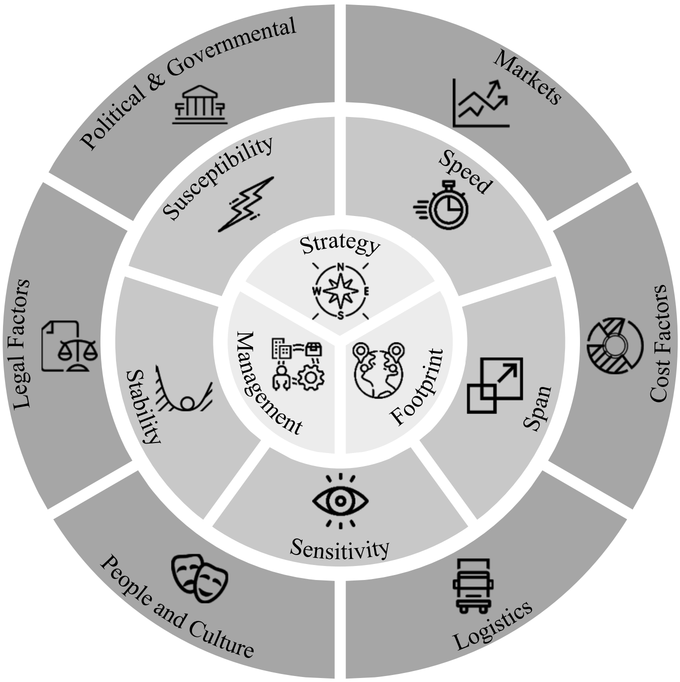

Figure 6: Framework to structure resilience measures by addressed influences, utilized mechanisms, and level of enactment

For researchers, this framework may offer a clearer understanding of the ways different measures impact the resilience of production networks. It can also show which types of combinations are not explored to their potential and direct future research. For practitioners, this framework can be used to categorize and assess current efforts to increase the production network resilience and match them with the company's strategic objectives. Also, it may help to identify additional measures that are unused.

The structuring of measures in *Table 2* allows some general observations. Many of the measures mentioned most commonly like supply chain collaboration, supply chain coordination, contingency plans, and flexible routing first and foremost increase the speed. These measures prepare the network to react more quickly when a disruption has occurred. They are also what could be considered typical supply chain perspective

	Influencing Factors						**Level**			**Mechanism**				
Measure	**Market & Market Development**	**Factor Costs**	**Logistics**	**Cultural Factors**	**Legal Factors**	**Political & Governmental Factors**	**Production Strategy**	**Network Footprint**	**Network Management**	**Susceptibility**	**Stability**	**Sensitivity**	**Span**	**Speed**
Short Supply Chains			x			x		x		x				
Diversification / Redundancy		x				x	x	x		x			x	x
Product Modularity	x						x				x		x	x
Strategic Stocks	x		x					x	x		x			
Contingency Plans			x						x					x
Flexible Routing	x		x					x	x				x	x
Supply Chain Collaboration		x	x				x		x		x		x	x
Agile Factory		x				x		x						x
Technological Manufacturing Flexibility	x						x						x	x
Scalable Value Creation Depth	x	x					x	x					x	x
Scalable Production Volume	x							x					x	
Traceability/Transparency			x		x				x			x		
Supply Chain Coordination			x						x			x		
Predictive Analytics	x		x						x			x		
Disturbance & Risk Management			x		x		x		x		x	x		
Multiple Sourcing		x	x				x	x		x	x		x	
Software Solution			x						x			x		x
SCRM Culture				x			x		x			x		x

Table 2: Classification of measures by addressed influencing factors, enactment level, and resilience mechanism

measures that focus on logistic based disruptions. Another group of measures that are enacted on the strategic level receive less attention but can also improve span and speed of adaptions and address challenges beyond logistics like factor costs and market and market developments. These measures are diversification and redundancy, product modularity, technological production flexibility, and scalable value creation depth. Measures increasing sensitivity such as predictive analytics, traceability and transparency, proactive disturbance management, and SCRM culture also exist but seem to concentrate on the management level.

It seems there is a lack of measures concentrating on decreasing susceptibility, as minimizing the exposure can be the most elegant solution to disruptions. Additional measures in this space could be enacted on the strategic and footprint level and make networks more resilient without the constant need for attention. Also measures that improve the sensitivity, speed and span of networks with regard to long-term changes in markets but also political factors and factor costs could significantly benefit production networks. In the following section a number of additional measures is proposed that could fill the described gap.

5.2 Additional Measures

As explained above, much of the existing literature on resilience in the context of production networks is originating from a supply chain perspective. While many of those measures are applicable in a more production-focused view, considering aspects of production as levers to increase resilience can uncover additional potential. Thus, several measures that have not yet been explored in the literature concerning their contribution to resilience are proposed here. The authors propose these additional measures based on their own research experience and discussion with other academics and practitioners. They resemble the difference between production network and supply chain perspective, as many of them either focus on potential for resilience increase through changes at the nodes of the network or concentrate on a focal company. There expected effect on production network resilience is described briefly in the following paragraphs and illustrated in *Table 3*.

Production as a Franchise is a concept where production capabilities are outsourced to partners while processes are standardized (*Dant* 1996; *Versaevel* 2002; *Ganebnykh et al.* 2018). On the one hand, this increases the ability to change production capacities at different locations, increasing speed. On the other hand, the susceptibility to market-based, legal and political risks is reduced.

Local for Local in the sense of local production for local markets allows companies to isolate themselves from risks regarding the trade relations between countries (*Crouch* 2003; *Sedita et al.* 2014). Local for local production involves creating a regional supplier structure and focusing on the local market and its needs, minimizing the length and complexity of the flow of goods. This measure increases robustness to market changes and transportation but also trade barriers.

Closed-Loop Manufacturing denotes value chains that can reuse the products after usage (*Yavari/Zaker* 2019; *Gaur et al.* 2020). Today, this practice is most common in industries with high material value and where the used materials can be recycled easily. In the future, when the limitations of finite resources become increasingly apparent, closed-loop manufacturing can become an even stronger concept to become independent of resource scarcity (*Klenk et al.* 2020).

Predictive Maintenance reduces the susceptibility to internal disruptions by continually monitoring the respective production processes and anticipating suitable approaches to reduce the risk of failures (*Chukwuekwe et al.* 2016; *Passath/Mertens* 2019). The dependency on factor costs can be minimized by reducing the required inputs. This measure can be implemented worldwide to make the best possible use of given factor costs. In the field of action, this measure focuses on the information between production lines and sites to improve network resilience.

Decentralized Decision-Making supports fast ways of communication, making problems transparent quickly (*Verhaelen et al.* 2021). In a decentralized decision setting, individual production sites have a high degree of autonomy, which they use for straightforward problem-solving. (*Maritan et al.* 2004; *McDonald et al.* 2008; *Lanza et al.* 2020) Different cultural influences and markets can be managed at the point of interest with the best possible knowledge.

Multimode Transport reduces the dependence on individual transport systems. Thus, worldwide restrictions in air traffic, for example, can be circumvented by rail or truck. Additionally, multimode transportation allows producing companies to circumvent material shortages, for example, through emergency deliveries or buffer excess material occurring due to own production delays (*Ishfaq* 2012; *Wan et al.* 2018). In addition to the influences from the area of transport, this measure in network management also shows interactions with the market side since demand changes can be buffered by using differentiated transport forms.

Lean on Capital Production describes the conscious forgoing of capital-intensive production processes (*Danese/Vinelli* 2009; *Rist et al.* 2014). By focusing on technologies

Measure	Influencing Factors						Level			Mechanism				
	Market & Market Development	Factor Costs	Logistics	Cultural Factors	Legal Factors	Political & Governmental Factors	Production Strategy	Network Footprint	Network Management	Susceptibility	Stability	Sensitivity	Span	Speed
Production as a Franchise	x				x	x	x			x				x
Local for Local	x	x				x	x	x		x				
Closed-Loop Manufacturing		x				x	x				x			
Predictive Maintenance		x							x	x				
Decentralized Decision-Making	x			x			x		x			x		x
Multimode Transport	x		x						x					x
Lean on Capital Production	x							x			x		x	
Digital Twin for Production Networks		x	x					x	x			x		

Table 3: Classification of additional measures by addressed influencing factors, enactment level, and resilience mechanism

with low fixed costs and using resources based on flexible leasing models, the reliance of profitability on a specific production volume can be decreased, and the span of feasible volumes is extended.

Digital Twin for Production Networks describes automatically synchronized network models for quantitative decision support (*Benfer et al.* 2019; *Lu et al.* 2020). These tools can help managers to identify problems and opportunities for change and assess the impacts of their decisions.

The aforementioned measures focus on the internal part of a supply chain or production network with a strong focus of production as lever to increase resilience. Furthermore, more digital approaches like the digital twin, predictive maintenance or decentralized decision-making may enhance the possibility to react to external disruptions within company boundaries and, thus, increase resilience.

6 Discussion

The review of existing literature shows that the topic of resilience and, by extension, robustness has been studied extensively in the supply chain-focused community. Several measures exist that focus on changes to the supply chain to enable increased resilience. However, research from the production science community has so far not examined the topic as thoroughly. Thus, through integrating supply chain-focused measures in a production network framework, the applicability of measures in production science can be better understood. Furthermore, based on the framework, additional measures that bear potential for further research were identified. These measures have not received the necessary attention and may enable more resilient production networks in the future.

The framework itself has been created based on theoretical consideration, a practical examination of the framework in different research settings and in the industrial practice is missing. However the authors expect the framework to guide both researchers and practitioners in understanding measures and their influence on production networks. It helps to better distinguish measures to improve resilience by showing which types of issues in global production networks they address. It also structures the mechanisms different measures utilize. The framework may be used both as a research portfolio structuring practical measures and as a specific company resilience portfolio to study and guide the management of a particular company concerning its production network resilience. The activities of the company to achieve resilience can be collected and better understood. Weaknesses and potentials in terms of unaddressed influences or not used mechanisms can be easily identified. Furthermore, measures identified and described in this review may inspire new activities in producing companies. The existing frameworks to structure resilience measures do not yet combine specific measures with generalist system characteristics of production networks and their management.

The selection of considered contributions was limited to one database, but due to a large number of overall approaches, the review succeeded in capturing the most commonly cited measures. The limitation to contributions available for download unfortunately restricts the comprehensiveness of the review. However, since the main purpose of the review was the identification of common measures and their structuring and because the examined sample was still quite large, the results are expected to remain similar even if a larger sample was considered. A review of approaches strictly limited to a production science background may uncover some additional measures. However, due to the large overlap between supply chain and production network research, such a limitation may be difficult to impose. The research method used does not evaluate the efficiency and effectiveness of these measures concerning improving resilience. A large empirical study may enable a more detailed understanding in this regard.

7 Summary and Outlook

This contribution offers a comprehensive overview of resilience measures commonly discussed in production networks and supply chain research. The contributions were selected in a systematic review process, and 17 common measures were identified and illustrated. Based on this, a conceptual framework to structure those measures was developed that describes them by the level of managerial enactment, the influences they address, and the mechanisms they employ to increase resilience. Based on the framework and the observations regarding the body of literature, eight additional measures were proposed.

Additional research is necessary on various aspects. As section 4 showed, the majority of contributions takes a supply chain perspective and as such proposes measures that increase resilience by addressing the flows of goods and information in the network. Though node based measures such as agile factories, technological production flexibility, and scalable production volumes are discussed, they are far less prevalent. Additional research is necessary to better understand how these can contribute to resilience. This research should also extend the focus on additional issues and help make production networks resilient against not just short term supply shortages but slower changes that often have a fundamental influence on a companies continued existence. This research direction ties into the challenge that the possible speed of adaption in production networks is generally slow as new facilities, changed procedures, and new equipment require significant time and investment. Thus, measures on the production network level, that address sensitivity, speed and span are necessary. The development of new production techniques which combine flexibility and efficiency, the modularization of production, and better tools to identify the need for adaption are necessary.

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Literature

Abe, M./Ye, L. (2013): Building Resilient Supply Chains against Natural Disasters: The Cases of Japan and Thailand, in: Global Business Review, 14. Jg., Nr. 4, S. 567–586.

Adenso-Diaz, B., et al. (2012): The impact of supply network characteristics on reliability, in: Supply Chain Management, 17. Jg., Nr. 3, S. 263–276.

Adenso-Díaz, B., et al. (2018): Assessing supply chain robustness to links failure, in: International Journal of Production Research, 56. Jg., Nr. 15, S. 5104–5117.

Adobor, H. (2019): Supply chain resilience: a multi-level framework, in: International Journal of Logistics Research and Applications, 22. Jg., Nr. 6, S. 533–556.

Adobor, H./McMullen, R. S. (2018): Supply chain resilience: a dynamic and multidimensional approach, in: International Journal of Logistics Management, 29. Jg., Nr. 4, S. 1451–1471.

Ali, A., et al. (2017a): Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review, in: Supply Chain Management, 22. Jg., Nr. 1, S. 16–39.

Ali, I., et al. (2017b): Building resilience in SMEs of perishable product supply chains: enablers, barriers and risks, in: Production Planning and Control, 28. Jg., Nr. 15, S. 1236–1250.

Alvarenga, M. Z., et al. (2018): Analytical supply chains: Are they more resilient? A model's proposition, in: Journal of Operations and Supply Chain Management, 11. Jg., Nr. 2, S. 46–58.

Amalnick, M. S./Saffar, M. M. (2017): An integrated approach for supply chain assessment from resilience engineering and ergonomics perspectives, in: Uncertain Supply Chain Management, 5. Jg., Nr. 3, S. 159–168.

Andersson, R., et al. (2014): Lean Six Sigma strategy in telecom manufacturing, in: Industrial Management and Data Systems, 114. Jg., Nr. 6, S. 904–921.

Annarelli, A./Nonino, F. (2016): Strategic and operational management of organizational resilience: Current state of research and future directions, in: Omega (United Kingdom), 62. Jg., S. 1–18.

Azadeh, A., et al. (2014): Modelling and improvement of supply chain with imprecise transportation delays and resilience factors, in: International Journal of Logistics Research and Applications, 17. Jg., Nr. 4, S. 269–282.

Azevedo, S. G., et al. (2013): Ecosilient Index to assess the greenness and resilience of the upstream automotive supply chain, in: Journal of Cleaner Production, 56. Jg., S. 131–146.

Azevedo, S. G., et al. (2016): LARG index: A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain, in: Benchmarking, 23. Jg., Nr. 6, S. 1472–1499.

Bailey, D./Propris, L. de (2014): Reshoring: Opportunities and limits for manufacturing in the UK – The case of the auto sector, in: Revue d'Economie Industrielle, 145. Jg., Nr. 1, S. 45–61.

Belhadi, A., et al. (2021): Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries, in: Technological Forecasting and Social Change, 163. Jg.

Benfer, M., et al. (2019): Determination of the abstraction level in production network models, in: Procedia CIRP, 81. Jg., S. 198–203.

Berle, Ø., et al. (2013): Optimization, risk assessment and resilience in LNG transportation systems, in: Supply Chain Management, 18. Jg., Nr. 3, S. 253–264.

Bevilacqua, M., et al. (2020): Fuzzy cognitive maps approach for analysing the domino effect of factors affecting supply chain resilience: a fashion industry case study, in: International Journal of Production Research, 58. Jg., Nr. 20, S. 6370–6398.

Bhattacharjya, J. (2018): The role of egocentric networks in achieving resilience: a case study from the apparel sector, in: International Journal of Physical Distribution and Logistics Management, 48. Jg., Nr. 7, S. 682–697.

Birkie, S. E., et al. (2017): Effectiveness of resilience capabilities in mitigating disruptions: leveraging on supply chain structural complexity, in: Supply Chain Management, 22. Jg., Nr. 6, S. 506–521.

Bode, C./Macdonald, J. R. (2017): Stages of Supply Chain Disruption Response: Direct, Constraining, and Mediating Factors for Impact Mitigation, in: Decision Sciences, 48. Jg., Nr. 5, S. 836–874.

Brandon-Jones, et al. (2014): A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness (2014) Journal of Supply Chain Management, 50 (3), pp. 55–73.

Brusset, X./Teller, C. (2017): Supply chain capabilities, risks, and resilience, in: International Journal of Production Economics, 184. Jg., S. 59–68.

Bühler, A., et al. (2016): Accounting for external turbulence of logistics organizations via performance measurement systems, in: Supply Chain Management, 21. Jg., Nr. 6, S. 694–708.

Cainelli, G., et al. (2012): Production and financial linkages in inter-firm networks: Structural variety, risk-sharing and resilience, in: Journal of Evolutionary Economics, 22. Jg., Nr. 4, S. 711–734.

Cardoso, S. R., et al. (2015): Resilience metrics in the assessment of complex supply-chains performance operating under demand uncertainty, in: Omega (United Kingdom), 56. Jg., S. 53–73.

Chang, W.-S./Lin, Y.-T. (2019): The effect of lead-time on supply chain resilience performance, in: Asia Pacific Management Review, 24. Jg., Nr. 4, S. 298–309.

Chauhan, V. K., et al. (2021): The relationship between nested patterns and the ripple effect in complex supply networks, in: International Journal of Production Research, 59. Jg., Nr. 1, S. 325–341.

Cheng, J.-H./Lu, K.-L. (2017): Enhancing effects of supply chain resilience: insights from trajectory and resource-based perspectives, in: Supply Chain Management, 22. Jg., Nr. 4, S. 329–340.

Chowdhury, M.M.H./Quaddus, M. (2016): Supply chain readiness, response and recovery for resilience, in: Supply Chain Management, 21. Jg., Nr. 6, S. 709–731.

Chowdhury, M.M.H./Quaddus, M. (2017): Supply chain resilience: Conceptualization and scale development using dynamic capability theory, in: International Journal of Production Economics, 188. Jg., S. 185–204.

Chowdhury, M.M.H./Quaddus, M. A. (2015): A multiple objective optimization based QFD approach for efficient resilient strategies to mitigate supply chain vulnerabilities: The case of garment industry of Bangladesh, in: Omega (United Kingdom), 57. Jg., S. 5–21.

Chowdhury, P., et al. (2021): COVID-19 pandemic related supply chain studies: A systematic review, in: Transportation Research Part E: Logistics and Transportation Review, 148. Jg.

Christopher, M./Holweg, M. (2017): Supply chain 2.0 revisited: a framework for managing volatility-induced risk in the supply chain, in: International Journal of Physical Distribution and Logistics Management, 47. Jg., Nr. 1, S. 2–17.

Christopher, M./Peck, H. (2004): Building the Resilient Supply Chain, in: The International Journal of Logistics Management, 15. Jg., Nr. 2, S. 1–14.

Chukwuekwe, D. O., et al. (2016): Reliable, Robust and Resilient Systems: Towards Development of a Predictive Maintenance Concept within the Industry 4.0 Environment.

Coe, N. M./Yeung, H. W.-C. (2015): Global production networks. Theorizing economic development in an interconnected world, Oxford.

Colicchia, C., et al. (2010): Increasing supply chain resilience in a global sourcing context, in: Production Planning and Control, 21. Jg., Nr. 7, S. 680–694.

Crouch, C. (2003): Local production systems in Europe. Rise or demise?, Oxford.

Danese, P./Vinelli, A. (2009): Supplier network relocation in a capital-intensive context: a longitudinal case study, in: International Journal of Production Research, 47. Jg., Nr. 4, S. 1105–1125.

Dant, S. P. (1996): Ownership structure in franchising: the effects of transaction costs, production costs and strategic considerations, in: The International Review of Retail, Distribution and Consumer Research, 6. Jg., Nr. 1, S. 53–75.

Das, K. (2018): Integrating resilience in a supply chain planning model, in: International Journal of Quality and Reliability Management, 35. Jg., Nr. 3, S. 570–595.

Das, K. (2019): Integrating lean, green, and resilience criteria in a sustainable food supply chain planning model, in: International Journal of Mathematical, Engineering and Management Sciences, 4. Jg., Nr. 2, S. 259–275.

Datta, P. (2017): Supply network resilience: A systematic literature review and future research, in: International Journal of Logistics Management, 28. Jg., Nr. 4, S. 1387–1424.

Dolgui, A., et al. (2018): Ripple effect in the supply chain: an analysis and recent literature, in: International Journal of Production Research, 56. Jg., Nr. 44228, S. 414–430.

Dubey, R., et al. (2021): Empirical investigation of data analytics capability and organizational flexibility as complements to supply chain resilience, in: International Journal of Production Research, 59. Jg., Nr. 1, S. 110–128.

Duong, L.N.K./Chong, J. (2020): Supply chain collaboration in the presence of disruptions: a literature review, in: International Journal of Production Research, 58. Jg., Nr. 11, S. 3488–3507.

Durach, C. F., et al. (2015): Antecedents and dimensions of supply chain robustness: A systematic literature review, in: International Journal of Physical Distribution and Logistics Management, 45. Jg., S. 118–137.

Durach, C. F./Machuca, J.A.D. (2018): A matter of perspective – the role of interpersonal relationships in supply chain risk management, in: International Journal of Operations and Production Management, 38. Jg., Nr. 10, S. 1866–1887.

Ekanayake, E.M.A.C., et al. (2021): Identifying supply chain capabilities of construction firms in industrialized construction, in: Production Planning and Control, 32. Jg., Nr. 4, S. 303–321.

Filkov, A. I., et al. (2020): Impact of Australia's catastrophic 2019/20 bushfire season on communities and environment. Retrospective analysis and current trends, in: Journal of Safety Science and Resilience, 1. Jg., Nr. 1, S. 44–56.

Friedli, T., et al. (2014): Strategic management of global manufacturing networks. Aligning strategy, configuration, and coordination, Heidelberg, New York, NY, Dordrecht, London, Berlin.

Fujimoto, T./Park, Y. W. (2014): Balancing supply chain competitiveness and robustness through "virtual dual sourcing": Lessons from the Great East Japan Earthquake, in: International Journal of Production Economics, 147. Jg., PART B, S. 429–436.

Ganebnykh, E., et al. (2018): Franchising technologies for sustainable economic development, in: MATEC Web of Conferences, 170. Jg., Nr. 1, S. 1044.

Gaur, J., et al. (2020): The impact of supply chain disruption on the closed-loop supply chain configuration profit: a study of sourcing policies, in: International Journal of Production Research, 58. Jg., Nr. 17, S. 5380–5400.

Gimenez-Escalante, P., et al. (2020): A method to assess the feasibility of implementing distributed Localised Manufacturing strategies in the food sector, in: Journal of Cleaner Production, 266. Jg.

Golan, M. S., et al. (2020): Trends and applications of resilience analytics in supply chain modeling: systematic literature review in the context of the COVID-19 pandemic, in: Environment systems & decisions, S. 1–22.

Golgeci, I./Ponomarov, S. Y. (2013): Does firm innovativeness enable effective responses to supply chain disruptions? An empirical study, in: Supply Chain Management, 18. Jg., Nr. 6, S. 604–617.

Golicic, S. L., et al. (2017): Building business sustainability through resilience in the wine industry, in: International Journal of Wine Business Research, 29. Jg., Nr. 1, S. 74–97.

Gunasekaran, A., et al. (2015): Supply chain resilience: Role of complexities and strategies, in: International Journal of Production Research, 53. Jg., Nr. 22, S. 6809–6819.

Gunessee, S., et al. (2018): Natural disasters, PC supply chain and corporate performance, in: International Journal of Operations and Production Management, 38. Jg., Nr. 9, S. 1796–1814.

Han, Y., et al. (2020): A systematic literature review of the capabilities and performance metrics of supply chain resilience, in: International Journal of Production Research, S. 1–26.

Hasani, A./Khosrojerdi, A. (2016): Robust global supply chain network design under disruption and uncertainty considering resilience strategies: A parallel memetic algorithm for a real-life case study, in: Transportation Research Part E: Logistics and Transportation Review, 87. Jg., S. 20–52.

Hearnshaw, E.J.S./Wilson, M.M.J. (2013): A complex network approach to supply chain network theory, in: International Journal of Operations and Production Management, 33. Jg., Nr. 4, S. 442–469.

Heckmann, I., et al. (2015): A critical review on supply chain risk – Definition, measure and modeling, in: Omega (United Kingdom), 52. Jg., S. 119–132.

Hohenstein, N.-O., et al. (2015): Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation, in: International Journal of Physical Distribution and Logistics Management, 45. Jg., S. 90–117.

Huang, A./Farboudi, J. M. (2021): Resilience building in service firms during and post COVID-19 [COVID-19 疫情之下的服务业的弹性], in: Service Industries Journal, 41. Jg., Nr. 44228, S. 138–167.

Huatuco, L. H., et al. (2010): Entropic-related complexity for re-engineering a robust supply chain: A case study, in: Production Planning and Control, 21. Jg., Nr. 8, S. 724–735.

Ishfaq, R. (2012): Resilience through flexibility in transportation operations, in: International Journal of Logistics Research and Applications, 15. Jg., Nr. 4, S. 215–229.

Itakura, K. (2020): Evaluating the Impact of the US–China Trade War, in: Asian Economic Policy Review, 15. Jg., Nr. 1, S. 77–93.

Ivanov, D., et al. (2016): Dynamic recovery policies for time-critical supply chains under conditions of ripple effect, in: International Journal of Production Research, 54. Jg., Nr. 23, S. 7245–7258.

Ivanov, D., et al. (2017a): Literature review on disruption recovery in the supply chain*, in: International Journal of Production Research, 55. Jg., Nr. 20, S. 6158–6174.

Ivanov, D. (2017b): Simulation-based ripple effect modelling in the supply chain, in: International Journal of Production Research, 55. Jg., Nr. 7, S. 2083–2101.

Ivanov, D. (2018): Revealing interfaces of supply chain resilience and sustainability: a simulation study, in: International Journal of Production Research, 56. Jg., Nr. 10, S. 3507–3523.

Ivanov, D., et al. (2019): The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics, in: International Journal of Production Research, 57. Jg., Nr. 3, S. 829–846.

Ivanov, D. (2020): ‘A blessing in disguise’ or ‘as if it wasn’t hard enough already’: reciprocal and aggravate vulnerabilities in the supply chain, in: International Journal of Production Research, 58. Jg., Nr. 11, S. 3252–3262.

Ivanov, D./Das, A. (2020): Coronavirus (COVID-19/SARS-CoV-2) and supply chain resilience: A research note, in: International Journal of Integrated Supply Management, 13. Jg., Nr. 1, S. 90–102.

Ivanov, D./Dolgui, A. (2019): Low-Certainty-Need (LCN) supply chains: a new perspective in managing disruption risks and resilience, in: International Journal of Production Research, 57. Jg., 15–16, S. 5119–5136.

Iyer, K.N.S. (2011): Demand chain collaboration and operational performance: Role of IT analytic capability and environmental uncertainty, in: Journal of Business and Industrial Marketing, 26. Jg., Nr. 2, S. 81–91.

Jabilles, E.M.Y., et al. (2019): Simulating the impact of inventory on supply chain resilience with an algorithmic process based on the supply-side dynamic inoperability input–output model, in: International Journal of Management Science and Engineering Management, 14. Jg., Nr. 4, S. 253–263.

Johnson, N., et al. (2013): Exploring the role of social capital in facilitating supply chain resilience, in: Supply Chain Management, 18. Jg., Nr. 3, S. 324–336.

Jüttner, U./Maklan, S. (2011): Supply chain resilience in the global financial crisis: An empirical study, in: Supply Chain Management, 16. Jg., Nr. 4, S. 246–259.

Kahiluoto, H., et al. (2020): Supplying resilience through assessing diversity of responses to disruption, in: International Journal of Operations and Production Management, 40. Jg., Nr. 3, S. 271–292.

Kamalahmadi, M./Parast, M. M. (2016): A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research, in: International Journal of Production Economics, 171. Jg., S. 116–133.

Khalili, S. M., et al. (2017): Integrated production–distribution planning in two-echelon systems: a resilience view, in: International Journal of Production Research, 55. Jg., Nr. 4, S. 1040–1064.

Khan, O., et al. (2012): Aligning product design with the supply chain: A case study, in: Supply Chain Management, 17. Jg., Nr. 3, S. 323–336.

Khemiri, R., et al. (2017): A fuzzy multi-criteria decision-making approach for managing performance and risk in integrated procurement–production planning, in: International Journal of Production Research, 55. Jg., Nr. 18, S. 5305–5329.

Klenk, F., et al. (2020): Approach for developing implementation strategies for circular economy in global production networks, in: *Brissaud, D. et al.* (Hrsg.): 27th CIRP Life Cycle Engineering Conference (LCE 2020). Advancing Life Cycle Engineering: from technological eco-efficiency to technology that supports a world that meets the development goals and the absolute sustainability, Bd. 90, S. 127–132.

Klibi, W./Martel, A. (2013): The design of robust value-creating supply chain networks, in: OR Spectrum, 35. Jg., Nr. 4, S. 867–903.

Kochan, C. G./Nowicki, D. R. (2018): Supply chain resilience: a systematic literature review and typological framework, in: International Journal of Physical Distribution and Logistics Management, 48. Jg., Nr. 8, S. 842–865.

Komoto, H., et al. (2011): Analyzing supply chain robustness for OEMs from a life cycle perspective using life cycle simulation, in: International Journal of Production Economics, 134. Jg., Nr. 2, S. 447–457.

Kumar, S., et al. (2013): Risk assessment and operational approaches to managing risk in global supply chains, in: Journal of Manufacturing Technology Management, 25. Jg., Nr. 6, S. 873–890.

Kwak, D.-W., et al. (2018): Investigating the relationship between supply chain innovation, risk management capabilities and competitive advantage in global supply chains, in: International Journal of Operations and Production Management, 38. Jg., Nr. 1, S. 2–21.

Lam, J.S.L./Bai, X. (2016): A quality function deployment approach to improve maritime supply chain resilience, in: Transportation Research Part E: Logistics and Transportation Review, 92. Jg., S. 16–27.

Lanza, G., et al. (2019): Global production networks: Design and operation, in: CIRP Annals, 68. Jg., Nr. 2, S. 823–841.

Lanza, G., et al. (2020): Transformation globaler Produktionsnetzwerke, in: ZWF Zeitschrift für wirtschaftlichen Fabrikbetrieb, 115. Jg., Nr. 4, S. 196–199.

Leat, P./Revoredo-Giha, C. (2013): Risk and resilience in agri-food supply chains: The case of the ASDA PorkLink supply chain in Scotland, in: Supply Chain Management, 18. Jg., Nr. 2, S. 219–231.

Li, H.-H.J.K., et al. (2011): Sustaining growth in electronic manufacturing sector: Lessons from Japanese mid-size EMS providers, in: International Journal of Production Research, 49. Jg., Nr. 18, S. 5415–5430.

Li, X., et al. (2017): An empirical examination of firm financial performance along dimensions of supply chain resilience, in: Management Research Review, 40. Jg., Nr. 3, S. 254–269.

Li, Y./Zobel, C. W. (2020): Exploring supply chain network resilience in the presence of the ripple effect, in: International Journal of Production Economics, 228. Jg., S. 107693.

Loh, H. S./van Thai, V. (2014): Managing port-related supply chain disruptions: A conceptual paper, in: Asian Journal of Shipping and Logistics, 30. Jg., Nr. 1, S. 97–116.

Lohr, S. (2011): Stress Test for the Global Supply Chain, in: The New York Times.

Lotfi, M./Saghiri, S. (2018): Disentangling resilience, agility and leanness Conceptual development and empirical analysis, in: Journal of Manufacturing Technology Management, 29. Jg., Nr. 1, S. 168–197.

Lu, Y., et al. (2020): Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues, in: Robotics and Computer-Integrated Manufacturing, 61. Jg., S. 101837.

Lücker, F./Seifert, R. W. (2017): Building up Resilience in a Pharmaceutical Supply Chain through Inventory, Dual Sourcing and Agility Capacity, in: Omega (United Kingdom), 73. Jg., S. 114–124.

Lund, K. A./Benediktsson, K. (2011): Inhabiting a risky earth: The Eyjafjallajökull eruption in 2010 and its impacts (Respond to this article at http://www.therai.org.uk/at/debate), in: Anthropology Today, 27. Jg., Nr. 1, S. 6–9.

Macdonald, J. R., et al. (2018): Supply chain risk and resilience: theory building through structured experiments and simulation, in: International Journal of Production Research, 56. Jg., Nr. 12, S. 4337–4355.

Mandal, S. (2017): The influence of organizational culture on healthcare supply chain resilience: moderating role of technology orientation, in: Journal of Business and Industrial Marketing, 32. Jg., Nr. 8, S. 1021–1037.

Mandal, S./Sarathy, R. (2018): The Effect of Supply Chain Relationships on Resilience: Empirical Evidence from India, in: Global Business Review, 19. Jg., 3_suppl, S196-S217.

Mangla, S. K., et al. (2014): A flexible decision framework for building risk mitigation strategies in green supply chain using SAP-LAP and IRP approaches, in: Global Journal of Flexible Systems Management, 15. Jg., Nr. 3, S. 203–218.

Manning, L./Soon, J. M. (2016): Building strategic resilience in the food supply chain, in: British Food Journal, 118. Jg., Nr. 6, S. 1477–1493.

Maritan, C. A., et al. (2004): Plant roles and decision autonomy in multinational plant networks, in: Journal of Operations Management, 22. Jg., Nr. 5, S. 489–503.

Matsuo, H. (2015): Implications of the Tohoku earthquake for Toyota's coordination mechanism: Supply chain disruption of automotive semiconductors, in: International Journal of Production Economics, 161. Jg., S. 217–227.

McDonald, F., et al. (2008): Autonomy, Embeddedness, and the Performance of Foreign Owned Subsidiaries, in: Multinational Business Review, 16. Jg., Nr. 3, S. 73–92.

Moher, D., et al. (2009): Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, in: PLoS medicine, Vol. 6, No. 7, e1000097.

Namdar, J., et al. (2018): Supply chain resilience for single and multiple sourcing in the presence of disruption risks, in: International Journal of Production Research, 56. Jg., Nr. 6, S. 2339–2360.

Nejad, A. E./Kuzgunkaya, O. (2015): On the value of response time characteristics in robust design of supply flow, in: Journal of Manufacturing Technology Management, 26. Jg., Nr. 2, S. 213–230.

Norrman, A./Wieland, A. (2020): The development of supply chain risk management over time: revisiting Ericsson, in: International Journal of Physical Distribution and Logistics Management, 50. Jg., Nr. 6, S. 641–666.

Pal, R./Torstensson, H. (2011): Aligning critical success factors to organizational design: A study of Swedish textile and clothing firms, in: Business Process Management Journal, 17. Jg., Nr. 3, S. 403–436.

Papadopoulos, T., et al. (2017): The role of Big Data in explaining disaster resilience in supply chains for sustainability, in: Journal of Cleaner Production, 142. Jg., S. 1108–1118.

Park, K. T., et al. (2020): The architectural framework of a cyber physical logistics system for digital-twin-based supply chain control, in: International Journal of Production Research, S. 1–22.

Passath, T./Mertens, K. (2019): Decision Making in Lean Smart Maintenance: Criticality Analysis as a Support Tool, in: IFAC-PapersOnLine, 52. Jg., Nr. 10, S. 364–369.

Pereira, C. R., et al. (2014): Achieving supply chain resilience: the role of procurement, in: Supply Chain Management, 19. Jg., S. 626–642.

Pettit, et al. (2010): Ensuring Supply Chain Resilience: Development of a Conceptual Framework (2010) Journal of Business Logistics, 31 (1), pp. 1–21.

Peukert, S., et al. (2020): Towards Increasing Robustness in Global Production Networks by Means of an Integrated Disruption Management, in: Procedia CIRP, 93. Jg., S. 706–711.

Ponis, S. T./Koronis, E. (2012): Supply chain resilience: Definition of concept and its formative elements, in: Journal of Applied Business Research, 28. Jg., Nr. 5, S. 921–930.

Purvis, L., et al. (2016): Developing a resilient supply chain strategy during 'boom' and 'bust', in: Production Planning and Control, 27. Jg., Nr. 44415, S. 579–590.

Rajesh, R., et al. (2015): Selection of risk mitigation strategy in electronic supply chains using grey theory and digraph-matrix approaches, in: International Journal of Production Research, 53. Jg., Nr. 1, S. 238–257.

Rajesh, R. (2016): Forecasting supply chain resilience performance using grey prediction, in: Electronic Commerce Research and Applications, 20. Jg., S. 42–58.

Rajesh, R./Ravi, V. (2015): Supplier selection in resilient supply chains: A grey relational analysis approach, in: Journal of Cleaner Production, 86. Jg., S. 343–359.

Ralston, P./Blackhurst, J. (2020): Industry 4.0 and resilience in the supply chain: a driver of capability enhancement or capability loss?, in: International Journal of Production Research, 58. Jg., Nr. 16, S. 5006–5019.

Rist, L., et al. (2014): Applying resilience thinking to production ecosystems, in: Ecosphere, 5. Jg., Nr. 6, art73.

Sá, M. M. de, et al. (2018): The role of collaboration for resilience of the sugarcane-energy supply chain, in: Journal of Operations and Supply Chain Management, 11. Jg., Nr. 1, S. 64–79.

Sabahi, S./Parast, M. M. (2020): Firm innovation and supply chain resilience: a dynamic capability perspective, in: International Journal of Logistics Research and Applications, 23. Jg., Nr. 3, S. 254–269.

Sabouhi, F., et al. (2020): A multi-cut L-shaped method for resilient and responsive supply chain network design, in: International Journal of Production Research, S. 1–29.

Sahu, A. K., et al. (2016): Evaluation and selection of resilient suppliers in fuzzy environment: Exploration of fuzzy-VIKOR, in: Benchmarking, 23. Jg., Nr. 3, S. 651–673.

Sahu, A. K., et al. (2017): Evaluation of performance index in resilient supply chain: a fuzzy-based approach, in: Benchmarking, 24. Jg., Nr. 1, S. 118–142.

Salehi, S. N., et al. (2015): Retail supply chain network design under operational and disruption risks, in: Transportation Research Part E: Logistics and Transportation Review, 75. Jg., S. 95–114.

Sanctis, I. de, et al. (2018): Resilience for lean organisational network, in: International Journal of Production Research, 56. Jg., Nr. 21, S. 6917–6936.

Sawik/T. (2013): Selection of resilient supply portfolio under disruption risks (2013) Omega, 41 (2), pp. 259–269.

Scavarda, L. F., et al. (2015): Supply chain resilience analysis: A Brazilian automotive case, in: RAE Revista de Administracao de Empresas, 55. Jg., Nr. 3, S. 304–313.

Schmitt, A. J./Singh, M. (2012): A quantitative analysis of disruption risk in a multi-echelon supply chain, in: International Journal of Production Economics, 139. Jg., Nr. 1, S. 22–32.

Scholten, K., et al. (2014): Mitigation processes – antecedents for building supply chain resilience, in: Supply Chain Management, 19. Jg., Nr. 2, S. 211–228.

Scholten, K., et al. (2019): Building routines for non-routine events: supply chain resilience learning mechanisms and their antecedents, in: Supply Chain Management, 24. Jg., Nr. 3, S. 430–442.

Scholten, K./Schilder, S. (2015): The role of collaboration in supply chain resilience, in: Supply Chain Management, 20. Jg., Nr. 4, S. 471–484.

Schönsleben, P. (2016): Integral Logistics Management. Operations and Supply Chain Management Within and Across Companies, Fifth Edition. 5th ed., Boca Raton.

Schuh, G., et al. (2018): Reduction of Decision Complexity as an Enabler for Continuous Production Network Design, in: *Moon, I. et al.* (Hrsg.): Advances in Production Management Systems. Production Management for Data-Driven, Intelligent, Collaborative, and Sustainable Manufacturing, Bd. 535, Cham, S. 246–253.

Sedita, S. R./Noni, I. de/*Pilotti, L.* (Hrsg.) (2014): How do related variety and differentiated knowledge bases influence the resilience of local production systems?, Padova.

Sharma, S. K./George, S. A. (2018): Modelling resilience of truckload transportation industry, in: Benchmarking, 25. Jg., Nr. 7, S. 2531–2545.

Sheffi, Y./Rice Jr., J. B. (2005): A Supply Chain View of the Resilient Enterprise, in: MIT Sloan Management Review, 47. Jg.

Shi, X.-Q., et al. (2020): Research on supply network resilience considering random and targeted disruptions simultaneously, in: International Journal of Production Research, 58. Jg., Nr. 21, S. 6670–6688.

Shin, N./Park, S. (2021): Supply chain leadership driven strategic resilience capabilities management: A leader-member exchange perspective, in: Journal of Business Research, 122. Jg., S. 1–13.

Shqairat, A./Sundarakani, B. (2018): An empirical study of oil and gas value chain agility in the UAE, in: Benchmarking, 25. Jg., Nr. 9, S. 3541–3569.

Singh, R. K., et al. (2018): Analysing the interaction of factors for resilient humanitarian supply chain, in: International Journal of Production Research, 56. Jg., Nr. 21, S. 6809–6827.

Siva, K. P./Anbanandam, R. (2020): Theory Building on Supply Chain Resilience: A SAP–LAP Analysis, in: Global Journal of Flexible Systems Management, 21. Jg., Nr. 2, S. 113–133.

Stone, J./Rahimifard, S. (2018): Resilience in agri-food supply chains: a critical analysis of the literature and synthesis of a novel framework, in: Supply Chain Management, 23. Jg., Nr. 3, S. 207–238.

Stricker, N., et al. (2015): Supporting multi-level and robust production planning and execution, in: CIRP Annals, 64. Jg., Nr. 1, S. 415–418.

Tan, R. R., et al. (2016): A fuzzy linear programming enterprise input–output model for optimal crisis operations in industrial complexes, in: International Journal of Production Economics, 181. Jg., S. 410–418.

Tan, W. J., et al. (2019): A graph-based model to measure structural redundancy for supply chain resilience, in: International Journal of Production Research, 57. Jg., Nr. 20, S. 6385–6404.

Tan, W. J., et al. (2020): Structural-aware simulation analysis of supply chain resilience, in: International Journal of Production Research, 58. Jg., Nr. 17, S. 5175–5195.

Tang/C.S. (2006): Robust strategies for mitigating supply chain disruptions (2006) International Journal of Logistics: Research and Applications, 9 (1), pp. 33–45.

Thun, J.-H./Hoenig, D. (2011): An empirical analysis of supply chain risk management in the German automotive industry, in: International Journal of Production Economics, 131. Jg., Nr. 1, S. 242–249.

Torabi, S. A., et al. (2015): Resilient supplier selection and order allocation under operational and disruption risks, in: Transportation Research Part E: Logistics and Transportation Review, 79. Jg., S. 22–48.

Tukamuhabwa, B., et al. (2017): Supply chain resilience in a developing country context: a case study on the interconnectedness of threats, strategies and outcomes, in: Supply Chain Management, 22. Jg., Nr. 6, S. 486–505.

Tukamuhabwa, B. R., et al. (2015): Supply chain resilience: Definition, review and theoretical foundations for further study, in: International Journal of Production Research, 53. Jg., Nr. 18, S. 5592–5623.

Urciuoli, L., et al. (2014): The resilience of energy supply chains: A multiple case study approach on oil and gas supply chains to Europe, in: Supply Chain Management, 19. Jg., Nr. 1, S. 46–63.

Valipour, P. S./Safaei, G. A. (2017): A resilience approach for supplier selection: Using Fuzzy Analytic Network Process and grey VIKOR techniques, in: Journal of Cleaner Production, 161. Jg., S. 431–451.

Váncza, J. (2014): Production Networks, in: *Laperrière, L./ Reinhart, G.* (Hrsg.): CIRP encyclopedia of production engineering, Berlin, S. 1–8.

Verhaelen, B., et al. (2021): Methodology for the strategy-oriented distribution of decision autonomy in global production networks, in: Procedia CIRP, 96. Jg., Nr. 2, S. 15–20.

Versaevel, B. (2002): Co-ordination costs and vertical integration in production franchise networks: a common agency model, in: Research in Economics, 56. Jg., Nr. 2, S. 157–186.

Vlajic, J. V., et al. (2012): A framework for designing robust food supply chains, in: International Journal of Production Economics, 137. Jg., Nr. 1, S. 176–189.

Wan, C., et al. (2018): Resilience in transportation systems: a systematic review and future directions, in: Transport Reviews, 38. Jg., Nr. 4, S. 479–498.

Wieland, A./Wallenburg, C. M. (2013): The influence of relational competencies on supply chain resilience: A relational view, in: International Journal of Physical Distribution and Logistics Management, 43. Jg., Nr. 4, S. 300–320.

Wieteska, G. (2020): The impact of supplier involvement in product development on supply chain risks and supply chain resilience, in: Operations and Supply Chain Management, 13. Jg., Nr. 4, S. 359–374.

Xu, M., et al. (2014): Predicted supply chain resilience based on structural evolution against random supply disruptions, in: International Journal of Systems Science: Operations and Logistics, 1. Jg., Nr. 2, S. 105–117.

Yavari, M./Zaker, H. (2019): An integrated two-layer network model for designing a resilient green-closed loop supply chain of perishable products under disruption, in: Journal of Cleaner Production, 230. Jg., S. 198–218.

Yuan, L., et al. (2015): Advertising and pricing decisions in a manufacturer-retailer channel with demand and cost disruptions, in: International Journal of Information Systems and Supply Chain Management, 8. Jg., Nr. 3, S. 44–66.

Zamanian, M. R., et al. (2020): A multi-objective optimization model for the resilience and sustainable supply chain: A case study, in: International Journal of Supply and Operations Management, 7. Jg., Nr. 1, S. 51–75.

Zeng, B./Yen, B.P.-C. (2017): Rethinking the role of partnerships in global supply chains: A risk-based perspective, in: International Journal of Production Economics, 185. Jg., S. 52–62.

Martin Benfer, M.Sc., is a Doctoral Student at the wbk Institute of Production Science at Karlsruhe Institute of Technology (KIT).

Bastian Verhaelen, M.Sc. M.Sc., is a Doctoral Student at the wbk Institute of Production Science at Karlsruhe Institute of Technology (KIT).

Sina Peukert, M.Sc., is a Group Leader at the wbk Institute of Production Science at Karlsruhe Institute of Technology (KIT).

Gisela Lanza, Prof. Dr.-Ing. is the Director of Production Systems Division at the wbk Institute of Production Science at Karlsruhe Institute of Technology (KIT).

Address: Karlsruhe Institute of Technology (KIT), wbk Institute of Production Science, Kaiserstrasse 12, D-76131 Karlsruhe, Tel.: +49 1523 950 2651, Mail: martin.benfer@kit.edu