

Digital? Local? Transparent? – Six truths of supply chains after Covid-19

Christina Schabasser

University of Applied Sciences Burgenland

christina.schabasser@live.at

Abstract

Supply chains were and always will be exposed to risks. The increasing complexity of today's supply chains pose the greatest challenges to supply chain management. Disruptions of the supply chain caused by disasters (e.g., the Covid-19 pandemic) indicates that the inter-organizational interaction between purchasing, production and logistics on a mostly global level does not work as smoothly as assumed. Although, there were serious disasters with dire effects on global supply chains even before Covid-19, supply chains have hardly lost any of their complexity or gained in transparency. Therefore, it is important to address this issue with the utmost urgency to make supply chains more resilient. The article aims to answer the question how the supply chains of the future could look like. Six levers for restructuring or redesigning supply chains are presented in this paper, for example, higher safety stocks and a diversified supplier portfolio. Even if the supply chains known to us will not cease to exist, current practices will certainly be reassessed. A conceptual model and its visualization opportunities is used to illustrate how a supply chain is skipped out of balance. It forces the reader to think about solutions to stabilize supply chains, resulting in a new (extended or deeper) understanding of phenomena for interested people, supply chain managers, practitioners, and researchers in this field.

Keywords: Supply chain disruption, Covid-19 pandemic, conceptual model



1. Introduction

Worldwide, the manufacturing processes are divided into different phases and carried out in different parts of the world, which are often far away from the consumer of the finished products. Supply chains around the world are stimulated by the idea of cost optimization, cost-cutting, and just-in-time production. Holding excessive inventories is often seen as a sign of waste (Javorcik, 2020). The growth of global supply chains resulted in an increasing specialization of companies in certain activities and phases in supply chains instead of taking care of all the subtasks. The huge importance of (global) supply chains is evidenced by the fact that over 70% of global trade results from intermediate goods and services and capital goods (OECD, WTO, World Bank Group, 2014). Nowadays, there is an ever-decreasing vertical range of manufacture. In return, this means that company's hand over responsibility, as fewer services are produced from in-house production.

The more complex and therefore intertwined and international the nature of supply chains, the more vulnerable they are to risks such as natural disasters, strikes and terrorism (Bundschuh, 2003). There seems to be a causal relationship between the complexity of the supply chain and the severity of an interruption. There is no such thing as a risk-free supply chain, therefore, supply chain disruptions are unavoidable; but some supply chain disruptions are more serious than others, which has to do with the complexity of a supply chain (Blackhurst et al, 2005). The growing number of disasters over the past decades should be enough reason to reflect on how resilient supply chains can be achieved in future. Figure 1 shows the exponential growth in natural and man-made (e.g., terrorist attacks) disasters over the years.

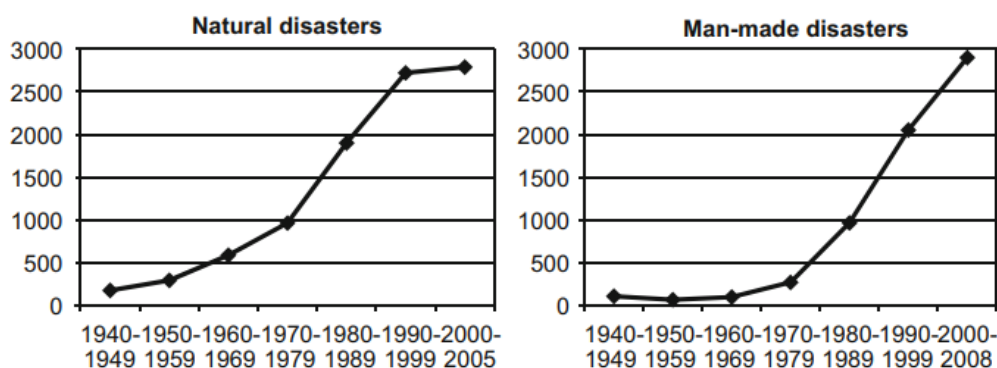


Figure 1. Distribution of natural and man-made disasters from 1940 to 2005

Source: Centre for Research on the Epidemiology of Disasters, 2004

Just-in-time (JIT) production, which is standardized in many industries, assumes that the supply chains always perform exactly as planned. Although, JIT is not a panacea to unplanned changes in the requirements that will be transmitted to the entire supply chain. JIT can be a successful concept in case of stable and predictable demand, but disastrous when everyone in the supply chain is only familiar with a certain part of production and therefore cannot take care of problem solving themselves in the event of a failure (Nahmias et al., 2015). As companies' supply chains become more complex and distributed, it becomes more difficult to establish transparent supply chains, but transparency in the supply chains would be important so that companies can understand them and reduce the inherent risk potential. If a company

does not know which suppliers are in its supply chain and then the supply chain of a company is interrupted, it can at least react and replenish the supply or replace the supplier. When this response is not possible due to a lack of transparency, the brand reputation of the company which is affected by the disruption in the supply chain suffers. Different stakeholder groups call for better visualization of suppliers and the flow of inputs, goods and services in a given supply chain (Kashmanian, 2017). The collapse in performance in China provoked by the Covid-19 pandemic and its worldwide impact showed once again the vulnerability of global supply chains. Whereas the end of globalization will hardly be a topic for debate, it is important to think about the supply chains of the future so that global manufacturing does not get further into a downward spiral (Holger et al., 2020). A survey from 2020 carried out by the Austrian Federal Economic Chamber provides information about the resilience of supplier networks of Austrian companies. It is worth mentioning that the questionnaires had to be submitted by mid-April 2020, in the middle of the Covid-19 pandemic. The study has shown how dependent Austrian companies of all sizes are on their suppliers and what disastrous consequences this has. Alarmingly, more than a third (1/3) of the companies surveyed stated that they had at least one supplier whose failure would lead to a complete business breakdown (Complexity Science Hub, 2020). Do resilient supply chains have a lot to do with fantasy and little to do with reality? The limitation or failure of production due to the lack of preliminary products caused by the Covid-19 pandemic gives rise to doubts about the international division of labor. Companies are strongly integrated into international supply chains when their products are based on inputs from specialized suppliers from all over the world (Bunde, 2021). The result for companies that focus too much on cost efficiency and less on security of supply becomes dramatically clear in the event of a collapse (Bogaschewsky, 2020).

Within the present work, the terms value chain and supply chain are understood as synonyms. There is no hard line to distinguish between supply chains and value chains. The difference could be determined by the fact that in supply chain relationships, one looks at the import of intermediate inputs and in the value chain one looks at the import of added value. Take the (fictive) example of VW Wolfsburg that imports automobile wheels from Poland, consisting of rims and car tires worth 100 euros each, Steel and light metal come from China (40 euros), valves from South Korea (10 euros), car tires from Japan (30 euros), the value of the assembly in Poland (20 euros). When looking at the intermediate inputs it can be stated that Germany imports inputs worth 100 euros from Poland (and it is completely dependent on Poland for car wheel deliveries). Considering the value-added imports, one can say that Germany imports value added worth 20 euros from Poland and the rest from the other countries mentioned. Here it becomes clear that Germany is depending on several countries for the supply of automobile wheels. If all of this can be assembled in Germany without major additional costs, one would not have to rely on imports from Poland at all, but only on imports from China, South Korea, and Japan (Petersen, T., email communication, May 16th, 2021).

2. Literature

2.1. Managing supply chain complexity

Before starting a more in-depth discussion, it makes sense to demonstrate the complexity of a supply chain. A complete supply chain can be imagined as a connection between nodes (organizational units) and arcs (all internodal relationships between the place of origin and the place of end use). The supply chain of manufacturer Z (see fig.2) includes different entities

(i.e., firms) which are linked by a physical flow of materials. If one imagines that manufacturer Z replaces a supplier with a poor performance by another, then this leads to a restructuring of the essence of the supply chain itself (Blackhurst et al., 2005).

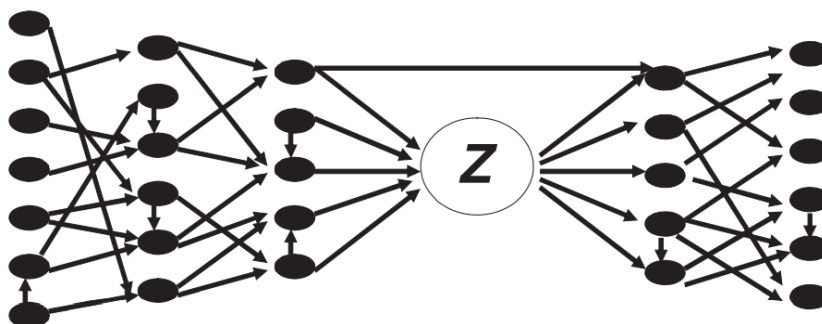


Figure 2: Supply chain structure for manufacturer Z

Source: Blackhurst et al., 2005

There are various forms of complexity in a supply chain, on the one hand, there is the static complexity that describes the connectivity and structure of the subsystems contributing to the supply chain (e.g., companies, business functions and processes). It is important to keep an eye on not only the structural but also the dynamic complexity stemming from the operating behavior of the system and its environment that addresses the factors time and randomness. Finally, there is also the complexity of decision-making, which includes elements of both structural and dynamic complexity, the inherent complexity in supply chain makes it difficult to manage them and therefore it is by no means inconsequential to claim that supply chain management is about managing the complexity of the supply chains. A supply chain complexity driver is any characteristic of a supply chain that heightens the supply chain complexity. Examples of static complexity drivers are number /variety of products and processes. Process uncertainties is an example of dynamic complexity. The decision as to whether a supply chain should be managed by a centralized or decentralized decision making or to what extent decision-making is automated, is part of the decision-making complexity (SerdarAsan, 2013).

2.2. Redundancy: a source of resilience

Sheffi et al. (2005) assume that the resilience of a supply chain, i.e., how quickly a supply chain is functional again after a disruption, can be achieved through redundancy or flexibility. Redundancy can be generated by multiple sourcing or safety stock. Additional suppliers as well as safety stocks are associated with costs, but this cost of redundancy should be seen as a sort of insurance premium.

2.2.1. Multiple Sourcing

At the latest after the outbreak of the Covid-19 pandemic, the word "redundancy" found its way into the supply chain vocabulary. Robustness or resilience of supply chains require redundancy in suppliers. The so-called supplier diversification can strengthen the "immune system" of the supply chain. If one supplier fails, another one can jump in and fix the

problem. This would be one of the advantages of a diversified supplier base. On the other hand, one must also consider that a less diversified pool of suppliers can also be advantageous. The higher purchasing volumes at concentrated supplier base also give buyers the opportunity to make investments that ensure a rapid recovery of the supply chain in the event of a disruption. Does the sourcing from many different suppliers enable faster recovery in the event of a disruption? Further influencing factors could also be the depth of the relationship to the suppliers (Jain et al., 2020). Berger et al 2004 investigate the question of whether one should opt for a single or multiple sourcing strategy from the point of view of risk management. The question is how high the number of suppliers should be to guarantee the functionality of the supply chain even in the event of a catastrophe? The authors present a decision-tree based on optimization model to evaluate both procurement strategies and differentiate between so-called "super-events" that affect all suppliers at the same time and so-called "unique-events" that only affect a specific supplier in the supply chain and calculate the probabilities for the occurrence of such "events". They find that the number of suppliers stays stable when the risk of super-events affecting suppliers is low. It also found that the optimal number of suppliers increases when the risk of events affecting suppliers increases significantly (Berger et al., 2004). According to the Institute for Supply Chain Management, the responses from companies to the Covid-19 pandemic suggest that much more attention is paid to the supply base and that risk diversification is sought by qualifying alternative and / or additional suppliers (Institute for Supply Management).

2.2.2. Safety Stocks

Since redundancy is to be understood in such a way that resources are kept in reserve for the event of a fault, safety stocks, besides the use of multiple suppliers, are also a common form of the redundancy concept (Sheffi et al., 2005). Although the JIT principle undoubtedly has its advantages, it is designed for nominal operation and not for interruptions. In the future, companies will concentrate more on ensuring operational continuity than on the issues of waste and inefficiencies. That would mean that in the future, companies would keep enough inventories to counter uncertainties in supply and demand. The issues of efficiency, flexibility, resilience, and reliability have no longer be trade-off. "Just in Case" means that companies create contingency plans for crisis scenarios and agree on higher procurement costs, accept longer times of delivery, and put more emphasis on reliability than on cost-effectiveness when selecting suppliers (Fonseca et al., 2020). Relatively at the beginning of the Covid-19 pandemic, it was already apparent how quickly efficient, cost-effective just-in-time production can develop into a cost-intensive, high-risk strategy. To be better prepared to global shocks like Covid-19 in the future, companies will probably have to reduce their dependence on global production chains and intermediate deliveries by holding larger inventories or buffers at or near their production location (Brakman et al., 2020).

2.3. Flexibility: an important resilience factor

Flexibility can be seen as the lever for resilient supply chains, if one realizes once again that the resilience of a supply chain can be generated through redundancy and flexibility, then one certainly has more opportunity to generate resilience by pressing the "flexibility lever". In a supply chain, the material flow from the supplier takes place through a conversion process as well as distribution channels and is governed by various systems that all work in terms of the corporate culture. Each of the five elements supply, conversion, distribution, control systems and corporate culture gives room for flexibility.

2.4. IT and digitization

The complexity of today's supply chains would probably not function without information technology and digitization. There are several advantages that IT and digitization create for supply chains. Examples include the reduction in cycle time, higher efficiency, higher performance and the traceability and visibility of the product flow. Despite these advantages that IT and digitization offer for supply chains, doubts can arise, especially in times of major disruptions such as the corona pandemic. (Gupta et al., 2020).

Table 1 gives an overview of main digitization tools used in Supply Chain management.

Table 1. Ground-breaking technologies in supply chains

Technology	Explanation of technology	Advantages through technology
Big data analytics, (Gupta et al., 2020)	The components of Big Data Analytics include predictive analytics, statistical analysis, and data mining.	The technology can lead to increased business profits and increases in efficiency.
Internet of Things (IoT), (Ben-Daya et al., 2019)	Intelligent objects communicate with their environment; the data they emit provide useful insight into all aspects of the supply chain.	IoT speeds up the time between data collection and decision making,
Blockchain Technology (Kim et al., 2018)	The promising Blockchain technologies can be seen as a decentralized database that provides highly secure and well-protected access to supply chain data.	Blockchain Technology can be a confidence-building measure within a supply chain.

Source: own representation

The Covid-19 pandemic raises the question of whether digitization turns out to be a false promise. The integration of artificial intelligence (AI) into digital processes has been largely assessed as progress, but the Covid-19 pandemic revealed deficits of AI, because the algorithms are fragile to extreme and ahistorical events. Inventory management systems that otherwise do a good job by predicting production rates and consumer demand have failed in the Covid-19 pandemic. AI-algorithm-supported digitization works reasonably well under "normal" circumstances due to its ability to self-correct and adapt to ordinary pattern changes. However, the pandemic made it necessary for humans to intervene in the highly digitized processes. The human with his expertise was needed to find out the causes and effects of sudden shifts in consumer demand patterns or to identify the impacts of the lockdown on the continuation of the supply chain and transport. The necessity of human expertise and judgement became apparent. It should not be forgotten that the systems are immensely powerful and often process exceptionally large amounts of data, but they have a naive worldview (Faraj et al., 2021).

2.5. Rising regionalism

The Covid-19 pandemic clearly demonstrates the weaknesses of globalization, the logical consequence arising from this could be a return to more regionalism. But it remains to be seen whether supply chains will become more local in the future. Even though voices are raised for more regionalization in supply chains, it is important to emphasize not only the strong points but also the weaknesses of more regional supply chains. The decline in global supply chains would have negative effects on the economic development of emerging and developing countries, especially from Southeast Asian. Countries that are currently not yet integrated into global supply chains (e.g., some countries in Africa) would have a harder time achieving this integration (Görg et al., 2020). According to a McKinsey study conducted in May 2020, 93% of the supply chain executives surveyed want to make their supply chains more resilient in the future, they want to achieve this, among other things, by regionalizing the supply chains (McKinsey Global Institute, 2020). If one were to turn one's back on hyper-globalization, then advantages such as high growth rates, reduced poverty and opportunities for less qualified workers would also be lost. The cost of regionalizing supply chains should not be underestimated, especially in places where support services are lacking and there are no efficient transport and communication links. To what extent regionalization of the supply chains will take place also depends on the industry.

2.6. Product variety – but not at all costs

Today's supply chains face a trade-off between product variety and supply chain performance. The dramatic increase in product variety in most industries does not stop at supply chains either. Many companies have misjudged the costs of a high variety of products and therefore keep a higher variety of products than would be good for them.

3. Research Methodology

The research objective of this study is to analyze the existing literature on supply chain disruption and to uncover six key truths about resilient and more resilient supply chains for the future. The study also tries to create awareness for supply chain managers at which points in the supply chain an adjustment leads to less complexity, for example. An expert interview with Prof. Dr. Rainer Thiele from IFW Kiel Institut für Weltwirtschaft shows how the trends are understood from the perspective of an expert.

Visualization of connections and causal dependencies can create transparency. Therefore, the situation of an economic downturn is visualized in a small conceptual model.

3.1. Design

An attempt is made to create a conceptual model on supply chain disruption using the Garp3 workbench. The models of cause-and-effect relationships implemented in Garp3 (Bredeweg et al., 2009) attempt to make the complexity of a corporate crisis manageable. The adequate formalization of the domain-specific knowledge not only creates transparency, understanding and traceability for decision-makers in supply chain management, but also for researchers in the field of complexity and crisis management.

3.2. Sample

The Covid-19 pandemic has brought the topic "supply chain disruptions" back into the economic headlines. To create the starting point for the article, current economic newspapers, articles, and online reports on the effects of Covid-19 on supply chains were searched

vigorously. So, a high practical relevance was in the foreground when deriving the 6 truths about the supply chains of the future (see fig. 3).

In addition, the economic literature was researched to check whether these six truths conform to the unanimous opinion and, where it was not so, to open a discussion.

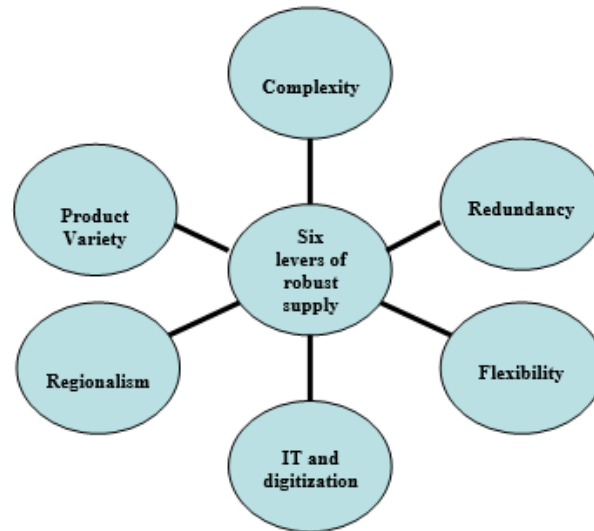


Figure 3: Six levers of robust supply chains

Source: own representation

3.3. Procedure

3.3.1. Expert opinion

Now the most important insights from the expert interview are summarized (Thiele, R., telephone interview, May 26th, 2021).

- The supply chains have become a bit shorter in general, but not only because of Covid-19.
- It may depend more on the branch of industry if supply chains will change or not.
- For example, a major technical change is taking place in the automotive supply chain (e.g. switching to e-cars), but this has nothing to do with Covid-19.
- Supply chains could change because a re-orientation in terms of China may take place.
- A step towards multiple sourcing will probably take place, but not only because of Covid-19.
- A regionalization of the supply chains will probably happen, but the stronger ones will prevail.
- Political cooperation also shows how little one can rely on, but structure is required for supply chains to work.
- Managers will weigh more risks and consider how to organize products and processes.
- Supply chains for booking travel and long-distance trips to African countries will be permanently affected by Covid-19.

3.3.2. Conceptual model

The current fate of the supply chains has shown that a rethink needs to take place. A great help in re-evaluating current practices in the supply chain is to work with conceptual models.

These can make visible what happens, for example, in the event of a supply chain disruption, i.e., what influences such a disruption can have and what measures could be taken to restore a peaceful and functioning balance in the supply chain. The catchphrases here are probably "transparency through visualization" and "visualization as an opportunity".

To put it simply, one could imagine a trade-off between the complexity of a supply chain and its vulnerability, which can subsequently also be understood as a conflict between advantages and downsides. The more complex supply chains are, the more vulnerable they are. One of the reasons for the increasing complexity is that companies want to remain competitive and thus also want to produce more cost-effectively.

The basic assumption is that "vulnerability" follows the development of "drive". In the example, the stimulus arises from a worldwide Covid-19 pandemic and determines the level of vulnerability of supply chains.

The model fragment "The Covid-19 pandemic as a trigger for supply chains' vulnerability" (see Fig. 4) consists of the entities "Covid19 pandemic" and "Global supply chain x", the two quantities "drive" and "vulnerability" as well as the configuration "influences". "Drive" and "vulnerability" are characterized by the quantity space {zero, plus}. A positive direct influence ("I+") describes the causality between "drive" and "vulnerability". "I+" causes the following development of the quantities: if the current value of "Drive" is positive, the "vulnerability" increases; if "Drive" has the value 0, then "vulnerability" remains unchanged. Expectations are as follows: the assumption is that "vulnerability" follows the development of "drive".

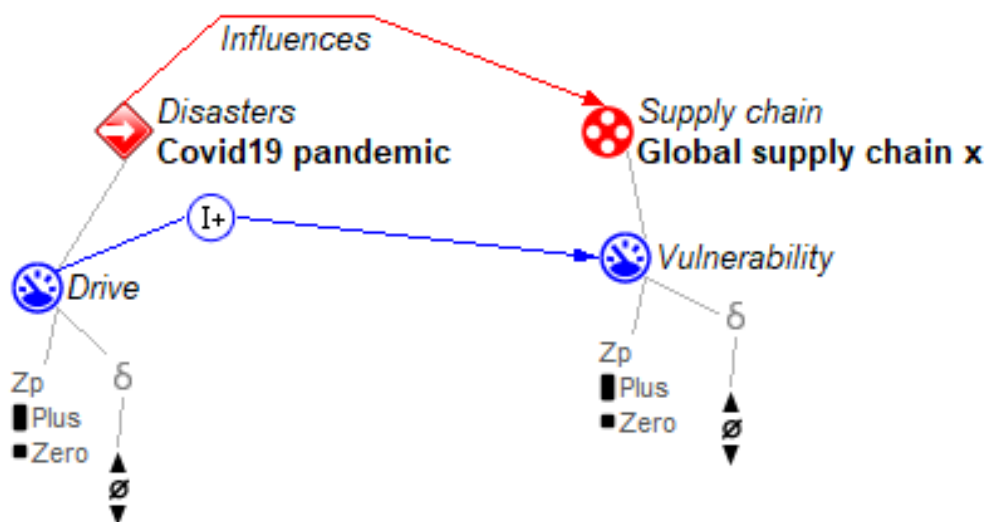


Figure 4: The Covid-19 pandemic as a trigger for supply chains' vulnerability

Source: own representation

In the model fragment "Rebalancing the supply chain" (see Fig. 5) a mathematical calculation (minus) is used to determine the "complexity rate" from the difference between "vulnerability" and "complexity". The causal relationship between the quantities is described by a positive proportionality ("P +"), which leads from the quantity "vulnerability" to the

quantity "complexity rate". "P +" means that the "complexity rate" increases when "vulnerability" increases, "complexity rate" decreases when "vulnerability" decreases and "complexity rate" remains the same when "vulnerability" remains the same. For the negative proportionality ("P-"), as it is used in the relationship between "complexity" and "complexity rate", exactly the opposite applies. A positive proportionality ("P +") is used to describe the causal relationship between the "complexity rate" and "diversification". The causality between "diversification" and "complexity" is described by a direct influence ("I +"). The expectation is that "diversification" decreases when "complexity" is bigger than "vulnerability". "Diversification" will increase until a balance (the quantities are qualitatively equal) between "vulnerability" and "complexity" is reached.

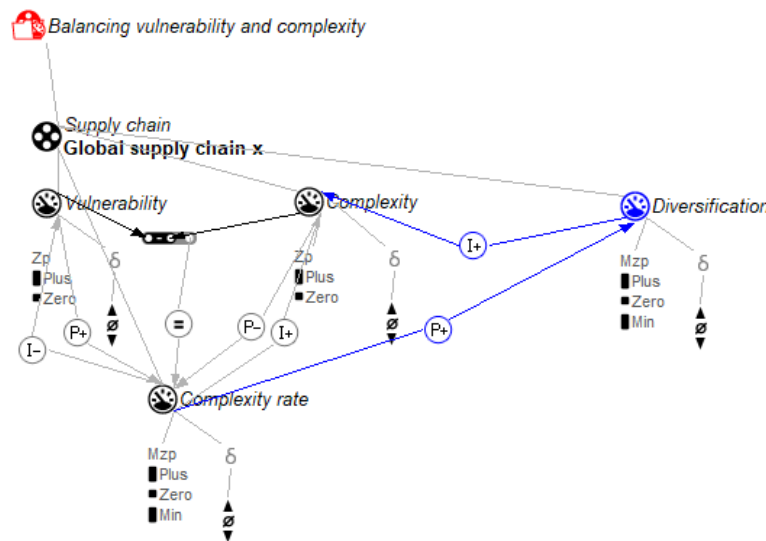


Figure 5: Rebalancing the supply chain

Source: own representation

3.4. Analysis

The purpose of this section is to analyze the simulation results. In the course of analyzing the simulation results, new perspectives can be created for decision-makers in the supply chain management field. The simulation provides a state graph of five states (Fig. 6). The path is {1-->2-->3-->4-->5}.



Figure 6: State graph with five states

Source: own representation (Garp3)

To get information about the development of the individual quantities, the value history from Fig. 7 is used. "Drive" increases in states 1 and 2, stabilizes in state 3 and decreases in states 4 and 5. "Vulnerability" follows the development of "Drive", i.e., its stabilized in state 4. "Complexity" pursues an opposite development in the states 1 and 2 compared to the quantities "drive" and "vulnerability" and stabilizes in states 3, 4 and 5. "Diversification" has an increasing trend in states 1 and 2, stabilizing in states 3 and 4 and a downward trend in state 5. "Complexity rate" starts from the qualitative value zero and moves in the interval "Plus" from the state 2 on.

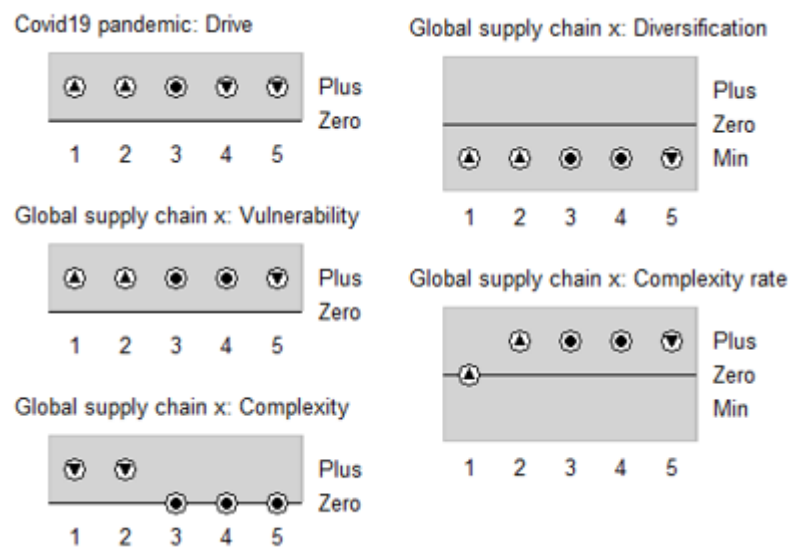


Figure 7: Value history

Source: own representation (Garp3)

4. Conclusion

The comprehensive literature research has shown that, in the author's opinion, there are six levers for more robust and thus more resilient supply chains. This research helps practitioners and decision-makers in supply chain management to identify such levers and control them in a targeted manner so that future supply chains can better react to disruptions. The six levers of robust supply chains are complexity, redundancy, flexibility, IT and digitization, regionalism, and product variety. If at least certain practices in supply chain management are reassessed, the goal of this work has been achieved. At the same time, a helpful way of thinking about systems and causal relationships in systems is presented. The conceptual models created in Garp3 force both the model creator and the model reader to think about components of a system (e.g., supply chain), their entities (e.g., suppliers and consumers) and certain quantities contained therein (e.g., service level, product variety, etc.). However, the basic statements of an interview conducted for this research show that one should not be too hopeful. The result of the Covid-19 pandemic will certainly not be a complete restructuring of the supply chains.

The topic is of the utmost relevance, especially since globalization does not end here. The aim is to conduct further expert interviews with supply chain managers and to present an even more extensive concept here.

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