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GLOBAL SUPPLY CHAIN DISRUPTION

Assessment of Risks & Proposal of Strategic Options

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STATUTORY DECLARATION

I hereby declare that the thesis submitted is my own unaided work, that I have not used other than the sources indicated, and that all direct and indirect sources are acknowledged as references.

This printed thesis is identical with the electronic version submitted.

Linz, 31.07.2020

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Abstract

Purpose

The purpose of this thesis is to offer a concise overview on the topic of global supply chain disruptions as well as strategic options to respond to these risks and mitigate them. The research questions acting as foundation are:

1. What are the main risks of disruption a company's global supply chain is exposed to?
2. Which strategic options can be adopted by companies to increase the resilience of their supply chains?

Methodology

A purely theoretical approach was taken. It involved a broad review of existing literature and concisely collecting the most important findings. No empirical study was done and there are no primary sources such as interviews or surveys. To gather secondary sources like papers, journal articles, reports, studies, etc. scientific databases and search engines such as EbscoHost, Scopus, ScienceDirect or Google Scholar were used. Due to the theoretical nature of this work, any proposals done are conclusions drawn from the review and structuring of literature.

Findings

As global supply chains are growing, the risks imposed to them and their management becomes more important to remain competitive. The main risk categories proposed in this work are: Supply-side risks, demand-side risks, operational risks and environmental risks. The latter are especially important to global supply chains which is underlined by the current COVID-19 health crisis.

To face these risks, a firm needs to adapt a strategic approach to supply chain risk management. Therefor, a generic supply chain risk management process (SCRMP) is proposed, consisting of four steps: Risk identification – finding and categorizing risks; Risk assessment – evaluating and prioritizing risks; Risk mitigation – taking preventive measures for possible risks and contingent measures for occurred risks; Risk monitoring – assessing the effectivity of the measures taken and scanning the environment for new risks.

Increasing the resilience of a global supply chain can be achieved by embracing the following characteristics of a supply chain: Agility – ability to quickly adapt to a new situation a restore a stable status after a disruption occurred; Flexibility and Redundancy – in case of disruption, existing capacities can fulfill a different purpose and duplicate capacities can act as short-term replacement (redundancy in terms of suppliers and plants in different countries is especially important for global supply chains); Collaboration – Closely working with supply chain partners to share information and gain mutual advantage as well as distribute risks.

Limitations/Future Research

Examining this topic empirically, with a real global supply chain as an example could offer better insight as to what is applicable in reality and what only works on paper. Suggestions for further research: Stakeholders and sustainability in connection to global supply chain risks; Stronger focus on risk monitoring; Cyber risks and digitalisation; Global supply chains and pandemics (COVID-19).

Keywords: Global supply chain disruption, Supply chain risks, Supply chain risk management, Supply chain resilience, SCRMP

Type of work: Undergraduate thesis

TABLE OF CONTENTS

1. Introduction

"The supply chain stuff is really tricky."

~ Elon Musk, 2016

Elon Musk has put this in a very simple, yet precise, statement. When a person that aspires to colonize mars (SpaceX.com, 2020), is the CEO of the most successful manufacturer of electric cars (Riley, 2019), is founder of one of the largest providers of solar power systems in the US (Benji, 2020, para. 7) and participated in the design and the concept of an underground high speed train that supposedly carries passenger at an astonishing pace of 1080km/h (Hyperloop-One.com, 2019) says that "supply chain stuff is tricky" then it is somewhat safe to deduce that indeed, managing a supply chain is a highly complex and difficult task. During an interview at the Code Conference in 2016, Musk talks about supply chain issues in Tesla's production of electric vehicles. The production of a car, particularly a new one, usually involves several thousand suppliers. Thus, things move just as fast as "the least lucky and least competent supplier". According to Musk, a shootout at the Mexican border in fact halted the production line of the Model X due to the border patrol refusing to release a truck which was due to deliver trunk carpets as it had bullet holes in it. Tesla strives to improve its internal capabilities to be able to produce internally in case of supply chain disruptions (Musk, 2016).

Literature suggests that there is a trend that competition is transforming from being "firm vs. firm" to being "supply chain vs. supply chain" (Hult et al., 2007, p. 1047). However, modern global supply chains are facing a vast number of risks of disruption. Disruption among a supply chain is certainly something a company wants to prevent, as it causes customer orders to be delayed or even cancelled, eventually leading to a loss in revenue as well as negative reputation on the brand (Rosenberg, 2018, p. 9). Whether it is natural or man-made, unexpected disasters can cause tremendous impacts on supply chains. Calamities, such as earthquakes, fires, floods or hurricanes, breakdowns of machinery or entire production plants, labour strikes, economic crises, bankruptcy of suppliers, deliberate sabotage or terrorist attacks (Material Handling & Logistics, 2018; Sawik, 2018, p. 2; Xu et al., 2020, p. 3508) – the list is sheer endless. Literature suggests that the likelihood of disruptions has supposedly increased in recent years (Barroso et al., 2011, p. 161). According to Palagyi (2004), supply chain executives state how often it is an issue that the "supply" does not match the required "demand" in cases where subassemblies are not manufactured in-house but overseas (Palagyi, 2004, p. 38). It is therefore safe to conclude that supply chain disruption and in further consequence proper strategic risk management to build resilience against disruption, are highly relevant topics in today's globalized world as supply chain disruption exerts negative influence on shareholder value (Hendricks & Singhal, 2003, p. 520, 2005a, p. 35) as well as on operating performance (e.g. sales, income, return on assets) (Hendricks & Singhal, 2005b, p. 695). Briefly put: Markets do not forgive improper response to disruptions of supply chains and a resilient supply chain is a valuable strategic asset (Wagner & Bode, 2006, pp. 301–302).

2. Problem

2.1. Problem Definition and Validation

Global manufacturing faces a “second unbundling”. Supply chains are more geographically spread, making them globally acting networks. These are subject to rapid growth – growth in terms of magnitude and complexity – caused by technological innovation. A historical example of this is the invention of the steam engine which was the foundation for the “first unbundling” (Baldwin, 2013, pp. 14–21). Current supply chains and networks are prone to disruption due to being wide-spread and very fragmented. A volatile economic environment, rapid technological changes and a general instability of global economy create threat of strong disruptions to supply chains (Calvo et al., 2020, pp. 38–39).

Linkages and therefore interdependency in supply chains exist as one activity within an element among the chain might affect cost and effectiveness of other processes. Therefore, a supply chain is a construct which becomes subject to optimization issues, often resulting in a necessity to do trade-offs. Furthermore, this interdependency requires coordination. For example, the more focus placed on on-time delivery, the more flawlessly a supply chain must work. By optimizing the coordination of links throughout the supply chain – inside a firm as well as to the outside, to its suppliers – a competitive advantage can be created (Porter & Millar, 1985, p. 3).

Firms specializing in a specific step of production and exporting the outcome – to gain comparative advantage over competitors (Porter & Millar, 1985, p. 3; Sindi & Roe, 2017, p. 48) – becomes an increasing factor of organization in global production. Multinational companies are therefore more affectionate towards more open trade, suggesting a tendency towards global supply chains (Meckling & Hughes, 2017, p. 225). The environment and the conditions among which global supply chains operate are highly volatile and erratic. It is historically shown that they are prone to disruption caused by events of different, partially unpredictable nature (Wagner & Bode, 2006, pp. 304–305).

First and foremost, problems due to disruption will, at their base, be of financial nature. Depending on the level of interdependence among the supply chain it can lead to a full halt of production – for example as it happened to some major companies in the automotive industry when the then world’s largest supplier for car-parts, the Robert Bosch GmbH, supplied faulty parts without realizing. Assembly lines of companies like Audi, BMW and Daimler (then: DaimlerChrysler) came to a halt and several thousand cars fell victim to a product recall. For these car companies, their supplier, Bosch, failed. For Bosch, the situation was similar, as the faulty parts came from one of their suppliers, a US company which also sourced the specific part from another company. However, the defect of one part resulted in a “waterfall” downstream the supply chain leading to three-digit-millions of Euros in costs and damage to the reputation of Bosch and major car producers (Wagner & Bode, 2006, p. 301).

Despite these very much critical facts, it seems that supply chains have become more vulnerable over the past years. This supposedly happens due to several factors: Ascending competition, racing globalisation and a tremendous pressure to make processes more efficient and production less cost-intensive by outsourcing large portions of it to low-cost countries are just some of the factors driving modern supply chain vulnerability. Considering this, it can be concluded that resilience of supply chains is highly rewarded, making the risk management strategy of supply chains a crucial topic for managers (Christopher & Lee, 2004, p. 388). Furthermore, a survey done in 2013 by PwC suggests that companies, that acknowledge their

supply chain as a strategic asset can achieve a performance increase of up to 70%. Some of the surveyed companies deliver on time in full at 96% which means satisfied customers and has a direct impact on earnings. The survey shows how important it is to see the supply chain as a crucial strategic element (Geissbauer et al., 2013, pp. 8–9). Unfortunately, a similar study that could provide the same numbers more up to date has yet to be conducted.

There is very recent evidence on the high relevance of the described problem. It goes by the term of the COVID-19 pandemic or simply called, the “corona crisis”. Never before have modern supply chains faced a global health crisis of comparable magnitude. There has never been a health crisis of this scale and severity in modern times (global supply chains were not a great issue during the black plague). The coronavirus pandemic has caused delays and other frustrations in businesses’ global supply chains. It highlights how vulnerable many are to unexpected disruption. Thus, response to the extreme extent of disruption has been reactive and mostly uncoordinated. This is partially a consequence of vital information not being accessible. The economic impact of coronavirus is of an extent that has never been seen before. No disastrous event has ever had a bigger economic impact. Almost all major car manufacturers across Europe had to shut down production completely (Chambers, 2020; Choi et al., 2020; Jones et al., 2020; Knowledge@Wharton, 2020; Reuters, 2020).

2.2. Aims and Research Questions

This undergraduate thesis mainly aims to analyse the topic of risks to global supply chains and their resilience to different kinds of disruption. To achieve that, it is necessary to lay out a basic theoretical foundation – one which covers the topic of global supply chains, strategic management of supply chains and supply chain risks. It is a rather extensive range of contents, yet it is in no way an attempt to cover the entire topic of the management of supply chains, let alone the solution of all the problems and difficulties which happen to occur in the management of supply chains, especially global ones. It is merely an attempt to dive into this interesting topic as it is an omnipresent issue in today’s connected world.

Following are – concisely expressed – the two main aims of this work:

- Examine the vulnerability of global supply chains and identify risks to them
- Discuss strategic approaches to increase resilience

These aims are supposed to answer the following research questions. These questions were the origin of this thesis, sparked by the current worldwide crisis due to the COVID-19 crisis and the tremendous disruptions to supply chains all over the globe.

1. What are the main risks of disruption a company’s global supply chain is exposed to?
2. Which strategic options can be adopted by companies to increase the resilience of their supply chains?

3. Methodology and Research Process

To answer the stated research questions thoroughly, an approach of fundamental research is taken. It is directed towards understanding different fields of interest that are covered by the topic and the research questions without a practical connotation. Fundamental research usually does not apply to a specific practical application but concludes the existing knowledge on a research area. Subsequently, it serves as a foundation for applied research which aims to examine a specific practical objective (Godwill, 2015, pp. 9–10).

Answering the research questions is realized in terms of conclusions based on scientific research and analysis of literature. Specifically, the first steps taken include a broad review of literature followed by a condensed representation of the most relevant findings. This fulfills the purpose of building a common base of knowledge (Oehlrich, 2019, p. 31). It is a necessary step in order to provide the information necessary, to reason any conclusions and proposals subsequently done (Oehlrich, 2019, pp. 121–123). In this first step, the vital concepts that are represented by the research questions are explained. The process of literature review involves going through reliable sources such as books, journal articles and papers, analysing and collecting concepts, models and proposals of different authors. To make sure that sources are qualitative, scientific sources, several “flags” will be considered: Journal articles can be considered qualitative sources if they were published in peer-reviewed journals. Also, it is good to cross-check who wrote an article. What does this person do? What experiences does he or she have? Is the author a renowned expert in this topic? Articles are chosen from renowned journals like the International *Journal of Production Research*, *Journal of Purchasing and Supply Chain Management* or *International Journal of Physical Distribution & Logistics Management*, just to name a few. Other sources like the Harvard Business Review or articles from McKinsey are also considered as reliable information. Another sign for reliability is, if names keep coming up in articles and books over a prolonged timespan. Whether it is new publications or being cited often – both usually shows that this author has been working thoroughly, and for extended periods, in this field and that he can be considered an expert. Books often have critical acclaims in the beginning. Familiar names showing up there can act as sort of “vouching” for the quality of this source (e.g. several familiar names of the field appearing in the critical acclaim of Cohen and Roussel’s book “Strategic Supply Chain Management”).

After knowing and understanding the analysed contents, relevant ones are taken into account to be represented and discussed in this work. Scientific databases are used to find papers, journal articles, reports, studies, dissertations and other work that cover the topics in question. Books and other sources such as serious newspapers or websites also provide as sources of information. As stated, there are solely secondary sources used in this work. No interviews or surveys (primary sources) are done. To gather information from secondary sources, research services such as EbscoHost, Web of Science, Scopus or ScienceDirect are used to search for scientific literature. EbscoHost offers access to several of the most important databases on scientific research (mostly used are Business Source Premier, EconLit, SocINDEX with Full Text, Academic Search Ultimate and Business Source Ultimate). Google Scholar is used to attain a wider, less specific scope of results and also to find possible other sources for certain articles (e.g. an article found on a database through EbscoHost to which access is locked, might be found with Google Scholar on another database to which institutional access is available). To find books on the topics, the university’s library service (LISSS), a bibliographic search engine or the regular Google search are used.

This work is an undergraduate thesis. Hence, it is a work that analyses literature. There is no empirical part included in the work as there are certain limitations, timewise as well as depth-wise. The chosen approach of critically reviewing and reciting existing literature and drawing conclusions from that analysis is deemed to be the most reasonable. The thesis aims to create links to current issues to put the theoretically compiled contents into perspective. Naturally, there are limitations to a work without real-world data to base conclusions or hypotheses on. Conclusions drawn and options for action stated are not based on actual analysis of evidence but on mere intuitions and a conglomerate of opinions and ideas among literature and should therefore be taken with caution.

4. Theoretical Foundations and Background

This chapter begins to elaborate briefly on the theoretical contents that are necessary to examine a topic as complex and complicated as the disruption of supply chains that are conceptualized as globally acting systems. It handles three topics: global supply chains as a basic concept, the strategic management of supply chains as well as risks that supply chains bear. The following image gives a brief overview on the theoretical structure of this thesis.

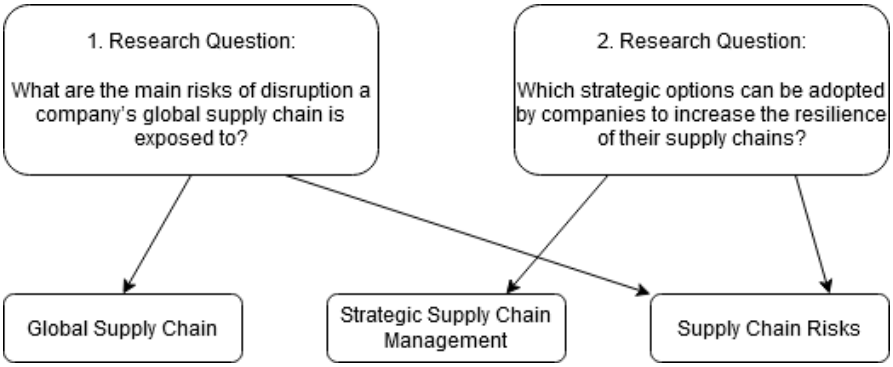

Figure 1: Theoretical Structure (Source: own elaboration)

4.1. Global Supply Chain

Starting with the theoretical foundations, this chapter aims to give an overview on the topic of supply chains and specifically global supply chains. It is either hard or easy, depending on the perspective, to define a term such as "(global) supply chain". This can be done at a very basic level, which often turns out to be too unspecified, or with higher complexity at the cost of clarity (Prokop, 2017, p. 1). In fact, this difficulty to find a clear definition can be problematic as firms may find it hard to define their own supply chain, ending up with a wrong understanding of what is necessary to hold their ground in the market (Sindi & Roe, 2017, p. 19). A rather recent attempt to define a supply chain was made by Ivanov et al. (2019). They define a supply chain as follows:

> *"A supply chain (SC) is a network of organizations and processes wherein a number of various enterprises (suppliers, manufacturers, distributors and retailers) collaborate (cooperate and coordinate) along the entire value chain to acquire raw materials, to convert*

these raw materials into specified final products, and to deliver these final products to customers."

(Ivanov et al., 2019, p. 7)

Hence, according to this definition, which is one of many, the supply chain starts at acquiring raw materials and ends at the customer's doormat. It can be deduced that this, especially in modern times, requires a tremendous amount of coordination effort, as products nowadays are made of a myriad of parts and components. Product complexity therefore adds significantly to the complexity of supply chains which is found widely among literature (Closs et al., 2010, pp. 52–54; Eckstein et al., 2015, p. 3029; Inman & Blumenfeld, 2014, pp. 1956–1957; Yazdani, 1999, pp. 29–30). This highly complex process should be accomplished in as little time as possible, in order to not have the customer waiting too long for the product – Palagyi (2004) mentions the "better, cheaper, now" mindset of customers in this context. Briefly said, one of the main goals of a supply chain is to build a stable, functioning bridge between suppliers and customers (Ivanov et al., 2019, p. 9).

Prokop (2017) adds to this another thought: The "nodes" of a supply chain (i.e. the companies within it) and their linkages form a whole that is worth more than just the mere sum of all the nodes (Prokop, 2017, p. 1). In simple terms, this means that the supply chain represents an intangible asset that is worth more than only the companies that it consists of. Global supply chains are the same as supply chains but for companies that are acting transnational. With the *global* factor adding to this, there are other factors that need to be considered when managing them. International teams, cross-cultural negotiations and in general higher risk (e.g. economic or political) all come with global supply chains. There can be trade barriers, different legal situations and also it requires a deeper consideration of transaction and transportation costs (Eyob & Tetteh, 2012, p. xi; Prokop, 2017, pp. 1–8). Rules of Origin can impose further issues onto the organisation of global supply chains (Ohmori et al., 2019, pp. 455–456). Rules of origin were taken into place to determine the origin country a product – its "nationality" – which is important due to custom duties and other restrictions (Ohmori et al., 2019, p. 448; WTO, 2020).

Global supply chains emerge increasingly, driven by globalisation, efforts of companies to gain market shares and orientation of countries around the globe towards more free trade. Supply chains developed from being simple chains of a handful, if even, suppliers to being complex networks that span around the entire world (Christopher et al., 2006, pp. 278–280; Eyob & Tetteh, 2012, p. xi). Global supply chains offer several benefits as well as downsides. With globalisation, firms or even nations can specialize production to focus on a narrow range of products, which enables efficiency and drawing advantages from economies of scale (Sindi & Roe, 2017, p. 48). However, there can be dangers. The high grade of specialization leaves the a country's or a firm's economy exposed to possible drastic changes of the environment, which is nothing unlikely due to its volatile and uncertain character (G. Johnson et al., 2017, p. 33; Mack et al., 2016, pp. 5–7; Magee, 1998, p. 1; Reisinger et al., 2017, pp. 56–57; Yarger, 2006, pp. 17–18). Global supply chains bring with them several issues, for example an increase in outsourcing as supply chain executives tend to choose suppliers based on several parameters (quality, quantity, price etc.) that are depending on customers' needs. This influences the geographical structure of the supply chain (Meijboom et al., 2007, pp. 566–568; Sindi & Roe, 2017, pp. 48–49). That means, depending on what is needed, the geographical focus of a supply chain can change with changing costumers' demands. Furthermore, with outsourcing often comes centralization and assimilation of decisions (Ivanov et al., 2019, pp. 9–11; Sindi & Roe, 2017, p. 49).

In today's ever-changing world it is not sufficient to have a "one size fits all" mindset when it comes to global supply chain strategies. Thus, the choice of strategy is an important issue among the topic of global supply chains (Christopher et al., 2006, pp. 278–280). A chosen strategy though is worth nothing if not executed properly. This leads to the group of the executives, the ones making the decisions. They must act in line with the strategy, otherwise the strategy is very likely doomed to fail. Decisions of a supply chain manager do have a direct impact onto the financial performance of a company. They make decisions about coordination of resources which has monetary implications. Therefore it is necessary to always keep in mind the financial goals of a firm when making decisions about the supply chain (Rosenberg, 2018, p. 1). Needless to say, that this becomes significantly more complex and critical when scaled at a global level rather than only domestically or even just regionally.

4.2. Strategic Supply Chain Management

In a firm, there are usually several strategies. Those are to be found among different levels and divisions. On the top position is the *company strategy*. This strategy basically tells the general direction which a firm is heading. It answers, in basic terms: How value is created, which products or services are offered, in which sector(s) the company acts, where (geographically) the company does business and how the company's resources are allocated. Beneath those are the *business-level strategies*. Strategies, which are defined for the different business units of a company. Often, the term of *competitive strategy* is used for this level of strategy. The business-level strategy determines how businesses ought to compete in their particular markets. This strategy should give information about how competitive advantage is created and how the company positions itself within the market. The third layer of strategies are the so-called *functional strategies*. This is where the question, about how the particular functional divisions of a company effectively deliver in order to follow the business-level and the company strategy, is answered. Functional strategies are more detailed and derive from the business-level strategies, guiding different functions – including but not limited to – production, technology, innovation, R&D and the *supply chain*. Functional strategies strive to support the goals of the company and business strategy to create competitive advantage. Therefore, they have to be in alignment with those underlying strategies (G. Johnson et al., 2017, pp. 10–11; Sennheiser & Schnetzler, 2008, pp. 288–289).

For years already, there is an emerging view – despite the still strong emphasis on business models – about the supply chain being a key driver of the business model's profit formula. In 2010, many companies stated that the main factor of profit gains were improvements among their supply chains (Cordón et al., 2013, p. 3). Bright et al. also note in a McKinsey article the importance of supply chains in revenue growth management (Bright et al., 2019). Therefore, the proposition became widely accepted that the supply chain should much rather be considered a source of value than a creator of costs. A well-designed, well-functioning supply chain can increase revenue, improve the implementation of a firm's value proposition for customers and help implementing its vision and strategy (Cordón et al., 2013, p. 3).

According to Govil and Proth (2002) it is crucial when strategically configuring a supply chain to analyse which consequences follow a decision within one activity along the supply chain and how they disperse through the supply chain. Also, it is critical to assess the financial implications of such a decision and its consequences along other activities (e.g. what financial effects does it have on the *sell* activity if more money is spent within the *make* activity to allow for shorter

delivery times – for further information on strategic activities in supply chains refer to Govil and Proth (2002, pp. 17–20)). It is important to always keep in mind that every change in one activity influences others and an attempt to cut costs in one activity can cause a disproportional increase in costs among another activity (Govil & Proth, 2002, p. 20). Dubois et al. (2004) also note the high impact of strong interdependencies among and within supply chains (Dubois et al., 2004). Therefore, it can be stated that any change in a supply chain has to be closely examined on how it affects other activities within that supply chain.

4.2.1. Supply Chain as a Strategic Asset

The management of a firm's supply chain ranges through different departments and involves the coordination and integration of raw materials as well as products in work or finished products. Furthermore, the transfer of information or financial assets to exploit the supply chain resources in a most efficient way throughout the entire value-adding chain, from supplier to customer is an important part of supply chain management. Therefore, the supply chain represents one of the key factors of an organization in its function as coordinator for supply and demand along the value-adding chain (Ivanov et al., 2019, pp. 7–9). It can thus be concluded that it is critical to have a thorough strategic approach to managing the supply chain. However, many companies nowadays do not consider their supply chain a strategic asset. Basically, the only time they think about their supply chain is after problems have already occurred. Whether it might be too high inventory levels – or too low ones – customers complaining about poor or missing service, a supplier fails to deliver a crucial resource etc. These are issues companies are facing which do not see the supply chain as an important strategic asset. They fail to recognize that a supply chain which is properly and strategically set up can in fact create a significant competitive advantage for a company. There are many examples which offer evidence to this proposition. As an example: Michael Dell realized the importance of the supply chain. He introduced supply chain innovations that managed to revamp a struggling PC manufacturer to become a market leading hardware giant, especially in corporate area, by innovating the supply chain to transform to being a textbook example of supply chain excellence (Cohen & Roussel, 2005, pp. 9–10; Hult et al., 2007, p. 1047; Kumar & Craig, 2007, pp. 210–213; Mentzer et al., 2007, p. 477; Mitra & Bhardwaj, 2010, pp. 49–50; Palagyi, 2004, p. 38).

To view the supply chain as a strategic asset, Cohen and Roussel (2005) proposed five key disciplines which should be followed to assure that the supply chain continuously acts as a source of competitive advantage for a company. Even though, their model is 15 years old, it is still considered highly relevant which is further proven by the fact that 4 out of the 5 principles did not change in their second edition from 2013 with the first principle being slightly adapted. The *original five core disciplines* of strategic supply chain management proposed are:

1. View the supply chain as a strategic asset. The supply chain strategy should be documented and clearly communicated. First, it must be clear which is the basis of competition of the company – cost, innovation, quality, service. Then it is a challenge to develop a supply chain strategy which is aligned with both the product and the marketing strategy. This is the basis to generate revenues, satisfy customers and lower the costs (Cohen & Roussel, 2005, pp. 9–10).

2. Develop an end-to-end process architecture. The process planning along the supply chain must be consistent with what the company wants to deliver – a supply chain which is "fit for purpose" (Cohen & Roussel, 2005, p. 49). This is best explained by an example: A company

has improved its manufacturing to be just-in-time with very short production times. Furthermore, there were efficiency improvements in the logistics department achieving a top-notch cost-strategy by only allowing full truckloads moving products from manufacturing facilities to distribution centres. Eventually the company ends up not being able to deliver their products to the customer within the estimated time. Why? Because the “good” practises in manufacturing and logistics respectively did not fit each other. The company had high stocks of finished products, sitting in their manufacturing facilities. Delivery times were calculated under the premise of the products immediately leaving production facilities after being finished which was not in line with the logistics strategy – the company did not have a focus on end-to-end supply chain processes (Cohen & Roussel, 2005, pp. 55–56).

3. Design the [supply chain] organization for performance. In order to provide effective end-to-end supply chain management, its organization should embrace the core supply chain processes – plan, source, make, deliver and return – and infrastructure. The supply chain processes should therefore be grouped, and performance objectives should be defined. In this integrated organization approach, a set of crucial skills is necessary to structure the organization, define roles and responsibilities and finding the right people with the right skills (Cohen & Roussel, 2005, p. 101; Palagyi, 2004, p. 38).

4. Build the right collaborative model. As supply chains become more complex and companies tend to narrow down the focus of their core competencies it becomes more important that each external partner within a company’s supply chain is highly competent. In more extended supply chains – extended in terms of more activities being outsourced to other companies, specialized in a particular activity – collaboration gets considerably higher significance. Collaboration is important as it can bring with it benefits such as an accelerated entry in a new market, an increase in flexibility or access to knowledge and expertise of other companies (Cohen & Roussel, 2005, pp. 139–140).

5. Use metrics to drive business success. Defining and measuring metrics of the supply chain is a difficult task, yet a vital one. In general, metrics are bases or standards of comparison – as defined by the Merriam-Webster dictionary. Supply chain metrics should be capable of translating financial objectives into actual measures of operational performance. They should, vice versa, be able to translate operational performance into predictions about earnings. Performance measurements is all about putting into place the right metrics to measure “supply chain health” (Cohen & Roussel, 2005, pp. 185–188).

Palagyi (2004) suggests three basic requirements for a supply chain to be a strategic asset. He has a less technical approach to formulating those premises and rather tries to create an overall picture of what criteria must be met. Firstly, he sets leadership as one factor of a strategic supply chain. With leadership he mainly calls out to the actual supply chain executives, that are responsible to implement the set business strategy into an actual operations strategy (Palagyi, 2004, p. 38). The importance of this alignment is further underlined by several authors (Chopra & Meindl, 2005; Cohen & Roussel, 2005; Evans & Danks, 1998; Govil & Proth, 2002; Happek, 2005, p. 4; Mitra & Bhardwaj, 2010; Simchi-Levi et al., 2007) and will be examined more detailed further into the chapter. Supply chain executives must know about priorities concerning the supply chain strategy (e.g. cost, time, quality etc. – see chapter 4.2.2) and they need to be aware of the competencies which customers are willing to pay for. The current constraints of the supply chain also play a key role. Secondly, Palagyi calls customer alignment of the supply chain as another factor to make it a strategic asset. He mentions “better, cheaper, now” as predominant mindset among the customers. Aligning the supply chain as tight as possible with

the customers is a differentiator. Lastly, the simplicity of solutions is the third named characteristic of a strategic supply chain. According to Palagyi, it is vital not to get lost in meeting every customers' individual need. This creates overhead, complications and prevents establishing core competencies in the management of a supply chain. The number of nodes within a supply chain is important. Also, merging customers that are alike – similar to market segmentation in the course of a strategic customer analysis (Reisinger et al., 2017, p. 69) – to reduce complexity seems to be an important consideration (Palagyi, 2004, pp. 38–39). Overall, it can thus be stated that viewing the supply chain as a strategic asset is not only useful but necessary to have a strategic approach to managing a firm's supply chain. Several proposals on this particular matter are examined to try and build a proper understanding of how the management of a supply chain can be approached strategically.

4.2.2. Supply Chain Strategies

Supply chain strategies play a significant role in determining the direction of supply chain management. Their primary purpose is to orientate supply chain management towards its goals. Theory does not provide with a clear, distinct definition, however, there are two important aspects of supply chain strategy according to Sennheiser and Schnetzler (2008): Firstly, the supply chain strategy defines how the supply chain contributes to a competitive advantage of a company with its processes and resources. The development and exploitation of logistic success potentials are the second main aspect. Hence, the authors derived the following definition for supply chain strategy, based on a generic definition of strategy, further specified to be more according to the topic:

> *"A supply chain strategy consists of prioritised goals of SCM and an adapted set of measures to reach these goals by developing and exploiting logistic success potentials*."
>
> (Sennheiser & Schnetzler, 2008, pp. 289–290)

The supply chain management goals to which this definition refers are defined as:

- **Quality:** Quality of product, process and organization
- **Reliable delivery:** Delivery being in time
- **Delivery time:** Time needed to send/deliver
- **Flexibility:** qualitative and quantitative flexibility in creating customer value and resource allocation
- **Investments in floating and fixed assets:** Number of products in stock and in production, liquidity as well as infrastructure and capacities
- **Operational costs as a price lever:** Costs of operational logistics management

(Sennheiser & Schnetzler, 2008, p. 290)

Logistic success potentials are specific abilities and resources in logistics and supply chain management. Firms can build these resources over a long period of time. They are sustainably relevant for a corporate success and are a main driver of goal realization. Mainly, they concern resource and information flow linked to the efficient execution of procurement (sourcing), production and distribution. Sennheiser and Schnetzler identified three main factors, the combination of which creates potential for success:

- Products and services, for which there is demand on the market

- Abilities and resources that enable to offer said products and services, that is, to develop, produce and distribute it as well as procure all necessary components
- Market potentials for products and services that are sufficient and a strong position in this/these market(s)

(Sennheiser & Schnetzler, 2008, pp. 292–293)

Potential market entries driven by satisfying customers' needs through fulfilling the demands on quality, delivery reliability or flexibility is one example of such potentials. Reduction by investments through elaborate investments into floating or fixed assets (e.g. product stock or plant infrastructure) and subsequent reduction of capital cost are another potential. Furthermore, cost reduction can result from rationalisation of costs of logistics (e.g. cost for material and information, stocking etc.) (Sennheiser & Schnetzler, 2008, pp. 292–293).

Hult et al. (2007) propose two different strategic approaches on how firms can "use their supply chain as competitive weapons", especially amid turbulent markets. Firstly, emphasizing a culture of competitiveness and secondly knowledge development. The culture of competitiveness builds on the basic strategic concept of the resource based view (G. Johnson et al., 2017, p. 97; Reisinger et al., 2017, pp. 39–40) and is represented by three orientations – innovativeness, entrepreneurial and learning – the latter being what connects it to the second approach of knowledge development. In their study of 201 companies they found that culture of competitiveness has a positive effect on cycle time performance whereas knowledge development does not (Hult et al., 2007, p. 1046). The cycle time refers to the total time passed from the reception of the customers' order to the delivery of the product. It is considered as an important metric to measure supply chain performance and corresponds to the above mentioned delivery time (Gunasekaran et al., 2001, pp. 73–74; Hult et al., 2007, p. 1036). Furthermore, Hult et al. found interaction between the two strategies but also suggest that firstly, the culture of competitiveness should be embraced, followed by knowledge development. Once both strategies are developed, there is room for synergies to take effect and potentially improve cycle time performance. In conclusion, it can be stated that it is vital to consider these two strategic approaches to supply chain management simultaneously in order to minimize cycle times (Hult et al., 2007, pp. 1046–1048).

Sindi and Roe (2017) suggest many approaches to supply chain strategy separated into eras in their book "Supply Chain Management". Closely examining all the strategies would go to much into detail for this work but in general it should be noted that they can be differentiated into two basic systems: The push system (e.g. the Progressive Flow Approach or the Configuration approach) and the pull system (e.g. the Agile Approach or the Lean Supply Chain Strategy) (Sindi & Roe, 2017, pp. 57–67). The push system production of goods is driven by a forecast of demand and usually involves higher stock building of finished products (Takahashi & Nakamura, 2004, p. 130) whereas the pull system is based upon the actual demand (Sindi & Roe, 2017, p. 17; Takahashi & Nakamura, 2004, p. 131). A pull system is less predictable and therefore requires shorter production times in order to keep the cycle times at a reasonable level (Christopher et al., 2006, pp. 283–284; Sindi & Roe, 2017, p. 17).

In conclusion, it can be stated that there is a sheer endless number of different approaches to supply chain strategy. This is reasoned by the mere importance of choosing a strategy based on thorough analysis (Christopher et al., 2006, pp. 277–278; Liu et al., 2019, p. 183; Morash, 2001, pp. 50–52). The choice of supply chain strategy is important for firms; thus, it should be taken with high caution and be revised periodically to uncover issues earliest possible. Strategic supply

chain management is preceded by input parameters and can be evaluated by criteria, some of which are examined in the following subchapter. It is clear though, that this work can not condense everything that can be found in literature as this topic is covered excessively, which underlines its importance.

Parameters and Criteria

Before realizing a supply chain strategy which conforms to the business strategy of a company there are certain input parameters that have to be taken into consideration when developing it. The following parameters are proposed by Sennheiser and Schnetzler (2008):

- **Position:** The market position (position in a specific niche or function) in terms of satisfying customer needs in the dimensions of quality, price, delivery (time, availability and loyalty) and flexibility as well as competitive advantages – a company must know where it is placed, what it offers that customers demand, and how it offers it, and what makes their offer better than what competitors offer (Sennheiser & Schnetzler, 2008, p. 297). This corresponds to the position-oriented view in general strategic management, which was strongly shaped by Porter (Reisinger et al., 2017, p. 38).
- **Order qualifiers:** Requirements that a company needs to fulfill in order to be competitive within a certain market. This can be considered the bare minimum to even have a possibility of having customers buy the product or service (Hill & Hill, 2009, pp. 63–66; Sennheiser & Schnetzler, 2008, p. 297).
- **Order winners:** Preceded by the order qualifiers are the order winners. These are the factor due to which a customer eventually chooses the product of one company over the product of its competitor – Order winners are congruent with competitive advantages (Hill & Hill, 2009, pp. 63–66; Sennheiser & Schnetzler, 2008, p. 297).
- **Bargaining power of customers:** The bargaining power of customers as input parameter for the supply chain strategy (Sennheiser & Schnetzler, 2008, p. 297) can be considered similarly important to the bargaining power of buyers according to Porter's Five-Forces Model (G. Johnson et al., 2017, pp. 68–69; Reisinger et al., 2017, p. 62).

Following the important input parameters it is also important to bear in mind some kind of criteria about whether a supply chain strategy is viable or not. Cohen and Roussel (2005) propose four criteria of a good supply chain strategy. These are also underlined by many other authors among literature, even though not in the same set of four. The main configuration components of a supply chain strategy and the choices made about them must be:

- **Aligned with the business strategy:** What is the business and what does it do? What the business is not and what it does not do is just as important. This comes down to the so-called "core strategic vision" of the supply chain strategy which is influenced by several internal and external conditions (Cohen & Roussel, 2005, pp. 20–22). The importance of this alignment is underlined multiple times by different authors throughout literature. The alignment of the supply chain strategy with the business level strategy is considered to be a critical factor. Failure to align these strategies can result in major supply chain issues, hence creating costs and causing a potential loss of customers (Mitra & Bhardwaj, 2010, p. 64; Van Hoek & Mitchell, 2006, pp. 279–280). Lee (2004) emphasizes the importance of alignment in his "Triple-A Supply Chain" model (Lee,

2004, pp. 110–111). Review of literature shows that this is further suggested by a broad range of authors. The alignment of the supply chain strategy with the business strategy is thus considered critical for success (Chaharsooghi & Heydari, 2011, pp. 331–335; Chopra & Meindl, 2007, pp. 22–24; Happek, 2005, pp. 1–2; Ivanov et al., 2019, p. 87).

- **Aligned with customers' needs:** Understand what customers demand. It must not be assumed that customers can always actually articulate their needs or are even aware of them. It is important to regularly check how customer needs are changing (Cohen & Roussel, 2005, pp. 27–28). The alignment with costumer needs is also emphasized by Palagyi (2004) which states that the supply chain strategy should be built around costumers' needs to increase cycle time performance (Palagyi, 2004, pp. 38–39).
- **Aligned with the power position (influence):** Be aware of the power and influence over customers and suppliers and act accordingly. The position within the market and the relative scale size is an important factor. It sets certain boundaries as to what can be achieved by supply chain configuration (Cohen & Roussel, 2005, pp. 30–32). Power and trust among and within supply chain (networks) and its members also play an key role in enhancing value creation (Sridharan & Simatupang, 2013, pp. 91–92).
- **Adaptive, as market conditions change:** The market changes. Corporate environment is a VUCA environment (volatile, uncertain, complex and ambiguous) (Magee, 1998, p. 1; Yarger, 2006, pp. 17–18) therefore the supply chain must adapt constantly (Cohen & Roussel, 2005, pp. 32–34). The importance of adaptability of the supply chain is also emphasized by Lee in his "Triple-A Supply Chain" model (Lee, 2004, pp. 107–110).

4.3. Supply Chain Risks

After talking about global supply chains and supply chain management and strategies it is due time to approach a highly relevant topic among this field. Supply chains are prone to a great number of risks. Yet, literature lacks a thoroughly structured, concise clarification on this topic. That of course does not mean that there is no literature, in fact, quite the opposite is the case – the vast number of publications makes it hard to represent the entire state of knowledge. A fact confirming the high interest of researchers in the topic is the number of literature reviews, for example of Xu et al. (2020), Louis & Pagell (2019), Fan & Stevenson (2018), Er Kara & Oktay Fırat (2017), Heckmann et al. (2015), Ho et al. (2015), Sodhi et al. (2012), O. Tang & Musa (2011), Rao & Goldsby (2009).

According to literature, the term "risk" does not have the clear and widely accepted definition it needs (Fischhoff et al., 1984, pp. 123–127; Rao & Goldsby, 2009, pp. 99–100). Heckmann et al. (2015) have called "risk" an elusive concept, hard to clearly define (Heckmann et al., 2015, p. 120). With taking different definitions and authors' approaches into account, Louis and Pagell (2019) defined risk as *"the unwanted variation from expected outcomes that may cause losses to a firm"*. Based on this definition they further defined supply chain risks as *"the unwanted negative deviation from expected outcomes that can adversely affect supply chain operations and may result in detrimental consequences to a focal firm"* (Louis & Pagell, 2019, p. 331). To this definition another detail, according to Heckmann et al. (2015) is added: The "negative deviation from expected outcomes" is caused by the *occurrence of triggering events* (Heckmann et al., 2015, p. 130). Despite possible differences in the interpretation of the terms risk and supply chain risk, this work uses them according to these definitions.

The previously mentioned increasing complexity of global supply chains leads to a higher probability of disruptions among supply chains. This view is widely acknowledged throughout literature (Hosseini et al., 2019, pp. 285–286; Kamalahmadi & Parast, 2016, pp. 116–117; Kim et al., 2015, pp. 43–44). In fact, according to Material Handling & Logistics (2018), the EventWatch Supply Chain Disruption Report done by Resilinc states that in the first half of the year 2018 the number of supply chain disruptions reached a record high of 1069 disruptive events since the company began monitoring in 2010. Among the most frequently occurring events were factory fires or explosions as well as natural calamities and climate-caused issues (Material Handling & Logistics, 2018). Considering these numbers, it can be concluded, that disruptions pose major risks to supply chains. They have direct, financial impact on firms which can manifest in high losses (Xu et al., 2020, p. 3508). The growing number of literature published about the topic of supply chain disruptions shows its relevance – it has been steadily growing from 1999 to 2019 (Xu et al., 2020, p. 3511), therefore it is very likely that this trend will continue.

4.3.1. Literature Overview

The categorization of supply chain risks throughout literature has seen many different approaches. The difference in categorization of risks is likely based on different perspectives from which authors looked at the issue – risks were categorized based on origin, cause, duration, controllability, source, threatened field etc. (Er Kara & Oktay Fırat, 2017, pp. 38–39). Due to the vast number of approaches this work lays out a few selected, the most common ones being the differentiation by supply-side and demand-side risks (Er Kara & Oktay Fırat, 2017, p. 45). However, to include a multitude of other ways of differentiation, the following table briefly lays out approaches of different authors. The table was originally conducted by Sodhi et al. (2012) and was extended by several rows.

Table 1: Supply Chain Risk Categorization (adapted from: Sodhi et al., 2012, p. 4)

Authors (chronological order)	Risk categorization
Jüttner et al. (2003)	Based on sources: environmental risk sources, network risk sources, and organizational risk sources
Spekman & Davis (2004)	Six dimensions of supply chain as risk sources, (1) inbound supply, (2) information flow, (3) financial flow, (4) the security of a firm's internal information system, (5) relationship with partners, and (6) corporate social responsibility
Cavinato (2004)	Based on five sub chains/networks as risk sources, (1) physical, (2) financial, (3) informational, (4) relational, and (5) innovative
Chopra & Sodhi (2004)	Categorize supply chain risks at a high level as disruptions or delays. These risks pertain to (1) systems, (2) forecast, (3) intellectual property, (4) receivable, (5) inventory and (6) capacity risk
Christopher & Peck (2004)	Categorize supply chain risks as (1) process, (2) control, (3) demand, (4) supply, and (5) environmental
Kleindorfer & Saad (2005)	Based on the sources and vulnerabilities of risks, (1) operational contingencies, (2) natural hazards, and (3) terrorism and political instability
Bogataj & Bogataj (2007)	Categorize supply chain risks as (1) supply risks; (2) process risks; (3) demand risks; and (4) control risks
Sodhi & Lee (2007)	Categorize supply chain risks in the consumer electronics industry broadly as

	those requiring strategic decisions and those requiring operational decisions, in three categories: (1) supply, (2) demand, and (3) contextual risks
C. Tang & Tomlin (2008)	Categorize supply chain risks as (1) supply, (2) process, (3) demand risks, (4) intellectual property risks, (5) behavioural risks, and (6) political/social risks
Manuj & Mentzer (2008b)	Categorize supply chain risks as (1) supply, (2) operations, (3) demand, and (4) other risks including security and currency risks
Manuj & Mentzer (2008a)	Categorize supply chain risks as (1) supply, (2) operational, (3) demand, (4) security, (5) macro, (6) policy, (7) competitive, and (8) resource risks
Oke & Gopalakrishnan (2009)	Consider low-impact high-frequency and high-impact low-frequency risks in three major categories: (1) supply, (2) demand, and miscellaneous retail risks
Rao & Goldsby (2009)	Categorize supply chain risks as (1) framework and (2) problem specific, and (3) decision making risk
Simchi-Levi (2010)	Categorizes by the controllability. (1) Unknown-Unknowns are uncontrollable, whereas (2) Known-Unknowns are more controllable
Tang & Nurmaya Musa (2011)	Categorize supply chain risks by (1) material flows, (2) financial flows and (3) information flows
Sawik (2013)	Categorizes supply chain risks by their cause, namely (1) natural and (2) man-made disasters
Bradley (2014)	Similar approach to Oke & Gopalakrishnan (2009), categorizing as frequent and rare risks
(Er Kara & Oktay Fırat, 2017)	Categorize by (1) financial, (2) organizational, (3) supply side, (4) manufacturing, (5) customer and market, (6) logistics and transportation, (7) technological, (8) environmental, (9) geopolitical, (10) regulatory, legal and bureaucratic, (11) deliberate acts, (12) industry-specific and (13) supply chain structural risks
(Shahbaz et al., 2019)	Categorized by (1) supply side risks, (2) process side risks, (3) demand side risks, (4) logistic side risks, (5) collaboration side risks, (6) financial side risks and (7) environment side risks

4.3.2. Supply Chain Risk Categorization

To take all the approaches into account is not deemed reasonable as it would wind up being a confusing conglomerate of categories, making it impossible to clearly assess risks. However, looking at the table, it becomes apparent that supply chain risks are often separated into two main categories, one of which points in the upstream direction of the supply chain (towards suppliers of materials or subproducts) whereas the other points downstream towards customers (therefore including everything that comes after production, e.g. distributing and delivering the products). These two variants of risk, the supply-side risks and the demand-side risks as well as a few other notions are briefly explained in this subchapter. One very clear distinction was done by Jüttner (2005) who, alongside other authors that chose a similar approach, differentiated by **supply-side, demand-side** and **environmental risks**. Extended by another category, called **operations/operational risk** by Manuj and Mentzer (2008a, 2008b) or internal risk by Christopher and Peck (2004), the four risk categories proposed by this work are:

Supply-Side Risks

Supply-side risks are such risks imposed by upstream suppliers or partners such as missing raw materials or subproducts. This means, that supply-side risks influence the capability of a firm to meet customers' demand as it will not be able to produce what is asked, at least not within an accepted or anticipated timeframe, if there are problems upwards along the supply chain (Manuj et al., 2014, p. 242; Zsidisin, 2003, p. 222). Previous research further shows that supply-side risks is usually perceived as "multi-dimensional" (Hallikas et al., 2002, pp. 54–55). Supply-side risks can not only be cause by failure of individual suppliers but also overall market conditions. The danger of an event occurring, causing problems at suppliers or supply markets, that prevents a company from acquiring materials needed to fulfill customers' demands or even threatens customers' life or safety can be used as brief definition of the term supply-side risk (Manuj & Mentzer, 2008a, pp. 138–139, 2008b, pp. 197–198; Zsidisin, 2003, p. 222). Supply-side risks are often not considered thoroughly enough by companies when making strategic decision in the supply chain. Firms switch from sourcing regionally/domestically to sourcing globally to gain from lower unit costs, without taking into consideration the increased risk to the supply chain due to increased lead times, reliance on partners that are themselves prone to disruptive events or potentially less control (Christopher & Peck, 2004, p. 6).

Demand-Side Risks

Contrary to the supply-side risks, the demand-side risks look downstream along the supply chain, towards the end-customer. Demand-side risks are such events that can cause disruptions to the outbound flow of products, information or money between a firm and the market. It relates not only to the supply chain nodes directly adjacent to the focal company (such as logistics companies) but rather everything that is based downstream, including end-customers (Christopher & Peck, 2004, p. 5). For example, uncertainty about whether customers are placing orders and the volume of demand are such downstream risks a company has to bear, as in reality customers' demand usually is uncertain (Manuj & Mentzer, 2008a, p. 139; Nagurney et al., 2005, p. 122; Sodhi, 2005, p. 72). It is a two-edged blade as, on one hand, too little stock prevents meeting customers' demand whereas on the other hand excess stocking is likewise risky. Latter may force the producer to sell at a discount and lose revenue (Sodhi, 2005, p. 72). Customers that are retailers and are acting in a risk-averse manner might have a significantly smaller order size, which is not profit-maximizing but risk-minimizing for them. For the manufacturer, this risk-averse attitude of retail-customers represents a demand-side risk (Y.-J. Chen & Seshadri, 2006, p. 1292). In general, there is a widely acknowledged view in literature, that uncertainty in demand strongly impacts stock and price management (Ballou & Burnetas, 2003, p. 68; Betts & Johnston, 2005, pp. 51–54; Cachon, 2004; Radke & Tseng, 2012, p. 387; Sodhi, 2005, pp. 69–70; Talluri et al., 2004, pp. 62–63; Xiao & Yang, 2008, p. 197). The intensity of demand-side risks is likely to vary with the type of product. Functional products are less risky than innovative products (Fisher, 1997, p. 106; M. E. Johnson, 2001, p. 116).

Operational Risks

The operational or operations risk involves risks within the processes of the focal company itself. Operational risks have an impact the company's ability to produce, deliver the desired/usual quality and do it in reasonable time while fulfilling economic dues (usually profitability). Operational risks usually originate from within the producing firm and is prompted by variations in production (e.g. machine downtime or time between production stations), internal disruptions

(e.g. breakdowns) or external factors (e.g. cyber attacks) (J. Chen et al., 2013, p. 2188; Manuj & Mentzer, 2008a, p. 139, 2008b, p. 198).

Environmental Risks

The differentiation suggested by Christopher and Peck (2004) chooses a slightly different approach. They separate internal and external risks within the supply chain as well as those that are external to the supply chain (such as environmental risks). Internal risks are further divided into process and control risks. These two categories together basically resemble the previously mentioned operational risks, just further segmented. External risks within the supply chain (but outside the firm) comprise the supply-side and the demand-side risks. Lastly, the external risks outside the supply chain, in this work called environmental risks, can affect either the company or the supply chain directly or indirectly, but as well the entire market (Christopher & Peck, 2004, pp. 4–5; Kleindorfer & Saad, 2005, pp. 53–54). For example, there can be contamination of products/materials making them unusable or a node (e.g. a supplier) within the supply chain ceases to exist or to be able to deliver due to accidents, natural calamities, weather conditions or regulatory restrictions. Risks of the environment can be consequences of triggering events of different nature, like socio-political, technical or economic. Some of these events might be predictable, their nature or timing might be estimable (Christopher & Peck, 2004, pp. 4–6). Those events, that are in some way predictable, can usually be presaged by scanning the corporate environment for so-called “weak signals” (Ansoff, 1976, p. 129, 1981; Welge et al., 2017, p. 439). Even though some events are predictable, research showed that companies often times fail to actually do so, despite having the chance (Christopher & Peck, 2004, pp. 4–6). This work also includes in the environmental risks the security risks, as named by Manuj and Mentzer (2008b), which are not constrained within the scope of the focal firm but can also impact along the entire supply chain, either manipulating operations of the producing firm or of all members of its supply chain (Manuj & Mentzer, 2008b, p. 198). Christopher et al. (2011) also include sustainability issues into the category of environmental risks (Christopher et al., 2011, p. 69).

To summarize the types of supply chain risks proposed, the following figure, adapted from Manuj and Mentzer (2008a), depicts the four categories of risks along the supply chain.

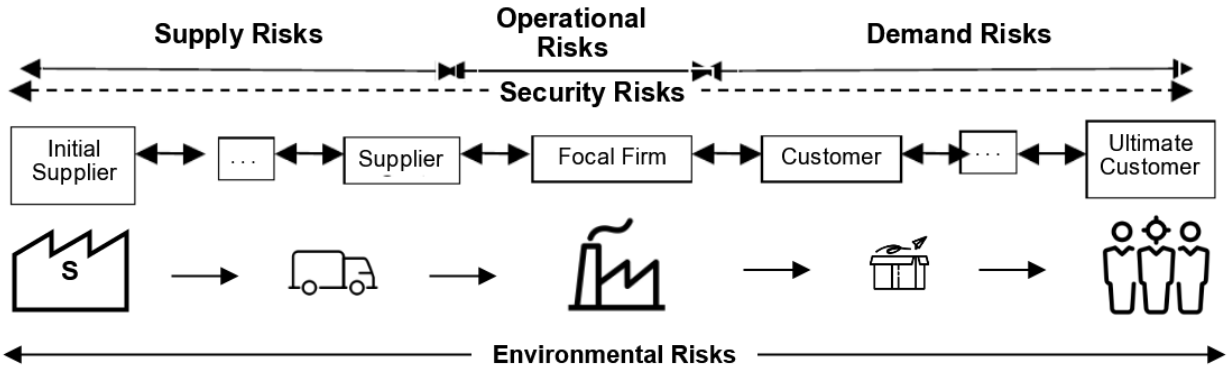

Figure 2: Types of Supply Chain Risks (adapted from: Manuj & Mentzer, 2008a, p. 138)

5. Supply Chain Disruption Risks

The following chapters briefly elaborate about concrete risks of the previously proposed risk categories. It is intended to create an image of how risks of the different categories can manifest

in reality. The risk of business interruptions, which includes supply chain disruption, was ranked the second biggest threat to global business in a survey, carried out in fall 2019, among more than 2700 risk management experts (consultants, senior managers, global corporate insurance experts) from customers (global businesses) of Allianz. Only the risk of cyber incidents (like hacker attacks, IT failures, data breaches, etc.) was considered slightly higher, which nevertheless also can affect the supply chain (Allianz, 2020, pp. 11–16; Manuj & Mentzer, 2008a, p. 139).

5.1. Supply-Side Risks

The supply-side risks are those, that originate within the upstream side of supply chains, thus towards the suppliers of a company (Manuj et al., 2014, p. 242; Zsidisin, 2003, p. 222). Upstream includes everything that happens within the supply chain before arriving at the focal firm – delivery of raw materials, subcomponents etc. Possible supply-side risks include supply lead time (Glock & Ries, 2013, pp. 43–45), bad quality (Barroso et al., 2011, p. 163; Handfield & McCormack, 2008, p. 93), delay of delivery (Talluri et al., 2006, p. 213; Talluri & Narasimhan, 2003, p. 544), shortage or uncertainty in the delivered quantity or failure to deliver at all (Barroso et al., 2011, p. 163; Handfield & McCormack, 2008, p. 93; He et al., 2017, pp. 17–18; Viswanadham & Samvedi, 2013, p. 6488), problems in logistics or transportation (Er Kara & Oktay Fırat, 2017, p. 7; He et al., 2017, pp. 16–17), problems due to geographical locations (Chan & Kumar, 2007, p. 422), any type of failure of a supplier (Ravindran et al., 2010, pp. 408–410; Ruiz-Torres et al., 2013, p. 375), financial problems (Lockamy & McCormack, 2010, p. 589) or even bankruptcy of a supplier (Handfield & McCormack, 2008, p. 93; Sawik, 2018, p. 2), general disruption of supply (Meena et al., 2011, pp. 1058–1059; D. D. Wu & Olson, 2010, p. 4920), insufficient service of suppliers, the capabilities in risk management of suppliers (Ho et al., 2015, p. 5045), or missing involvement of a supplier (Chaudhuri et al., 2013, p. 2792). This is not a full list but a mere fraction of what is suggested among literature and represents well the variety of supply-side risks a firm can encounter.

Especially shortages of materials are suggested to be one of the biggest supply-side risks. According to the DHL Resilience360 Annual Risk Report 2018, raw material shortages are among the top ten risks for supply chains. Although, there is a trend towards regional production of final products, many components are still sourced globally. Hence, such components are prone to disruptions, e.g. demand spikes or bottlenecks in production. As an example, materials used to produce lithium-ion batteries, that are needed for products like phones or electric vehicles, are facing strong disruptions. Lithium demand will spike in the upcoming years. Another important material for the batteries (cobalt) is mostly mined in Congo, where instability could cause a disruption of supply – the differentiation between supply-side risk and environmental risk is fluent in this case. It can be either, but in this case, it is categorized as supply-side risk for the focal firm. This risk is undermined by the fact that some companies, that usually buy finished batteries from producers, started purchasing cobalt themselves (Kamal & Larsson, 2019, p. 31).

Supply-side risks can also be invoked by the focal firm itself. Lead time risks occur when companies underestimate the necessary quantity of a material and replenishment orders are not placed in time. Especially with less common components or materials, lead times can be high, therefore making the consequences of underestimation of demand worse (Jian et al., 2015, pp. 61–62). Furthermore, as depicted in figure 2, environmental issues can have an impact

throughout all parts of the supply chain, thus also on the supply side (e.g. the cobalt issue). Another example therefor is the case of a firm for packaged consumer goods. There was a customs strike in a country where the company had a production plant. The plant should have had materials for three weeks of production in stock but only had enough for one week as part of it was in transit. Due to the customs strike, the plant had to stop production after a week. In such a case, fixed costs as well as labour costs must still be paid. Although the company had other plants that produce the same goods, there were not enough capacities to package it, therefore making it impossible to substitute the shut down plant. After the strike was over, the company invested money into overtime production to catch up, leading to effectively only delivering a few days' worth of production late. Despite that, the cost of this disruption was approximately a million dollars (Schmitt & Singh, 2012, p. 22).

Supply-side risks in particular can often not be directly mitigated by influencing the corresponding risk source – the supplier in question. Thus, it is important for firms to focus on having a diversified supplier portfolio and collaborating closely with a set of reliable suppliers, to build a solid foundation for a well-functioning supply chain (see chapter 6.2). To achieve that, it is helpful if the supply chain is seen as a strategic asset that requires careful elaboration and development of a strategy.

5.2. Demand-Side Risks

Opposing to the supply-side risks, the demand-side risks are located downstream along the supply chain, towards customers, cause by any type of inbound disruption to consumer markets. One source of demand-side risks are uncertainties in the level of demand (Manuj & Mentzer, 2008a, p. 139; C. S. Tang & Tomlin, 2009, p. 159). A discrepancy between what a firm predicts to be demanded vs. what customers actually demand shows missing alignment of the supply chain strategy with customers' needs and can have severe consequences. On the one hand, if a firm overestimates demand and therefore stocks more products than demanded, it might eventually be forced to sell at a discount. On the other hand, if there is too little stock, the firm can not fill customers' demand and burden a loss of potential revenue (Jian et al., 2015, p. 61). Sometimes, wrong predictions are caused by a lack of communication with customers (Diabat et al., 2012, p. 3044). Through bad planning and poorly timed product introductions, a company can miss market opportunities and/or be forced to write-off residual stock. Demand volatility can also originate in seasonality or short-term trends, leading to short product life cycles, or any sort of chaos caused by overreactions or flow of distorted information (e.g. "fake news") causing panic reactions or a bullwhip effect (M. E. Johnson, 2001, p. 122; Jüttner, 2005, p. 123; Wilding, 1998, pp. 602–604). The bullwhip effect describes a phenomenon where demand distortion along the supply chain leads to excessive stocking. For example, if the demand forecast of actual end-customers is about correct (maybe already slightly to high), each entity upstream along the supply chain is assumed to add a small "safety buffer", blowing up the numbers before reaching the production firm, causing it to produce an amount that is far off what customers eventually buy (Li et al., 2017, p. 5423). Apart from the firm itself, its logistics partners, retailers and customers, another source of demand-side risks can be competitors. New product introductions by competitors can lead to demand variations (Manuj & Mentzer, 2008a, p. 139). Aside from the demand quantity, the distribution of products is another area which is prone to risks – this is true for the supply side as well – especially transportation and the distribution network. For example, a strike of truck drivers might make it impossible for a firm to deliver

products to customers or retailers resulting in lost revenue and potentially bad reputation (Wagner & Bode, 2009, p. 275). The bargaining power of customers, one of Porter's Five Forces (G. Johnson et al., 2017, pp. 68–69), can also have an impact on a supply chain if it is exceptionally high due to disruptive events. This emphasizes the importance of considering the bargaining power of customers when developing the supply chain strategy.

In 2018, fluctuating consumer demand was ranked the second biggest (19.7%) challenge that companies are facing in supply chains, with visibility (21.1%) being on the first rank. Visibility can be understood as "transparency" along supply chain processes. For example, knowing how raw materials get to production plants was a major worry of producers as well as transparency of material/product flows in general (eft, 2018). The risks imposed by demand quantity become increasingly more with the range of products or product variants a firm offers. Demand volume is hard to predict as well as the distribution between product variants. Furthermore, some products need to be localized for certain regions or countries, which means that demand forecasts must be conducted individually for each region as it is hard or even impossible to sell adapted products in other regions than the supposed ones (C. S. Tang & Tomlin, 2009, p. 159).

Demand risks can not always be traced back to a particular triggering event. As it is the customers' preferences which makes them buy a product, it is, if anything, only market psychology that can serve a reason. Some demand disruptions though, can certainly be justified by triggering events or situations. If the economy is in a downtrend it is conclusive that demand is going to decrease. Concluding based on the theory, threat of demand-side can be invoked if the supply chain strategy does not fulfill certain criteria like being aligned with the business strategy and especially with customers' needs. Failure in alignment leads to discrepancies between what the firm offers and what the customers demand, thus imposing risks on the supply chain.

5.3. Operational Risks

Operational risks generally reside within the focal firm, which does not mean, that triggering events only come inside. They can be caused by a multitude of triggers within the firm, for example, through breakdown or malfunction of equipment or machines, manufacturing mistakes, too many variations of processes or technology changes (Manuj & Mentzer, 2008a, p. 139). However, there are also external sources that can impact on a firm's ability to operate, for example through cyberattacks on IT systems, publication of leaked information or human-based issues like vandalism, sabotage, strikes or accidents (Chopra & Sodhi, 2004; Manuj & Mentzer, 2008a, p. 139; Spekman & Davis, 2004, p. 422; Wagner & Bode, 2006, pp. 311–312).

An especially high threat to operations of a firm constitute cyber risks. Cyber risks can be assigned to the category of security risks, which is, according to the theoretical framework of this work, part of the environmental risks. This is reasoned by the fact, that security risks, thus also cyber risks, can impact along the entire supply chain and originate from outside of it. From a firm's perspective, cyber risks pose a high threat to their operations. In fact, according to the Allianz risk survey of more than 2700 experts, cyber risk was ranked the biggest risk to global businesses in 2020. To put this into perspective, this risk source has seen an astounding rate of growth. In 2013, in the same report, this risk finished on the 15th rank, with just 6% responses. Cyber risks like ransomware, cyber attacks and data breaches continue to grow in number and impact. Especially data breaches become bigger threats, as the economic importance of

personal data is growing at a tremendous rate. Data has been dubbed the new oil many times (Bhageshpur, 2019; The Economist, 2017), hence it can be concluded that it is a valuable asset, prone to risks from cyber attacks (Allianz, 2013, p. 4, 2020, pp. 11–13). A rather old, yet well-aged example of cyber risk is the spread of the “love-bug”, a computer virus that spread globally in the beginning of the millennium. It had major impact on several big institutions and organizations like the Pentagon, the NASA, Ford and the UK parliament – just to name a few – and allegedly caused billions of dollars of estimated damage (Chopra & Sodhi, 2004). Just recently, the creator of this virus, a now 44 years old Filipino was found in Manila. He said, he released the virus to gather passwords to get internet access, which he could not afford back then. Causing a worldwide “pandemic” by spreading his virus and inflicting financial damage was not his intention and he allegedly regrets it (White, 2020).

Breakdown of machines was found to be a major fear of global businesses, as 30% of more than 1000 participants of a survey, conducted by Allianz in 2019, stated (Allianz, 2020, p. 16). According to the framework, the risk of breakdown of machinery can be assigned to the operational risks. Just as the supply-side risks, the operational risks within a supply chain also strongly influence the ability of a firm to deliver its products in a consistent quality, an adequate lead time and with delivery reliability (Manuj & Mentzer, 2008a, p. 139), which are some of the main goals of a good supply chain strategy.

5.4. Environmental Risks

Finally, the fourth group of risks are the environmental risks. These are the ones external to the supply chain that can have an impact on the entire supply chain or even on entire markets (Christopher & Peck, 2004, pp. 4–5; Kleindorfer & Saad, 2005, pp. 53–54). Examples for risks external to the supply chain are calamities like earthquakes, fires, explosions, hurricanes, storms or other natural hazards, terrorism or political instability, systemic failures such as grid blackouts, human-based disruptions like strikes (Kleindorfer & Saad, 2005, pp. 54–55), wage increases or currency risks through changes in exchange rates (Manuj & Mentzer, 2008b, p. 201), the latter being especially relevant in global supply chains as they operate across borders, thus in different currency areas (Manuj & Mentzer, 2008b, p. 198). The interruption of business, which includes supply chain disruptions, was ranked the second biggest risk to global businesses, according to the Allianz Risk Barometer 2020 (Allianz, 2020, pp. 14–16). As the report does not specifically examine risks to supply chains, but risks to global businesses in general, the differentiation is not the same (i.e. supply chain disruption as part of business interruption while, for example, fires are a distinct category). Yet the report states a variety of risks that can be assigned to the environmental risk category according to the framework of this work.

5.4.1. Calamities – Earthquakes, Tsunamis, Storms

The problem with environmental risks is often their unpredictability. In March 2011, the Tōhoku earthquake, often called the Great East Japan Earthquake, shook the earth with an astounding magnitude of 9.1 approximately 70km off the coast (Hayes et al., 2017, p. 91) – The fourth largest earthquake ever recorded (USGS, 2020). The earthquake was followed by a heavy tsunami and had devastating consequences (BBC, 2011), which is likely an understatement. The consequences to supply chains were severe. During the weeks after the quake, 80% of automotive plants in Japan had stopped producing. For example, Nissan had a capacity loss of

approximately 270.000 cars (Strom et al., 2013, p. 3). Toyota, the biggest car manufacturer in the world (Forbes, 2020), had to delay the release of two new models (Reuters, 2011). An earthquake can hardly be predicted over a long term and even if, the possibilities to prepare are meagre and the probability of an earthquake can not be manipulated.

Among the top ten risks for global businesses according to the Allianz Risk Barometer 2020, half of them are risks that belong to the category of environmental risks (Allianz, 2020, pp. 11–23). Among more than 1100 corporate insurance claims between 2011 and 2018, a third was caused by storms and water damage. The DHL Resilience360 Annual Risk Report 2018 examined the top ten risks for supply chains in 2019 and has shown very similar results. Six of the identified risks can be assigned to the category of environmental risks (Kamal & Larsson, 2019, pp. 30–33). The environmental risks, not in terms of the definition in this work, but in terms of extreme weather, climate or natural disasters, are by far the most prevalent category of risks for four years now, according to the Global Risks Report 2020 conducted by the World Economic Forum. The report shows top five rankings of global risks over the years, firstly in terms of likelihood and secondly in terms of impact. For four years consecutively, extreme weather was ranked on the first place in terms of likelihood while always being within the top four impact-wise (World Economic Forum, 2020, fig. I). Even though this report is not specifically targeting global supply chains, the relevance of disruptive events like extreme weather conditions, natural disasters, mass destruction weapons and societal risks like water crises for supply chains is evident.

5.4.2. Accidents – Fires, Explosions

Allianz as insurance partner of global businesses analysed over 1100 corporate insurance claims between 2013 and 2018, that had both, property damage, as well as business interruption components and an overall value of 7,1 Billion USD. Almost a third (30%) of these incidents were caused by fires (Allianz, 2020, p. 15). DHL found containership fires to be among the top ten supply chain risks of 2019, highlighting two large fires at Maersk-operated ships in 2018 as well as several ship fires in the beginning of 2019. Often, fires on cargo ships break out due to improper securing of the load (Kamal & Larsson, 2019, p. 32). As this is an issue of lack of diligence by workers, fires like these can also be categorized as operational risks or supply risks, depending on the perspective (i.e. operational for the logistic firm operating the ship; supply-side for the customer of the logistic firm). It shows that the boundaries between the categories are sometimes fluent.

5.4.3. Political Unrest and Regulatory Restrictions

Political unrest is another source for environmental supply chain risks. Protests in the past year, such as in Hong Kong, Chile or France have affected global businesses and resulted in property damage and business interruptions. Amid the protests against the Chilean government for example, many supermarkets, including Walmart, had to close for an extended period of time causing enormous losses due to business interruption (Allianz, 2020, p. 15). Another source of risk among the category of political and regulatory risks are trade wars, tariffs and sanctions. Probably the best example for a fully-grown trade war is the ongoing dispute between the USA and China. By the beginning of 2018, average tariffs in the US on products from China were at 3,1%. Today, they are sitting at an incredible 19,3% (Bown, 2020). Another negative example is

the Brexit – which became effective with the 31st of January 2020 (EU, 2019) – which has and will have a huge impact on global supply chains (Nakamura et al., 2019, pp. 994–995).

5.4.4. Epidemics and Pandemics

Epidemics as well as pandemics an environmental risk which is less likely to occur, but if it does, its impact is often high. Due to outbreaks of viral infections, travel restrictions can come into effect, restricting materials transports, or plants might even have to shut down. There is a wide range of literature examining the effects of epidemics and pandemics on supply chains. Especially focussed among research are influenza outbreaks (Queiroz et al., 2020, p. 10). The impact of epidemics and pandemics is best analysed by taking an example.

COVID-19 – The 2020 Coronavirus Pandemic

The latest, ongoing example for epidemics and pandemics acting as sources of disruption risk to global supply chains is the 2020 COVID-19 pandemic. In a survey of 300 “shipping and freight professionals”, almost 98% of respondents replied that coronavirus has at least somewhat affected their operations (58,8% said there was a significant impact). Only 1,3% said that there was no impact (Shipping and Freight Resource, 2020). Note that this survey was conducted in April, while the pandemic is still rampaging across the globe as of July 2020. Even though this topic is not older than half a year, the amount of research on it is gigantic, which reflects the remarkable extent of this global disruption. Supply chains around the globe are shaken to their very foundations. Assessing the complete extent of disruption is impossible at this moment, as the world is still right in the thick of this pandemic. However, until now, the consequences have already been devastating, with a negative GDP growth in Q1 of 2020 in a majority of countries worldwide (Jones et al., 2020). The pandemic caused a vast variety of supply chain disruptions and showed how unprepared some are. Hand sanitizer shortages are a reasonable example: Supply chains failed to meet demand because they were not built to provide such quantities caused by an enormous demand spike. Toilet paper, however, is a different case. Shortages started when panic selling became virulent, further kindled by media frequently reporting about it. However, after the first spike levelled out, shortages persisted, even though the capacities – in terms of paper mills – were there to meet the demand. The problem was based in the type of demand. With mandatory stay-at-home regulations, demand almost completely shifted to private households. Public demand for toilet paper (companies, school, restaurants) dropped significantly, rendering production sites that specialized in producing for bulk buyers obsolete. A similar story with an even greater extent was dry yeast. In a US grocery chain that carries one brand of dry yeast, which has never before run out of stock, only 6% of its stores had dry yeast left in a particular week in April. Again, demand strongly shifted from industrial to private (Taylor et al., 2020).

These issues are good examples for a lack of flexibility, one goal of supply chain management. A good supply chain strategy is adaptive, thus able to move with the demand. The shift towards private demand and the failure of supply chains to adapt to this change of market conditions proves the lack of agility and flexibility. Developing strategies on how to shift between retail and industrial demand more quickly can thus be deemed an important consideration for supply chain strategists.

However, there are other heavy disruptions of global supply chains, with a higher economic magnitude as well as a higher threat level to human health. One of the hardest economic

impacts can be observed in the automotive industry. Firstly, travel was restricted and in the automotive industry there is significant international sourcing. Thus, part supply was missing. Further, basically all major car manufacturers had to close their plants (Reuters, 2020). Lastly, demand plummeted. In the US, Tesla was the only car manufacturer that was able to book a growth of 6,8% in sales. Other manufacturers had losses of US sales ranging from roughly 7% (Mazda) up to almost 40% (Nissan) (Thiel, 2020). The pharmaceutical industry experienced a rough shock as well. This is particularly critical as it is a crucial industry in times of a worldwide health crisis. India is a main producer of paracetamol, which is used to treat COVID-19 symptoms. For the production of generics India sources a majority of its ingredients from China – the world's largest provider of active pharmaceutical ingredients, where Hubei is one of the main hubs (Oxford Business Group, 2020).

5.5. Summary – Supply Chain Disruption Risks

As table 1 shows very well, there is an almost infinite number of variants how to differentiate supply chain risks. After all, the categorization is not the most crucial part but rather serves as mere structure to base further risk treatment on. Therefore, this work suggests a basic categorization which simply represents the major parts of a supply chain. The following table briefly summarizes these categories.

Table 2: Overview of proposed Supply Chain Categories

Risk Category	Notes/Examples
Supply-Side Risks	Upstream along the supply chain, e.g. failure of a supplier to deliver in time or bankruptcy of a supplier or other upstream partner (e.g. logistics)
Demand-Side Risks	Downstream along the supply chain, e.g. sudden demand spikes or plummets or wrong production quantities due to bullwhip effect
Operational Risks	Inside the focal firm, e.g. machine breakdowns or human-based failure
Environmental Risks	External to the supply chain, usually hard to predict and prepare for, can have impact on all parts of supply chain, e.g. earthquakes, fires, wars, currency fluctuations, pandemics, ...

6. Strategic Management in Global Supply Chains

This chapter examines different disciplines of strategic risk management within global supply chains. Firstly, supply chain disruption management is analysed by assessing the supply chain risk management process (SCRMP) and its different frameworks that can be found within literature. The SCRMP proposed in this work – comprising risk identification, assessment, mitigation and monitoring – should act as a framework for firms with global supply chains to manage risks imposed to them. Secondly, three common disciplines to increase supply chain resilience are discussed – agility, flexibility and redundancy as well as collaboration.

6.1. Disruption Management – The Supply Chain Risk Management Process (SCRMP)

As with everything around this widely acknowledged and frequently studied topic, there is a significant number of different approaches to supply chain risk management to be found in literature. Again, there is no “one way” but countless ways and terminologies. In spite of this wide range of approaches, there are mostly recurring elements. The conglomerate of literature suggests following steps in this order, yet with varying nomenclature, as the general SCRMP: (1) risk identification, (2) risk assessment, (3) risk mitigation and (4) risk monitoring (Aqlan & Lam, 2015a, pp. 58–60; Fan & Stevenson, 2018, pp. 214–218; Hachicha & Elmsalmi, 2014, p. 1307; Ho et al., 2015, pp. 5038–5052; Huang, 2020; ISO, 2018; Kern et al., 2012, p. 63; Kırılmaz & Erol, 2017, p. 56; Louis & Pagell, 2019, p. 333; Manuj & Mentzer, 2008a, p. 137; Mullai, 2009, p. 93; Tummala & Schoenherr, 2011, p. 477; Zsidisin & Ritchie, 2009, p. 4). This process is an important task that firms should be continuously doing amid the immense amount of risks to global supply chains (Dong & Cooper, 2016, p. 155; Kırılmaz & Erol, 2017, p. 56). It is useful as it enables managers to concentrate their risk mitigation efforts onto those risks that have the highest relevance. This allows the best possible preparation.

6.1.1. Risk Identification

The first step of the SCRMP this work proposes is, widely congruent with literature, the step of *risk identification*. Firstly, risks must be found, described and allocated to categories. As such categories, the ones previously treated in the risk categorization – supply-side, demand-side, operational and environmental risks – can be used. Of course, there are other possible ways of differentiation, Aqlan and Lam (2015a) for example suggest a categorization by suppliers, producers, customers and transportation (Aqlan & Lam, 2015a, p. 58). A firm should decide for itself which form of risk categorization it deems best fitting. Sometimes this process of identifying and categorizing is also called “supply chain mapping and risk registering”. Firms should take this step very seriously, as any risk that is overlooked will not be taken into account in the remaining process and therefore poses a big threat to the firm. Thus, the groups that are participating in this process should be as heterogenous as possible (Kırılmaz & Erol, 2017, p. 56). A group of only top management perhaps will not uncover some risks that might be obvious to workers. To successfully identify risks, it is further necessary to understand the drivers of supply chain risks (Fan & Stevenson, 2018, p. 214). When identifying risks, keep in mind that there can be a high interdependence between risks of different categories (Tummala & Schoenherr, 2011, p. 476). As an example, Aqlan and Lam (2015a), whose categorization model, in contrast to the proposed categories in this work, does not have the environmental risks as it’s own category, note that environmental risks can be relevant for all categories (Aqlan & Lam, 2015a, p. 58). Several authors emphasize the importance of early risk detection (Bradley, 2014, p. 486) and attempts of prediction (Dani, 2009, p. 59). Especially for finding external (environmental) risks it is helpful to scan the environment for weak signals (Ansoff, 1976, p. 129, 1981; Welge et al., 2017, p. 439).

Apart from only putting the identified risks into categories of some sort, Manuj and Mentzer (2008a) suggest an extended process of “risk profiling”. Adding to mere categorization, they suggest evaluating a few more characteristics of each risk. Is the risks atomistic or holistic, is it quantitative or qualitative and is its area of effect global, domestic or both (Manuj & Mentzer, 2008a, p. 144)? Structuring risks in a table is suggested for risk identification and profiling. Other

tools that can be helpful with the step of risk identification are supply chain mapping, maintaining checklists, event tree analyses, fault tree analyses, failure mode and effect analyses (FMEA) or Ishikawa diagrams (Tummala & Schoenherr, 2011, p. 476).

The gist is, that in the first step, possible risks need to be identified (found and described) and categorized. As categories, the above mentioned four segments of risk (supply, demand, operational and environmental) are suggested. It needs to be done in an ambitious manner, with heterogenous teams to minimize the risk of overlooking things. Managers from the field of procurement are likely to be able to better identify supply risks, workers and managers with production-scope are probably best at identifying operational risks and employees and managers from departments like marketing, sales and distribution have it easiest with demand side risks. To identify environmental risks, it could be advisable to consult experts but also rely on top management's perspectives.

6.1.2. Risk Assessment

After identifying and structuring the risks, the next step is to assess them. The purpose of this step is to examine the results of the risk identification, to prioritize risks and to uncover interdependencies between those risks (Louis & Pagell, 2019, p. 333). This step is important inasmuch as not every risk imposes a threat to every supply chain. A firm's supply chain may be immune to one risk but highly vulnerable to another (Manuj & Mentzer, 2008a, p. 145). Risk assessment can be formal or informal and quantitative or qualitative, depending on the value a firm assigns to this process (Zsidisin et al., 2004, p. 398). Highly risk-exposed companies (for example with a very innovative product) should assess a higher value to SCRMP.

Before prioritizing the risks, two crucial factors of each risk respectively should be estimated, namely the probability and the severity/impact. Probability describes the likelihood of a risk event occurring and severity/impact defines the magnitude of negative consequences that the event has on the supply chain (Dong & Cooper, 2016, pp. 148–149). This process is sometimes called risk measurement (Kırılmaz & Erol, 2017, p. 57; Tummala & Schoenherr, 2011, p. 476). To make this estimation more accurate, Aqlan and Lam (2015a) suggest the use of fuzzy sets and probability theories (Aqlan & Lam, 2015a, p. 60). Aside from probability and severity, there is another aspect that must be considered, which is the possible duration of a risk event (Heckmann et al., 2015, pp. 126–127; Lockamy & McCormack, 2010, p. 596; Zsidisin et al., 2004, p. 398). The reason, why most authors do not explicitly name this dimension might be that the potential duration of a risk event can be seen as part of its impact (Bradley, 2014, p. 485). Additionally it is possible to assess the risks for each category separately (Ho et al., 2015, pp. 5038–5047). Numerically evaluating risks has the implicit advantage of making them easy to compare, rank and prioritize. Keep in mind, it is hard to precisely evaluate risks with numbers. The most important part is to evaluate the risks relatively to each other. Dong and Cooper (2016) use a suitable analogy to describe this – It is hard to determine the exact weight of an apple without a scale, but it is easier to tell if one apple is heavier than another (Dong & Cooper, 2016, p. 149). The previously evaluated risks should now be put into a ranking to declare the most important (i.e. threatening) of the identified risks and develop mitigation strategies for them.

At this stage, it is also necessary to clarify, which level of risk is acceptable, which can be tolerable, and which are unacceptable. Acceptable risks are such, that have either a low enough probability or impact that they can be lived with. Tolerable risks are not vitally impacting production but should be acted upon whereas inacceptable risks require immediate action as

they pose a serious threat to production. For example if a supplier of a crucial part is unable to deliver and there is no stock of this part, the production has to shut down – this would be an unacceptable risk that needs immediate action and such risks should be evaluated with high priority to developing a mitigation strategy (Tummala & Schoenherr, 2011, p. 477).

Finally, part of risk assessment should also be to closely analyse risks for interdependencies. Interdependencies between risks can have a significant impact on the threat level of risks or risk-pairs. One risk event for example can be rather harmless, yet carry within it a domino-effect, invoking multiple other disruptions (Venkatesh et al., 2015, p. 162). It is likely that inter-relationships will be found as risk events usually do not come around isolated (Fan & Stevenson, 2018, p. 215).

In conclusion, risk assessment involves reflecting on the risks identified in the first step and proceed to evaluate the probability of occurrence as well as the magnitude of impact on the supply chain of each risk respectively. Examine interdependencies between risks and then continue to prioritize them. Note that one particular risk that seems mild can create multiple other disruptions through inter-relationship between events or drivers. The result of risk assessment should be a comprehensive list of prioritized risks that can serve as profound basis for developing mitigation strategies. Also, in this step, the strengths of specialized groups from the first step are the same. In general, the teams should be as heterogenous as possible to allow a wide-range perspective.

6.1.3. Risk Mitigation

The next step in the SCRMP is about action. Risk mitigation means to take actual measures. Most important in this step is to develop and select proper strategies and then implement them to cope with the risks identified and assessed in the previous steps (Louis & Pagell, 2019, p. 333). Instead of risk mitigation, some authors also call this step “risk treatment”, where risk mitigation is one subordinate form of risk treatment (Fan & Stevenson, 2018, p. 216; ISO, 2018; Louis & Pagell, 2019, p. 333). This is yet another issue of mere terminology, eventually it comes down to the same course of action. This work refers to this step of selecting and implementing strategies as “risk mitigation”.

In literature, there are different proposals of risk mitigation strategies. Some mitigation strategies are implemented before a risk events happens, therefore being of preventive nature, whereas others are contingency plans whose objectives are to contain consequences of already happened risk events (Kern et al., 2012, pp. 65–66). It is suggested to focus on preventive measures instead of containing consequences after risk events happened (Kleindorfer & Saad, 2005, p. 55). To achieve quick action, it is necessary to consider SCRM as an important management task. It is also suggested, to collaborate with supply chain partners in order to make mitigation measures more effective and put them in place more rapidly. The risk mitigation step is especially important, as it is the only one that actually changes the risk aversion of the supply chain. The previous steps of identification and assessment have supportive functions for the third step (Kern et al., 2012, pp. 65–66).

This work distinguishes four generic mitigation strategies that are widely found among literature. All of them are preventive, therefore being implemented before the corresponding risk event happens. Note that these are just generic patterns and most certainly need adaption or combination to provide proper risk mitigation in real-world supply chains. Also, the

interdependencies of risks must be kept in mind as a mitigation strategy for one risk can possibly mitigate but also aggravate other risks (Aqlan & Lam, 2015b, p. 5654).

Risk Avoidance

This strategy aims to prevent a risk from occurring by eliminating the triggering event. The goal is to completely remove the risk, means there must not be any probability of the risk occurring. Risk avoidance is deemed best fitting for risk that have high probability as well as severe impact, that can actually stop the supply chain operation. Risks of this kind are the most threatening and harmful and therefore require the highest investment in measures to eliminate them. Risk avoidance can sometimes even be connected with removing a product, supplier or market/segment from the firm's portfolio (Aqlan & Lam, 2015b, p. 5642; Fan & Stevenson, 2018, p. 217; Giannakis & Papadopoulos, 2016, p. 458; Manuj & Mentzer, 2008b, pp. 210–211).

Risk Reduction

The goal of risk reduction is to lower the probability of the risk event happening until it reaches a level where it can be accepted. With this strategy, the probability of the risk event happening does not go to zero (Aqlan & Lam, 2015b, p. 5642; Giannakis & Papadopoulos, 2016, p. 458). Risks with a high probability of occurrence but relatively low impact on the supply chain are best treated by risk reduction (Aqlan & Lam, 2015b, p. 5642; Fan & Stevenson, 2018, p. 217). Fan and Stevenson (2018) suggest that reduction of the impact of a risk event is also a goal of a risk reduction strategy (Fan & Stevenson, 2018, p. 216). Although a reduction of impact is desirable, it should not be the main focus of this strategy, as the risks it handles are such that already have a low impact. An example for risk reduction is a diversified portfolio of suppliers, preferably from different countries/regions (e.g. having more expensive, domestic suppliers as backup suppliers, in case of any issue in the origin country of cheaper suppliers, such as calamities, currency fluctuations or trade barriers) (Manuj & Mentzer, 2008b, p. 208). Risk reduction in terms of quality can also mean to assure quality among a firm's suppliers by doing audits on suppliers' sites or for materials (Manuj & Mentzer, 2008b, p. 211).

Risk Sharing/Transfer

Risks can also be handled by means of sharing or transferring. The former refers to sharing some or even all risks, that a firm's supply chain faces, with other parties. This can be done for example by contracts where certain cost-sharing clauses in case of any disruptions are included. Risk transfer is somewhat similar to sharing but the goal here is to pass on as much of the impact of the risk as possible to another party, although it is not always possible to pass on the entire impact (Fan & Stevenson, 2018, p. 216). Risk sharing/transferring measures include insurances (e.g. interruption insurance) or contracts with other firms, for example to agree on a carbon footprint threshold for supply chains in a certain industry or geographic area (Aqlan & Lam, 2015b, p. 5642; Giannakis & Papadopoulos, 2016, p. 458). Risks that are not very likely to happen, but have a severe aftermath when they do (e.g. natural calamities, terrorist attacks), should be handled by countermeasures in terms of risk sharing or transferring (Aqlan & Lam, 2015b; Fan & Stevenson, 2018, p. 217).

Risk Acceptance

With this strategy, a firm decides for a specific risk that it is acceptable to take without preventive measures. Note that the level of acceptability is a variable that a company must determine individually as it is dependent on many factors. Acceptable however, does not mean that the risk should be ignored, it should still be monitored and a plan for containing the consequences should be made, to be able to react rapidly in case of occurrence (Fan & Stevenson, 2018, p. 216; Kırılmaz & Erol, 2017, p. 57). This strategy usually only viable for such risks, that were evaluated as acceptable in the risk assessment (Tummala & Schoenherr, 2011, p. 477). For example, this can be the case for risk events, where the cost of prevention exceeds the cost of potential damage (Giannakis & Papadopoulos, 2016, p. 458). These risks are therefore low in both dimensions of the risk profile (probability and impact).

Aside from these generic strategies, Aqlan and Lam (2015b) propose two more strategies which are ignoring the risk as well as risk exploitation. Ignoring the risk is somewhat similar to risk acceptance but with risk dimensions that are so low as to allow to completely ignore this risk, thus neither monitoring nor preparing a contingency plan. However, as these risks are usually not even identified as risks, therefore not making it through the second step, this strategy is not included in the proposed framework. Risk exploit describes a reaction strategy for risks whose impact is positive. As such risks are usually neither found or identified as risks, this strategy is also excluded (Aqlan & Lam, 2015b, p. 5642).

The described approach to risk mitigation strategies is one which is widely found among literature. However, there are other ideas, for example, distinguishing the mitigation strategies by risk categories. Hence, there would be: *supply risk mitigation strategies*, involving considerations about sourcing decisions (single-sourcing, multi-sourcing), behaviour-based management techniques, relationships to suppliers, less complexity among the supplier base or order allocation programming; *demand risk mitigation strategies*, like order-based replenishment plans or production control systems, buyer's risk adjustment, simulations, several programming models, demand forecasting, risk sharing contracts or guaranteed maximum lead times amid demand uncertainties; *operational risk mitigation strategies*, attempting to mitigate risks in manufacturing like risks of quality, supplier lead time uncertainties, capacity inflexibility or machine failures, again by programming models or strategic analyses of different kinds; *environmental mitigation strategies*, such as strategic approaches to selection of site locations or pollution liability insurance contracts (Gao et al., 2018, pp. 245–246; Ho et al., 2015, pp. 5047–5049).

The variety of approaches once more shows that firms must not rely on choosing a generic approach for each risk depending on its risk profile, but rather develop an individual strategy based on them to cope with risks. To select a proper strategy of risk mitigation, there are frameworks that help managers with that decision, for example, the decision support system (DSS) by Micheli et al. (2014). Based on a wide range of literature, this work proposes four generic strategies of risk mitigation, that can be adopted by firms and applied to the assessed and prioritized risks from the previous steps. The following table concisely summarizes these generic strategies.

Table 3: Generic risk mitigation strategies

Strategy	Risk Profile	Information	Example

	(Probability-Impact)		
Risk **Avoidance**	**High-High**	Eliminate a risk by containing the trigger event	Removal of product, supplier, market, ...
Risk **Reduction**	**High-Low**	Reduce probability of risk occurrence	Multiple, geographically distributed suppliers; backup suppliers
Risk **Sharing**/Transfer	**Low-High**	Reduce impact by sharing or transfer	Insurances; contracts with other firms
Risk **Acceptance**	**Low-Low**	Accept and monitor when cost of mitigation exceeds damage	Monitor the risk; prepare contingency plans

6.1.4. Risk Monitoring

After implementing risk mitigation strategies, it is crucial to have a follow-up process, as a firm's environment and thus the risks imposed by it are never static but volatile, uncertain, complex and ambiguous (VUCA) (Hallikas et al., 2004, p. 54; Yarger, 2006, pp. 17–18). The effectiveness of measures taken should be assessed by monitoring the identified and treated supply chain risks which is the main task of this step (Kern et al., 2012, p. 66; Tummala & Schoenherr, 2011, p. 480). Yet, monitoring can also enable to uncover potential new risks early (Kırılmaz & Erol, 2017, p. 59). By implementing mitigation strategies, risks can change, making it important to be watched continuously (Mullai, 2009, p. 96). The necessity for risk monitoring depends on the type of risk. While it might be sufficient for some risks to be monitored only once a year, others might require ongoing monitoring (e.g. weekly or even daily). Especially when it comes to environmental risk events, monitoring becomes essential. Due to the complexity of global supply chains (Manuj & Mentzer, 2008b, p. 213), a firm must keep in mind that environmental risks can not only affect the firm itself or its directly adjacent suppliers but also tier-2 suppliers (a supplier's supplier). Often times, firms do not even know about some higher tier suppliers until a disruption originating from them impacts the firm's supply chain (McCormack, 2008, p. 71).

Several authors state that the step of risk monitoring has seen the least focus among literature even though it is considered to be a vital part of SCRM (Blackhurst et al., 2008, p. 146; Ho et al., 2015, p. 5061). Developing the best strategies to cope with risks is worthless if it is succeeded by poor implementation. Risk can only be mitigated significantly if strategies are carefully applied. By periodically monitoring the further development of risks, that are being treated by a risk mitigation strategy, a company makes sure that it recognizes potential changes and realizes, if adaptions to the strategy might be due (Fan & Stevenson, 2018, p. 217; Kern et al., 2012, p. 66). However, this process should be implemented in a thorough way, thus with formally defined processes, to make sure it is not just mere estimations that are driving it (Fan & Stevenson, 2018, p. 217). The reason behind why many firms do not emphasize risk monitoring is likely to be its high resource requirements. It takes a lot of time to properly set up and execute a risk monitoring process. If anything, firms decide to continuously monitor just a small set of risks (Hoffmann et al., 2013, p. 202). Hoffmann et al. (2013) stress the necessity of a tool to implement monitoring in terms of numbers. A framework for monitoring risks, however, can be similar to a risk assessment framework, as the objectives are almost the same. For example, Blackhurst et al. (2008) proposed a framework for pro-active risk monitoring by tracking risk indices, which is in fact very similar to what is done during the risk assessment step. This is the

reason, why managers often combine monitoring with risk assessment (Fan & Stevenson, 2018, p. 217). However, it is suggested to include into the monitoring process considerations of the implemented mitigation strategies to evaluate their effectivity and constantly seek to improve them (Giannakis & Papadopoulos, 2016, p. 458; Kern et al., 2012, p. 66; Ritchie & Brindley, 2009, p. 16).

In conclusion, the last step of the SCRMP is to implement ongoing monitoring of the risks that are treated by mitigation strategies. There are few frameworks yet, thus a firm may do well by adapting its practises from the risk assessment step and apply them in this step. To do so, it is important to include the applied mitigation strategies, as a main goal of risk monitoring is to assess the effectivity of those strategies. That way, the entire process of SCRM can see constant improvement over time and a firm can minimize the risk of not being prepared for disruptions in its supply chain.

6.1.5. Overview – Supply Chain Risk Management Process

The proposed process of supply chain risk management is a generic framework and can be further adapted by a firm, according to its requirements. There is no clear uniformity in literature about a risk management process in global supply chains, however, the proposed framework is considered to serve a profound basis. Implemented as a continuous, cyclic process, it allows to periodically reassess taken measures. To summarize the SCRMP, the following figure concisely depicts the four steps of the process.

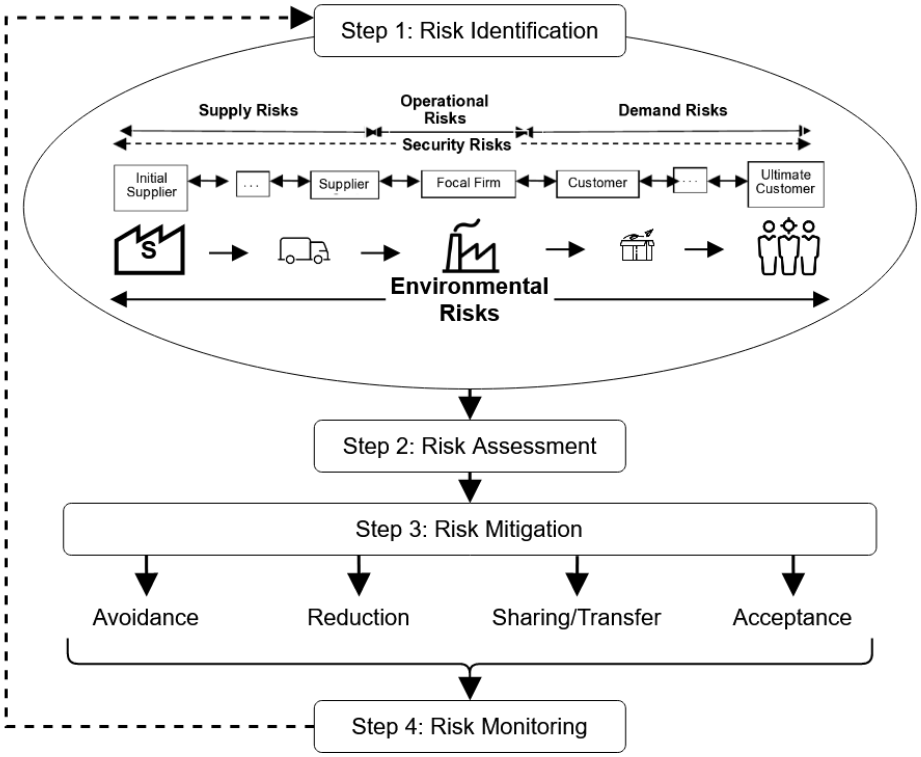

Figure 3: Supply Chain Risk Management Process (adapted from: Manuj & Mentzer, 2008a, p. 144)

6.2. Increasing Supply Chain Resilience

The increasing complexity that global supply chains are facing these days inflates the uncertainties and risk exposure. A firm thus should strive to make its supply chain more resilient. The SCRMP and the findings that a company makes while implementing it can be an indicator about how necessary measures to increase the resilience are. Supply chain resilience is a term which is broadly discussed among literature. The best SCMRP and the best forecast process will not be able to uncover and predict every possible risk event. A firm with a global supply chain must always be ready for unexpected events of any magnitude – the COVID crisis is a great example therefor. Hence, building a resilient supply chain is, along with a thorough SCRMP, another important way to prepare for possible disruptions of any probability and impact. In literature, a myriad of definitions of supply chain resilience can be found, some more complex than others, which all include similar elements (Carvalho et al., 2012, pp. 330–331; Güller & Henke, 2019, pp. 74–75).

The core statement is that a resilient supply chain is capable of dealing with risks. That means, the supply chain is prepared for the occurrence of such events. To be prepared, the supply chain must be adaptive, not only to changing market conditions as stated in the theoretical foundations, but also to any other type of risk. Further, the supply chain must be able to withstand and react accordingly to disruptions in a way that it is not irreparably damaged. The last critical part of supply chain resilience is its ability to recover from disruptions, either by restoring the previous, stable state or a new, possibly better state (Carvalho et al., 2012, p. 331; Christopher & Peck, 2004, pp. 10–11; Güller & Henke, 2019, pp. 74–75; Ponomarov & Holcomb, 2009, p. 131). It shows that resilience of supply chains comprises two major components: resistance (preparation) and recovery (disruption management). Resistance can be seen as the step of risk mitigation within the SCRMP for risk events that have not yet occurred, whereas recovery describes mitigation of risks that became reality (Melnyk et al., 2014, p. 36). Before and during the resistance component, some authors also add a dimension of anticipation (Kamalahmadi & Parast, 2016, pp. 121–122; Ponis & Koronis, 2012, pp. 925–926), which coincides with the proposed SCRMP framework as risk identification and assessment have anticipative characteristics.

This work covers some frequently found elements of resilient supply chains but does not propose another framework along with the SCRMP. As there are several interconnections between the SCRMP and the major components of supply chain resilience it is suggested to follow a structured approach of a SCRMP and to implement along with it a supply chain strategy to achieve the following characteristics. To visualize the components of supply chain resilience, the following figure of Calvo et al. (2020) has been used and slightly adapted.

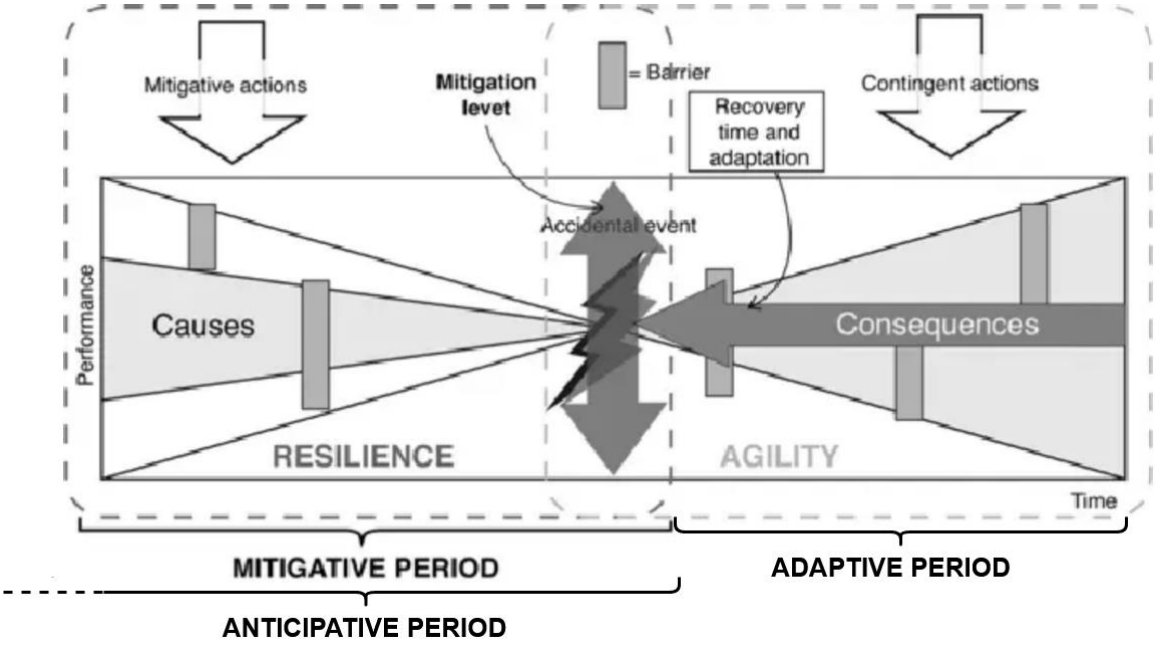

Figure 4: Supply Chain Resilience Components (adapted from: Calvo et al., 2020, p. 55)

6.2.1. Agility

Agility describes one part of supply chain resilience, namely the ability of a firm to recover from a disruption and restore a stable state of the supply chain (Calvo et al., 2020, p. 54). It can be seen as an extension of the criteria of a good supply chain strategy to be adaptive to market changes. Especially in a global context, it is important that not only the focal firm's supply chain is agile, but all the supply chain partners upstream as well as downstream (Christopher et al., 2011, p. 71).

Agility is divided into velocity and visibility, where velocity describes the pace at which a supply chain is able to recover from a disruption. Visibility is a more often treated concept. Visibility was stated as the biggest challenge that supply chains are facing in 2018 in a survey of more than 100 supply chain executives (eft, 2018). Visibility implies clear knowledge about everything that happens along the supply chain: Upstream – Which suppliers are there? How many of them? Which materials come from which supplier? How often are they ordered? How are the materials delivered? Who transports and delivers them? How are the supplier's situations? How are the situations of logistic partners? ...; Downstream – Which customers are there? How many customers? Where do the customers come from? How/where do they buy? How often do they buy? How are the products delivered to them? By whom are the products delivered? ...; Inside the firm – Which machines produce which products? How many machines are there? Are there backup machines? How many plants are there? Where are the plants? Which plant needs which materials? Which plant produces what? What is where in stock? ... (Azadeh et al., 2014, p. 270; Soni et al., 2014, p. 15; Wei & Wang, 2010, p. 239). The point is, the more complex and geographically dispersed a global supply chain is, the harder it is to have clear sight over it. Visibility roots in investments into information structuring and sharing (Melnyk et al., 2014, p. 40) and close collaboration with supply chain partners. It can also counteract against the bullwhip effect (Christopher & Peck, 2004, p. 10) and can act as a driver of competitive advantage as it makes a supply chain more reconfigurable (Wei & Wang, 2010, pp. 245–246). Agility plays a

major role in the second component, recovery. Here, the firm needs to adapt its supply chain in order to restore stability in a new situation. If the agility is high enough to adapt rapidly, a competitive edge over other firms can be gained (Calvo et al., 2020, p. 54).

6.2.2. Flexibility and Redundancy

Flexibility describes a similar concept to agility. In fact, as these terms are often used interchangeably, it is hard to clearly distinguish them from each other. Generally, flexibility describes the capability of the supply chain to “bend” amid disruptive situations. This means, that it describes how easily a supply chain can change its operations in terms of quantity, quality and methods of fulfilling customers’ demands. Flexibility therefore focusses on the ability to find solutions for a disruptive situation with existing capacities (Azadeh et al., 2014, p. 270; Sheffi, 2019, p. 159). Redundancy on the other hand means that certain capacities are redundant (duplicate) so that one can replace the other in case of failure (extra stock, workers, machines, suppliers or, especially in case of global supply chains, entire plants) (Carvalho et al., 2012, p. 331; Jüttner & Maklan, 2011, p. 247). Of course, maintaining flexibility and redundant capacities is not cost minimizing, yet it is suggested as preparation for disruptions. The trade-off between redundancy and cost-efficiency requires thorough consideration when developing a supply chain strategy (Christopher & Peck, 2004, p. 8).

Flexibility and redundancy can be subject in many areas, such as inventory, transportation, labour distribution or sourcing (Carvalho et al., 2012, p. 337; Hosseini et al., 2019, p. 293). One of the easiest forms of redundancy is to have extra stock of materials or finished products. This allows to easily react to slight demand fluctuations. A firm must bear in mind that extra stock means extra cost and additional risk, depending on the quantities. Another form of redundancy is diversified sourcing, i.e. having multiple suppliers and backup suppliers. Having a broad portfolio of suppliers with different risk profiles provides advantages on the one hand, that is failure safety, whereas on the other hand it adds to the complexity of the supply chain and usually adds cost as it is harder to benefit from bulk discounts when sourcing from multiple suppliers (Kleindorfer & Saad, 2005, p. 55; Sheffi, 2019, pp. 157–159).

Flexibility is sometimes seen as part of agility, once again showing that there are many overlaps among these resilience elements (Güller & Henke, 2019, p. 76). Contrary to agility, flexibility and redundancy are based in both, the resistance as well as the recovery component of supply chain resilience. Having redundant capacities and being able to use existing capacities for other purposes is a measure which prepares for disruptions, which then comes into play after a disruptive event occurred. It can be seen as a short-term “bridging” discipline while the supply chain adapts to the new situation through agility. The decision whether a firm focusses its supply chain stronger on flexibility or on redundancy should be assessed individually (Kamalahmadi & Parast, 2016, pp. 122–123). Note that flexibility and redundancy are somewhat complementary, as redundancy can act as short-term gap-solution for a disruptive situation while the firm implements the necessary steps to “switch purpose” of flexible assets (e.g. reconfiguring machines, plants, operations in general) (Sheffi, 2019, p. 159). To approach supplier redundancy in a strategic way, Sawik (2013) developed a framework for creating a diversified supplier portfolio as well as allocating orders among these suppliers. He uses a mixed integer programming approach to assess the supplier portfolio and adds a system to determine worst-case costs. The baseline is, that a firm should neither purely focus on flexibility nor on redundancy, as they are complementary to each other.

6.2.3. Collaboration

Collaboration between supply chain nodes is crucial. Global supply chains are threatened by risks on a network-level. Therefore, it is vital to maintain collaboration throughout the entire supply chain. Collaboration enables firms to work together effectively and reduces risk by distributing it. Many studies have shown that collaboration creates mutual benefit and in general improves risk resilience of global supply chains (Christopher et al., 2011, p. 71; Donadoni et al., 2019, pp. 181–182; Hosseini et al., 2019, p. 293; Kamalahmadi & Parast, 2016, p. 124; Kleindorfer & Saad, 2005, p. 55). By collaboration, the participating firms can acquire market knowledge and gain competitive advantage (Güller & Henke, 2019, p. 78; Wei & Wang, 2010, p. 238). Collaboration is a key driver for supply chain visibility (Christopher & Peck, 2004, p. 10; Güller & Henke, 2019, p. 88; Soni et al., 2014, pp. 14–15) which in turn increases the agility of the supply chain (Christopher et al., 2011, p. 71). Kleindorfer and Saad (2005) also mention that weak links within supply chains can hardly be uncovered without collaboration (Kleindorfer & Saad, 2005, p. 55).

Collaboration can be implemented in simple terms, such as mere information and knowledge sharing (Christopher & Peck, 2004, p. 9; Güller & Henke, 2019, p. 88), which was also identified as key supply chain strategy (Hult et al., 2007, p. 1046), but can also go more into depth, for example with vendor-managed inventory (VMI) systems (Güller & Henke, 2019, p. 88) or innovative collaboration models like open foresight (Wiener et al., 2020, p. 10).

6.2.4. Summarizing Global Supply Chain Resilience

In summary, it became clear that there is a growing interest among researchers in the topic of supply chain resilience, especially global supply chains. The proposed disciplines of increasing the resilience of global supply chains are a selection of the most common elements found in literature, but of course not the only ones. There are other disciplines, such as reversibility, sustainability, knowledge management systems as extension of information sharing, synchronized supply chains or frameworks like CPFR (collaborative planning, forecasting and replenishment).

7. Conclusion

Global supply chains are constantly growing nowadays. Customers' demands are changing rapidly, yet there is one constant: Customers want their products fast, in excellent quality and as customizable as possible. To achieve this, global supply chains need to be working as flawless as possible. Hence, firms need to address risk issues that their global supply chains are facing in order to remain competitive. That requires a strategic approach to supply chain risk management. To fulfill the goals and answer the research questions of this thesis, a purely theoretical approach was chosen, consisting of literature review in scientific databases and condensing the findings.

The first research question was: *What are the main risks of disruption a company's global supply chain is exposed to?* This thesis offers following answer:

To implement proper risk management, it is necessary to know about the possible risks and their nature. This work suggests the use of four categories of risks for global supply chains: Supply-side risks (upstream, towards suppliers), demand-side risks (downstream, towards customers), operational risks (inside the firm) and environmental risks (external to the supply chain, can impact along entire supply chain). Depending on a firm's specific situation, additional categories can be introduced, these are the core categories that are considered necessary.

The second research question – *Which strategic options can be adopted by companies to increase the resilience of their supply chains?* – is answered in two parts:

Due to the amount of risks, it is not enough to just have a good supply chain strategy, assuming that everything will run like a clockwork at all times. Firms should expect disruptions and make efforts to prepare for them, mitigate them and have appropriate measures in place when disruptions occur. That requires adequate disruption management. Therefor, this thesis proposes the use of a generic framework. The suggested supply chain risk management process (SCRMP) consists of four steps: Risk identification – find risks and allocate them to categories; Risk assessment – evaluate risk profiles and prioritize risks; Risk mitigation – take preventive measures or implement contingency strategies; Risk monitoring – continuously monitor of measures are effective and scan environment for possible new risks. This process should be implemented continuously.

To increase supply chain resilience, focus on the following supply chain characteristics: Agility – the supply chain is able to quickly adapt to a new situation and restore a stable status after a disruption happened; Flexibility and Redundancy – the supply chain has capabilities of using existing capacities for different purposes and has redundant capacities to act as short-term replacements in case of a disruption; Collaboration – the firm works closely with upstream and downstream partners to share information and gain mutual advantages as well as distribute risk. Redundancy in terms of suppliers and plants in different countries is especially important for global supply chains, to prepare for potential regional issues.

At this point, a subtle reminder:

"The supply chain stuff is really tricky."

~ Elon Musk, 2016

8. Limitations and Future Research

This thesis is a purely theoretical work on a topic that is often not as easily implemented in reality like planned on paper. Therefore, there are certain limitations to it. Empirical data of firms that implement the proposed approaches to assess their effectivity, find weaknesses and fix them is the logical next step. Even though the proposed procedures seem simple, it is certainly much more complicated to implement them in a real global supply chain. Perhaps it makes more sense to firstly examine current procedures of a firm's global supply chain, to then assess which framework can possibly be adapted and in the next step adopted to revamp and improve the risk management process and increase the resilience of the supply chain.

Although there is a tremendous amount of research on the topic of supply chain disruption and risk management, there are still gaps to be filled. A stronger focus on different groups of stakeholders connected to certain risks is one gap. Sustainability of global supply chains is another emerging topic that should be getting increasing research interest. It was not deeply covered in this work as it is not yet prevalent in literature, but it is on a rising path. Sustainability issues can either be part of environmental risks or also as a category on its own.

Risk monitoring has also seen significantly less interest of researchers, compared to the other steps of the SCRMP, although it plays a crucial role in the process – there's no point in taking measures if no one knows whether they are effective. More empirical work in this sector would be desirable.

Cyber risks are ranked number one among the biggest risks for global businesses in 2020 (Allianz, 2020, pp. 11–13). It is clearly becoming the topic of the future and should therefore see significantly more research interest. Today's world is a world of IT. Computers are omnipresent and they become mightier than most people like to admit. Digitalisation is on the rise and it strongly affects supply chains. That means, also digital risks are on the rise.

Lastly, a global supply chain topic that is going to be highly interesting and perhaps heavily covered: The vulnerability of global supply chains against pandemics and health crises. COVID-19 and its consequences are textbook examples of a magnitude of global disruption that many – probably most – people would never have believed to be possible. If someone said a few months ago "A viral disease can spread so rapidly within few months that almost every country in the world will be forced to almost completely shut down its economy for several weeks up to months and impose curfews on its population.", this person would have probably been waved off as being a conspiracist.

9. List of Tables

10. List of Figures

11. References

Allianz. (2013). *Allianz Risk Barometer 2013*.

Allianz. (2020). *Allianz Risk Barometer 2020*.

Ansoff, I. H. (1976). Managing surprise and discontinuity: strategic response to weak signals. *Zeitschrift Für Betriebswirtschaftliche Forschung*, *28*(3), 129–152.

Ansoff, I. H. (1981). Die Bewältigung von Überraschungen und Diskontinuitäten durch die Unternehmensführung – Strategische Reaktionen auf schwache Signale. In H. Steinmann (Ed.), *Planung und Kontrolle* (pp. 233–265). Vahlen.

Aqlan, F., & Lam, S. S. (2015a). A fuzzy-based integrated framework for supply chain risk assessment. *International Journal of Production Economics*, *161*, 54–63. https://doi.org/10.1016/j.ijpe.2014.11.013

Aqlan, F., & Lam, S. S. (2015b). Supply chain risk modelling and mitigation. *International Journal of Production Research*, *53*(18), 5640–5656. https://doi.org/10.1080/00207543.2015.1047975

Azadeh, A., Atrchin, N., Salehi, V., & Shojaei, H. (2014). Modelling and improvement of supply chain with imprecise transportation delays and resilience factors. *International Journal of Logistics Research and Applications*, *17*(4), 269–282. https://doi.org/10.1080/13675567.2013.846308

Baldwin, R. (2013). *Global supply chains: Why they emerged, why they matter, and where they are going* (CEPR Discussion Papers, Issue 9103). C.E.P.R. Discussion Papers.

Ballou, R. H., & Burnetas, A. (2003). PLANNING MULTIPLE LOCATION INVENTORIES. *Journal of Business Logistics*, *24*(2), 65–89. https://doi.org/10.1002/j.2158-1592.2003.tb00046.x

Barroso, A. P., Machado, V. H., & Cruz Machado, V. (2011). Supply Chain Resilience Using the Mapping Approach. In L. Pengzhong (Ed.), *Supply Chain Management* (pp. 161–184). InTech.

BBC. (2011, March 11). Japan earthquake: Tsunami hits north-east. *BBC News*.

Benji, J. (2020). *Meet the top 7 US companies dominating the $17 billion solar-energy industry*. BusinessInsider Prime. https://www.businessinsider.com/top-7-companies-dominating-the-17-billion-us-solar-industry-2020-2?r=DE&IR=T

Betts, J. M., & Johnston, R. B. (2005). Just-in-time component replenishment decisions for assemble-to-order manufacturing under capital constraint and stochastic demand. *International Journal of Production Economics*, *95*(1), 51–70. https://doi.org/10.1016/j.ijpe.2003.10.020

Bhageshpur, K. (2019, November 15). Data Is The New Oil -- And That's A Good Thing. *Forbes*.

Blackhurst, J. V., Scheibe, K. P., & Johnson, D. J. (2008). Supplier risk assessment and monitoring for the automotive industry. *International Journal of Physical Distribution & Logistics Management*, *38*(2), 143–165. https://doi.org/10.1108/09600030810861215

Bogataj, D., & Bogataj, M. (2007). Measuring the supply chain risk and vulnerability in frequency space. *International Journal of Production Economics*, *108*(1–2), 291–301. https://doi.org/10.1016/j.ijpe.2006.12.017

Bown, C. P. (2020). *US-China Trade War Tariffs: An Up-to-Date Chart*. Peterson Institute for International Economics. https://www.piie.com/research/piie-charts/us-china-trade-war-tariffs-date-chart

Bradley, J. R. (2014). An improved method for managing catastrophic supply chain disruptions. *Business Horizons*, *57*(4), 483–495. https://doi.org/10.1016/j.bushor.2014.03.003

Bright, K., Kouba, J., Lyn, S., & Reynders, P. (2019). *Revenue growth management: The next horizon*. McKinsey. https://www.mckinsey.com/business-functions/marketing-and-sales/our-

insights/revenue-growth-management-the-next-horizon

Cachon, G. P. (2004). The Allocation of Inventory Risk in a Supply Chain: Push, Pull, and Advance-Purchase Discount Contracts. *Management Science*, *50*(2), 222–238. https://doi.org/10.1287/mnsc.1030.0190

Calvo, J., Olmo, J. L. Del, & Berlanga, V. (2020). Supply chain resilience and agility: a theoretical literature review. *International Journal of Supply Chain and Operations Resilience*, *4*(1), 37–69.

Carvalho, H., Barroso, A. P., Machado, V. H., Azevedo, S., & Cruz-Machado, V. (2012). Supply chain redesign for resilience using simulation. *Computers & Industrial Engineering*, *62*(1), 329–341. https://doi.org/10.1016/j.cie.2011.10.003

Cavinato, J. L. (2004). Supply chain logistics risks. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 383–387. https://doi.org/10.1108/09600030410545427

Chaharsooghi, S. K., & Heydari, J. (2011). Strategic Fit in Supply Chain Management: A Coordination Perspective. In L. Pengzhong (Ed.), *Supply Chain Management* (pp. 331–350). InTech.

Chambers, J. (2020, April 12). Coronavirus should inspire businesses to prepare their supply chains for the future. *Fortune*.

Chan, F. T. S., & Kumar, N. (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega*, *35*(4), 417–431. https://doi.org/10.1016/j.omega.2005.08.004

Chaudhuri, A., Mohanty, B. K., & Singh, K. N. (2013). Supply chain risk assessment during new product development: a group decision making approach using numeric and linguistic data. *International Journal of Production Research*, *51*(10), 2790–2804. https://doi.org/10.1080/00207543.2012.654922

Chen, J., Sohal, A. S., & Prajogo, D. I. (2013). Supply chain operational risk mitigation: a collaborative approach. *International Journal of Production Research*, *51*(7), 2186–2199. https://doi.org/10.1080/00207543.2012.727490

Chen, Y.-J., & Seshadri, S. (2006). Supply chain structure and demand risk. *Automatica*, *42*(8), 1291–1299. https://doi.org/10.1016/j.automatica.2005.11.008

Choi, T. Y., Roger, D., & Vakil, B. (2020, March). Coronavirus Is a Wake-Up Call for Supply Chain Management. *Harvard Business Review*.

Chopra, S., & Meindl, P. (2005). *Supply Chain Management* (3rd ed.). Pearson.

Chopra, S., & Meindl, P. (2007). *Supply Chain Management: Strategy, Planning, and Operation* (3rd ed.). Pearson Education.

Chopra, S., & Sodhi, M. S. (2004, October 15). Managing Risk to Avoid Supply-Chain Breakdown. *MIT Sloan Management Review*.

Christopher, M., & Lee, H. (2004). Mitigating supply chain risk through improved confidence. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 388–396. https://doi.org/10.1108/09600030410545436

Christopher, M., Mena, C., Khan, O., & Yurt, O. (2011). Approaches to managing global sourcing risk. *Supply Chain Management: An International Journal*, *16*(2), 67–81. https://doi.org/10.1108/13598541111115338

Christopher, M., & Peck, H. (2004). Building the Resilient Supply Chain. *The International Journal of Logistics Management*, *15*(2), 1–14. https://doi.org/10.1108/09574090410700275

Christopher, M., Peck, H., & Towill, D. (2006). A taxonomy for selecting global supply chain strategies. *The International Journal of Logistics Management*, *17*(2), 277–287. https://doi.org/10.1108/09574090610689998

Closs, D. J., Nyaga, G. N., & Voss, M. D. (2010). The differential impact of product complexity, inventory level, and configuration capacity on unit and order fill rate performance. *Journal of Operations Management*, *28*(1), 47–57. https://doi.org/10.1016/j.jom.2009.04.003

Cohen, S., & Roussel, J. (2005). *Strategic Supply Chain Management - The Five Disciplines for Top Performance* (1st ed.). McGraw-Hill. https://doi.org/10.1036/0071454497

Cordón, C., Hald, K. S., & Seifert, R. W. (2013). *Strategic Supply Chain Management* (1st ed.). Routledge. https://doi.org/10.4324/9780203124451

Dani, S. (2009). Predicting and Managing Supply Chain Risks. In G. A. Zsidisin & B. Ritchie (Eds.), *Supply Chain Risk: A Handbook of Assessment, Management, and Performance* (pp. 53–66). Springer Science+Business Media.

Diabat, A., Govindan, K., & Panicker, V. V. (2012). Supply chain risk management and its mitigation in a food industry. *International Journal of Production Research*, *50*(11), 3039–3050. https://doi.org/10.1080/00207543.2011.588619

Donadoni, M., Roden, S., Scholten, K., Stevenson, M., Caniato, F., van Donk, D. P., & Wieland, A. (2019). The Future of Resilient Supply Chains. In G. A. Zsidisin & M. Henke (Eds.), *Revisiting Supply Chain Risk* (pp. 169–186). Springer International Publishing. https://doi.org/10.1007/978-3-030-03813-7_10

Dong, Q., & Cooper, O. (2016). An orders-of-magnitude AHP supply chain risk assessment framework. *International Journal of Production Economics*, *182*, 144–156. https://doi.org/10.1016/j.ijpe.2016.08.021

Dubois, A., Hulthén, K., & Pedersen, A.-C. (2004). Supply chains and interdependence: a theoretical analysis. *Journal of Purchasing and Supply Management*, *10*(1), 3–9. https://doi.org/10.1016/j.pursup.2003.11.003

Eckstein, D., Goellner, M., Blome, C., & Henke, M. (2015). The performance impact of supply chain agility and supply chain adaptability: the moderating effect of product complexity. *International Journal of Production Research*, *53*(10), 3028–3046. https://doi.org/10.1080/00207543.2014.970707

eft. (2018). *What is the biggest challenge you are facing in your supply chain?* Statista. https://www.statista.com/statistics/829634/biggest-challenges-supply-chain/

Er Kara, M., & Oktay Fırat, S. Ü. (2017). Supply chain risks: Literature review and a new categorization. *Beykent University Journal of Science and Engineering*, *10*(1), 31–60.

EU. (2019). *European Union (Withdrawal) Act 2018 (Exit Day) (Amendment) (No. 3) Regulations 2019* (No. 1423). European Council Decision. https://www.legislation.gov.uk/uksi/2019/1423/made#f00001

Evans, R., & Danks, A. (1998). Strategic supply chain management: Creating shareholder value by aligning supply chain strategy with business strategy. In J. Gattorna (Ed.), *Strategic Supply Chain Alignment*. Routledge. https://doi.org/10.4324/9781315242262

Eyob, E., & Tetteh, E. (2012). *Customer-Oriented Global Supply Chains: Concepts for Effective Management*. IGI Global.

Fan, Y., & Stevenson, M. (2018). A review of supply chain risk management: definition, theory, and research agenda. *International Journal of Physical Distribution & Logistics Management*, *48*(3), 205–230. https://doi.org/10.1108/IJPDLM-01-2017-0043

Fischhoff, B., Watson, S. R., & Hope, C. (1984). Defining risk. *Policy Sciences*, *17*(2), 123–139. https://doi.org/10.1007/BF00146924

Fisher, M. L. (1997). What Is the Right Supply Chain for Your Product? *Harvard Business Review*, 105–116.

Forbes. (2020). *Revenue of leading automakers worldwide in 2019*. Statista. https://www.statista.com/statistics/232958/revenue-of-the-leading-car-manufacturers-worldwide/

Gao, Y., Li, Z., Wang, F., Wang, F., Tan, R. R., Bi, J., & Jia, X. (2018). A game theory approach for corporate environmental risk mitigation. *Resources, Conservation and Recycling*, *130*, 240–247. https://doi.org/10.1016/j.resconrec.2017.12.009

Geissbauer, R., Roussel, J., Schrauf, S., & Strom, M. A. (2013). *PwC Global Supply Chain Survey 2013*.

Giannakis, M., & Papadopoulos, T. (2016). Supply chain sustainability: A risk management approach. *International Journal of Production Economics*, *171*, 455–470. https://doi.org/10.1016/j.ijpe.2015.06.032

Glock, C. H., & Ries, J. M. (2013). Reducing lead time risk through multiple sourcing: the case of stochastic demand and variable lead time. *International Journal of Production Research*, *51*(1), 43–56. https://doi.org/10.1080/00207543.2011.644817

Godwill, E. A. (2015). *Fundamentals of Research Methodology : A Holistic Guide for Research Completion, Management, Validation and Ethics*. Nova Science Publishers.

Govil, M., & Proth, J.-M. (2002). *Supply Chain Design and Management: Strategic and Tactical Perspectives*. Academic Press.

Güller, M., & Henke, M. (2019). Resilience Assessment in Complex Supply Networks. In G. A. Zsidisin & M. Henke (Eds.), *Revisiting Supply Chain Risk* (pp. 73–98). Springer International Publishing. https://doi.org/10.1007/978-3-030-03813-7_5

Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management*, *21*(1/2), 71–87. https://doi.org/10.1108/01443570110358468

Hachicha, W., & Elmsalmi, M. (2014). An integrated approach based-structural modeling for risk prioritization in supply network management. *Journal of Risk Research*, *17*(10), 1301–1324. https://doi.org/10.1080/13669877.2013.841734

Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V.-M., & Tuominen, M. (2004). Risk management processes in supplier networks. *International Journal of Production Economics*, *90*(1), 47–58. https://doi.org/10.1016/j.ijpe.2004.02.007

Hallikas, J., Virolainen, V.-M., & Tuominen, M. (2002). Risk analysis and assessment in network environments: A dyadic case study. *International Journal of Production Economics*, *78*(1), 45–55. https://doi.org/10.1016/S0925-5273(01)00098-6

Handfield, R. B., & McCormack, K. (Eds.). (2008). *Supply Chain Risk Management: Minimizing Disruptions in Global Sourcing*. Auerbach Publications, Taylor & Francis Group.

Happek, S. (2005). *Supply Chain Strategy - The Importance of Aligning Your Strategies*. UPS Supply Chain Solutions.

Hayes, G. P., Meyers, E. K., Dewey, J. W., Briggs, R. W., Earle, P. S., Benz, H. M., Smoczyk, G. M., Flamme, H. E., Barnhart, W. D., Gold, R. D., & Furlong, K. P. (2017). Tectonic summaries of magnitude 7 and greater earthquakes from 2000 to 2015. In *Open-File Report*. https://doi.org/10.3133/ofr20161192

He, R., Zhu, W., Feng, Z., & Amin, F. (2017). *Supply Side Risks Assessment of the Supply Chain - A case study of the Supply Side Risks Assessment in HUAWEI's Supply Chain*. Linnaeus University, Kalmar Växjö.

Heckmann, I., Comes, T., & Nickel, S. (2015). A critical review on supply chain risk – Definition, measure and modeling. *Omega*, *52*, 119–132. https://doi.org/10.1016/j.omega.2014.10.004

Hendricks, K. B., & Singhal, V. R. (2003). The effect of supply chain glitches on shareholder wealth. *Journal of Operations Management*, *21*(5), 501–522. https://doi.org/10.1016/j.jom.2003.02.003

Hendricks, K. B., & Singhal, V. R. (2005a). An Empirical Analysis of the Effect of Supply Chain Disruptions on Long-Run Stock Price Performance and Equity Risk of the Firm. *Production and Operations Management*, *14*(1), 35–52. https://doi.org/10.1111/j.1937-5956.2005.tb00008.x

Hendricks, K. B., & Singhal, V. R. (2005b). Association Between Supply Chain Glitches and Operating Performance. *Management Science*, *51*(5), 695–711. https://doi.org/10.1287/mnsc.1040.0353

Hill, A., & Hill, T. (2009). *Manufacturing Strategy* (3rd ed.). Palgrave Macmillan.

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: a literature review. *International Journal of Production Research*, *53*(16), 5031–5069.

https://doi.org/10.1080/00207543.2015.1030467

Hoffmann, P., Schiele, H., & Krabbendam, K. (2013). Uncertainty, supply risk management and their impact on performance. *Journal of Purchasing and Supply Management*, *19*(3), 199–211. https://doi.org/10.1016/j.pursup.2013.06.002

Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research Part E: Logistics and Transportation Review*, *125*, 285–307. https://doi.org/10.1016/j.tre.2019.03.001

Huang, J. (2020). How to drive holistic end-to-end supply chain risk management. *Journal of Supply Chain Management, Logistics and Procurement*, *2*(4), 294–306.

Hult, G. T. M., Ketchen, D. J., & Arrfelt, M. (2007). Strategic supply chain management: Improving performance through a culture of competitiveness and knowledge development. *Strategic Management Journal*, *28*(10), 1035–1052. https://doi.org/10.1002/smj.627

Hyperloop-One.com. (2019). *Hyperloop One - FAQ*. https://hyperloop-one.com/facts-frequently-asked-questions

Inman, R. R., & Blumenfeld, D. E. (2014). Product complexity and supply chain design. *International Journal of Production Research*, *52*(7), 1956–1969. https://doi.org/10.1080/00207543.2013.787495

ISO. (2018). Risk management - Guidelines. In *ISO 31000:2018*. International Standards Organisation.

Ivanov, D., Tsipoulanidis, A., & Schönberger, J. (2019). *Global Supply Chain and Operations Management* (2nd ed.). Springer International Publishing. https://doi.org/10.1007/978-3-319-94313-8

Jian, M., Fang, X., Jin, L., & Rajapov, A. (2015). The impact of lead time compression on demand forecasting risk and production cost: A newsvendor model. *Transportation Research Part E: Logistics and Transportation Review*, *84*, 61–72. https://doi.org/10.1016/j.tre.2015.10.006

Johnson, G., Whittington, R., Scholes, K., Angwin, D., & Regnér, P. (2017). *Exploring Strategy: Text and Cases* (11th ed.). Pearson.

Johnson, M. E. (2001). Learning from Toys: Lessons in Managing Supply Chain Risk from the Toy Industry. *California Management Review*, *43*(3), 106–124. https://doi.org/10.2307/41166091

Jones, L., Palumbo, D., & Brown, D. (2020, April 30). Coronavirus: A visual guide to the economic impact. *BBC News*.

Jüttner, U. (2005). Supply chain risk management. *The International Journal of Logistics Management*, *16*(1), 120–141. https://doi.org/10.1108/09574090510617385

Jüttner, U., & Maklan, S. (2011). Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Management: An International Journal*, *16*(4), 246–259. https://doi.org/10.1108/13598541111139062

Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics Research and Applications*, *6*(4), 197–210. https://doi.org/10.1080/1367556031000162701 6

Kamal, S., & Larsson, T. (2019, May). The top 10 supply chain risks of 2019. *Supply Chain Quarterly*.

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. *International Journal of Production Economics*, *171*, 116–133. https://doi.org/10.1016/j.ijpe.2015.10.023

Kern, D., Moser, R., Hartmann, E., & Moder, M. (2012). Supply risk management: model development and empirical analysis. *International Journal of Physical Distribution & Logistics Management*, *42*(1), 60–82. https://doi.org/10.1108/09600031211202472

Kim, Y., Chen, Y.-S., & Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of Operations Management*, *33–34*(1), 43–59. https://doi.org/10.1016/j.jom.2014.10.006

Kırılmaz, O., & Erol, S. (2017). A proactive approach to supply chain risk management: Shifting orders among suppliers to mitigate the supply side risks. *Journal of Purchasing and Supply Management*, *23*(1), 54–65. https://doi.org/10.1016/j.pursup.2016.04.002

Kleindorfer, P. R., & Saad, G. H. (2005). Managing Disruption Risks in Supply Chains. *Production and Operations Management*, *14*(1), 53–68. https://doi.org/10.1111/j.1937-5956.2005.tb00009.x

Knowledge@Wharton. (2020). *Coronavirus and Supply Chain Disruption: What Firms Can Learn*. University of Pennsylvania. https://knowledge.wharton.upenn.edu/article/veeraraghavan-supply-chain/

Kumar, S., & Craig, S. (2007). Dell, Inc.'s closed loop supply chain for computer assembly plants. *Information Knowledge Systems Management*, *6*, 197–214.

Lee, H. L. (2004). THE TRIPLE-A Supply Chain. *Harvard Business Review*, *82*(10), 102–112.

Li, G., Yu, G., Wang, S., & Yan, H. (2017). Bullwhip and anti-bullwhip effects in a supply chain. *International Journal of Production Research*, *55*(18), 5423–5434. https://doi.org/10.1080/00207543.2017.1319087

Liu, Z., Gao, R., Zhou, C., & Ma, N. (2019). Two-period pricing and strategy choice for a supply chain with dual uncertain information under different profit risk levels. *Computers & Industrial Engineering*, *136*, 173–186. https://doi.org/10.1016/j.cie.2019.07.029

Lockamy, A., & McCormack, K. (2010). Analysing risks in supply networks to facilitate outsourcing decisions. *International Journal of Production Research*, *48*(2), 593–611. https://doi.org/10.1080/00207540903175152

Louis, M., & Pagell, M. (2019). Categorizing Supply Chain Risks: Review, Integrated Typology and Future Research. In G. A. Zsidisin & M. Henke (Eds.), *Revisiting Supply Chain Risk* (pp. 329–366). Springer International Publishing. https://doi.org/10.1007/978-3-030-03813-7_20

Mack, O., Khare, A., Krämer, A., & Burgartz, T. (Eds.). (2016). *Managing in a VUCA World*. Springer International Publishing. https://doi.org/10.1007/978-3-319-16889-0

Magee, R. R. (1998). *Strategic Leadership Primer*.

Manuj, I., Esper, T. L., & Stank, T. P. (2014). Supply Chain Risk Management Approaches Under Different Conditions of Risk. *Journal of Business Logistics*, *35*(3), 241–258. https://doi.org/10.1111/jbl.12051

Manuj, I., & Mentzer, J. T. (2008a). Global Supply Chain Risk Management. *Journal of Business Logistics*, *29*(1), 133–155. https://doi.org/10.1002/j.2158-1592.2008.tb00072.x

Manuj, I., & Mentzer, J. T. (2008b). Global supply chain risk management strategies. *International Journal of Physical Distribution & Logistics Management*, *38*(3), 192–223. https://doi.org/10.1108/09600030810866986

Material Handling & Logistics. (2018). *Supply Chains Disruptions at Highest Rate in 3 Years*. https://www.mhlnews.com/global-supply-chain/article/22055340/supply-chains-disruptions-at-highest-rate-in-3-years#close-olyticsmodal

McCormack, K. (2008). Measuring and Managing Risk. In R. B. Handfield & K. McCormack (Eds.), *Supply Chain Risk Management: Minimizing Disruptions in Global Sourcing* (pp. 65–91). Auerbach Publications, Taylor & Francis Group.

Meckling, J., & Hughes, L. (2017). Globalizing solar: Global supply chains and trade preferences. *International Studies Quarterly*, *61*(2), 225–235. https://doi.org/10.1093/isq/sqw055

Meena, P. L., Sarmah, S. P., & Sarkar, A. (2011). Sourcing decisions under risks of catastrophic event disruptions. *Transportation Research Part E: Logistics and Transportation Review*, *47*(6), 1058–1074. https://doi.org/10.1016/j.tre.2011.03.003

Meijboom, B., Voordijk, H., & Akkermans, H. (2007). The effect of industry clockspeed on supply chain co-ordination. *Business Process Management Journal*, *13*(4), 553–571. https://doi.org/10.1108/14637150710763577

Melnyk, S., Closs, D. J., Griffis, S., Zobel, C., & Macdonald, J. (2014). Understanding supply chain resilience. *Supply Chain Management Review*, *18*(1), 34–41.

Mentzer, J., Myers, M., & Stank, T. (2007). *Handbook of Global Supply Chain Management*. SAGE Publications, Inc. https://doi.org/10.4135/9781412976169

Micheli, G. J. L., Mogre, R., & Perego, A. (2014). How to choose mitigation measures for supply chain risks. *International Journal of Production Research*, *52*(1), 117–129. https://doi.org/10.1080/00207543.2013.828170

Mitra, A., & Bhardwaj, S. (2010). Alignment of Supply Chain Strategy with Business Strategy. *IUP Journal of Supply Chain Management*, *7*(3), 49–65.

Morash, E. A. (2001). Supply Chain Strategies, Capabilities, and Performance. *Transportation Journal*, *41*(1), 37–54.

Mullai, A. (2009). Risk Management System – A Conceptual Model. In G. A. Zsidisin & B. Ritchie (Eds.), *Supply Chain Risk: A Handbook of Assessment, Management, and Performance* (pp. 83–102). Springer Science+Business Media.

Musk, E. (2016). *Code Conference 2016 - Elon Musk*.

Nagurney, A., Cruz, J., Dong, J., & Zhang, D. (2005). Supply chain networks, electronic commerce, and supply side and demand side risk. *European Journal of Operational Research*, *164*(1), 120–142. https://doi.org/10.1016/j.ejor.2003.11.007

Nakamura, K., Yamada, T., & Tan, K. H. (2019). The impact of Brexit on designing a material-based global supply chain network for Asian manufacturers. *Management of Environmental Quality: An International Journal*, *30*(5), 980–1000. https://doi.org/10.1108/MEQ-12-2018-0206

Oehlrich, M. (2019). *Wissenschaftliches Arbeiten und Schreiben*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-58204-6

Ohmori, S., Huang, Q., & Yoshimoto, K. (2019). Global logistics network design problem with rules of origin. *Journal of Industrial Engineering and Management*, *12*(3), 447. https://doi.org/10.3926/jiem.2977

Oke, A., & Gopalakrishnan, M. (2009). Managing disruptions in supply chains: A case study of a retail supply chain. *International Journal of Production Economics*, *118*(1), 168–174. https://doi.org/10.1016/j.ijpe.2008.08.045

Oxford Business Group. (2020). *The impact of Covid-19 on global supply chains*. https://oxfordbusinessgroup.com/news/impact-covid-19-global-supply-chains

Palagyi, S. (2004). Making The Supply Chain A Strategic Asset. *World Trade*, *17*(10), 38–40.

Ponis, S. T., & Koronis, E. (2012). Supply Chain Resilience: Definition Of Concept And Its Formative Elements. *Journal of Applied Business Research (JABR)*, *28*(5), 921. https://doi.org/10.19030/jabr.v28i5.7234

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management*, *20*(1), 124–143. https://doi.org/10.1108/09574090910954873

Porter, M. E., & Millar, V. E. (1985). How information gives you competitive advantage. *Harvard Business Review*, *63*(4), 149–160.

Prokop, D. J. (2017). *Global Supply Chain Security and Management Appraising Programs, Preventing Crimes*. Elsevier Inc.

Queiroz, M. M., Ivanov, D., Dolgui, A., & Fosso Wamba, S. (2020). Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Annals of Operations Research*. https://doi.org/10.1007/s10479-020-03685-7

Radke, A. M., & Tseng, M. M. (2012). A risk management-based approach for inventory planning of engineering-to-order production. *CIRP Annals*, *61*(1), 387–390. https://doi.org/10.1016/j.cirp.2012.03.064

Rao, S., & Goldsby, T. J. (2009). Supply chain risks: a review and typology. *The International Journal of Logistics Management*, *20*(1), 97–123. https://doi.org/10.1108/09574090910954864

Ravindran, A. R., Ufuk Bilsel, R., Wadhwa, V., & Yang, T. (2010). Risk adjusted multicriteria supplier selection models with applications. *International Journal of Production Research*, *48*(2), 405–424. https://doi.org/10.1080/00207540903174940

Reisinger, S., Gattringer, R., & Strehl, F. (2017). *Strategisches Management: Grundlagen für Studium und Praxis* (2nd ed.). Pearson.

Reuters. (2011). *UPDATE 3-Supply chain disruptions force more delays in Japan*. https://www.reuters.com/article/japan-supplychain-idUSL3E7EN0ND20110323

Reuters. (2020). *Factbox: Carmakers suspend European production over coronavirus*. Business News. https://www.reuters.com/article/us-health-coronavirus-autos-production-f/factbox-carmakers-suspend-european-production-over-coronavirus-idUSKBN2161HK

Riley, C. (2019). *The Great Electric Car Race is just beginning*. CNN Business. https://edition.cnn.com/interactive/2019/08/business/electric-cars-audi-volkswagen-tesla/

Ritchie, B., & Brindley, C. (2009). Effective Management of Supply Chains: Risks and Performance. In T. Wu & J. Blackhurst (Eds.), *Managing Supply Chain Risk and Vulnerability* (pp. 9–28). Springer London.

Rosenberg, S. (2018). *The Global Supply Chain and Risk Management*. Business Expert Press.

Ruiz-Torres, A. J., Mahmoodi, F., & Zeng, A. Z. (2013). Supplier selection model with contingency planning for supplier failures. *Computers & Industrial Engineering*, *66*(2), 374–382. https://doi.org/10.1016/j.cie.2013.06.021

Sawik, T. (2013). Selection of resilient supply portfolio under disruption risks. *Omega*, *41*(2), 259–269. https://doi.org/10.1016/j.omega.2012.05.003

Sawik, T. (2018). *Supply Chain Disruption Management Using Stochastic Mixed Integer Programming* (Vol. 256). Springer International Publishing. https://doi.org/10.1007/978-3-319-58823-0

Schmitt, A. J., & Singh, M. (2012). A quantitative analysis of disruption risk in a multi-echelon supply chain. *International Journal of Production Economics*, *139*(1), 22–32. https://doi.org/10.1016/j.ijpe.2012.01.004

Sennheiser, A., & Schnetzler, M. (2008). *Wertorientiertes Supply Chain Management*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-74531-0

Shahbaz, M. S., RM Rasi, R. Z., & Bin Ahmad, M. F. (2019). A novel classification of supply chain risks: Scale development and validation. *Journal of Industrial Engineering and Management*, *12*(1), 201. https://doi.org/10.3926/jiem.2792

Sheffi, Y. (2019). Preparing for the Worst. In G. A. Zsidisin & M. Henke (Eds.), *Revisiting Supply Chain Risk* (pp. 155–168). Springer International Publishing. https://doi.org/10.1007/978-3-030-03813-7_9

Shipping and Freight Resource. (2020). *How has the coronavirus impacted your operations?* Statista. https://www.statista.com/statistics/1129401/impact-covid-supply-chains/

Simchi-Levi, D. (2010). *Operations Rules: Delivering Customer Value through Flexible Operations*. MIT Press.

Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2007). *Designing and Managing the Supply Chain: Concepts, Strategies, Case Studies* (3rd ed.). McGraw-Hill.

Sindi, S., & Roe, M. (2017). *Strategic Supply Chain Management*. Springer International Publishing. https://doi.org/10.1007/978-3-319-54843-2

Sodhi, M. S. (2005). Managing Demand Risk in Tactical Supply Chain Planning for a Global

Consumer Electronics Company. *Production and Operations Management*, *14*(1), 69–79. https://doi.org/10.1111/j.1937-5956.2005.tb00010.x

Sodhi, M. S., & Lee, S. (2007). An analysis of sources of risk in the consumer electronics industry. *Journal of the Operational Research Society*, *58*(11), 1430–1439. https://doi.org/10.1057/palgrave.jors.2602410

Sodhi, M. S., Son, B.-G., & Tang, C. S. (2012). Researchers' Perspectives on Supply Chain Risk Management. *Production and Operations Management*, *21*(1), 1–13. https://doi.org/10.1111/j.1937-5956.2011.01251.x

Soni, U., Jain, V., & Kumar, S. (2014). Measuring supply chain resilience using a deterministic modeling approach. *Computers & Industrial Engineering*, *74*, 11–25. https://doi.org/10.1016/j.cie.2014.04.019

SpaceX.com. (2020). *SpaceX - Advancing the Future*. About SpaceX. https://www.spacex.com/about

Spekman, R. E., & Davis, E. W. (2004). Risky business: expanding the discussion on risk and the extended enterprise. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 414–433. https://doi.org/10.1108/09600030410545454

Sridharan, R., & Simatupang, T. M. (2013). Power and trust in supply chain collaboration. *International Journal of Value Chain Management*, *7*(1), 76. https://doi.org/10.1504/IJVCM.2013.057344

Strom, M. A., Simchi-Levi, D., Vassiliadis, C. G., Bijsterbosch, J.-W., Diks, E., & Kyratzoglou, I. M. (2013). *Supply chain and risk management - Making the right risk decisions to strengthen operations performance*.

Takahashi, K., & Nakamura, N. (2004). Push, pull, or hybrid control in supply chain management. *International Journal of Computer Integrated Manufacturing*, *17*(2), 126–140. https://doi.org/10.1080/09511920310001593083

Talluri, S., Cetin, K., & Gardner, A. J. (2004). Integrating demand and supply variability into safety stock evaluations. *International Journal of Physical Distribution & Logistics Management*, *34*(1), 62–69. https://doi.org/10.1108/09600030410515682

Talluri, S., & Narasimhan, R. (2003). Vendor evaluation with performance variability: A max–min approach. *European Journal of Operational Research*, *146*(3), 543–552. https://doi.org/10.1016/S0377-2217(02)00230-8

Talluri, S., Narasimhan, R., & Nair, A. (2006). Vendor performance with supply risk: A chance-constrained DEA approach. *International Journal of Production Economics*, *100*(2), 212–222. https://doi.org/10.1016/j.ijpe.2004.11.012

Tang, C. S., & Tomlin, B. (2008). The power of flexibility for mitigating supply chain risks. *International Journal of Production Economics*, *116*(1), 12–27. https://doi.org/10.1016/j.ijpe.2008.07.008

Tang, C. S., & Tomlin, B. (2009). How Much Flexibility Does It Take to Mitigate Supply Chain Risks? In G. A. Zsidisin & B. Ritchie (Eds.), *Supply Chain Risk: A Handbook of Assessment, Management, and Performance* (pp. 155–174). Springer Science+Business Media.

Tang, O., & Musa, S. N. (2011). Identifying risk issues and research advancements in supply chain risk management. *International Journal of Production Economics*, *133*(1), 25–34. https://doi.org/10.1016/j.ijpe.2010.06.013

Taylor, D., Pritchard, A., Duhan, D., & Mishra, S. (2020). *Demand disruption and channel-based supply chain flexibility*. Supply Chain Management Review. https://www.scmr.com/article/demand_disruption_and_channel_based_supply_chain_flexibility

The Economist. (2017, May 6). The world's most valuable resource is no longer oil, but data. *The Economist*.

Thiel, W. (2020). *2020 US Auto Sales Figures By Manufacturer*.

https://www.goodcarbadcar.net/2020-us-auto-sales-figures-by-manufacturer/

Tummala, R., & Schoenherr, T. (2011). Assessing and managing risks using the Supply Chain Risk Management Process (SCRMP). *Supply Chain Management: An International Journal*, *16*(6), 474–483. https://doi.org/10.1108/13598541111171165

USGS. (2020). *20 Largest Earthquakes in the World*. https://www.usgs.gov/natural-hazards/earthquake-hazards/science/20-largest-earthquakes-world?qt-science_center_objects=0#qt-science_center_objects

Van Hoek, R. I., & Mitchell, A. J. (2006). The challenge of internal misalignment. *International Journal of Logistics Research and Applications*, *9*(3), 269–281. https://doi.org/10.1080/13675560600859342

Venkatesh, V. G., Rathi, S., & Patwa, S. (2015). Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling. *Journal of Retailing and Consumer Services*, *26*, 153–167. https://doi.org/10.1016/j.jretconser.2015.06.001

Viswanadham, N., & Samvedi, A. (2013). Supplier selection based on supply chain ecosystem, performance and risk criteria. *International Journal of Production Research*, *51*(21), 6484–6498. https://doi.org/10.1080/00207543.2013.825056

Wagner, S. M., & Bode, C. (2006). An empirical investigation into supply chain vulnerability. *Journal of Purchasing and Supply Management*, *12*(6), 301–312. https://doi.org/10.1016/j.pursup.2007.01.004

Wagner, S. M., & Bode, C. (2009). Dominant Risks and Risk Management Practices in Supply Chains. In G. A. Zsidisin & B. Ritchie (Eds.), *Supply Chain Risk: A Handbook of Assessment, Management, and Performance* (pp. 271–290). Springer Science+Business Media.

Wei, H.-L., & Wang, E. T. G. (2010). The strategic value of supply chain visibility: increasing the ability to reconfigure. *European Journal of Information Systems*, *19*(2), 238–249. https://doi.org/10.1057/ejis.2010.10

Welge, M. K., Al-Laham, A., & Eulerich, M. (2017). *Strategisches Management: Grundlagen - Prozess - Implementierung* (7th ed.). Springer Fachmedien. https://doi.org/10.1007/978-3-658-10648-5

White, G. (2020, May 3). Love Bug's creator tracked down to repair shop in Manila. *BBC News*.

Wiener, M., Gattringer, R., & Strehl, F. (2020). Collaborative open foresight - A new approach for inspiring discontinuous and sustainability-oriented innovations. *Technological Forecasting and Social Change*, *155*, 119370. https://doi.org/10.1016/j.techfore.2018.07.008

Wilding, R. (1998). The supply chain complexity triangle: Uncertainty generation in the supply chain. *International Journal of Physical Distribution & Logistics Management*, *28*(8), 599–616. https://doi.org/10.1108/09600039810247524

World Economic Forum. (2020). *The Global Risks Report 2020* (15th ed.).

WTO. (2020). *Technical Information on Rules of Origin*. https://www.wto.org/english/tratop_e/roi_e/roi_info_e.htm

Wu, D. D., & Olson, D. (2010). Enterprise risk management: a DEA VaR approach in vendor selection. *International Journal of Production Research*, *48*(16), 4919–4932. https://doi.org/10.1080/00207540903051684

Xiao, T., & Yang, D. (2008). Price and service competition of supply chains with risk-averse retailers under demand uncertainty. *International Journal of Production Economics*, *114*(1), 187–200. https://doi.org/10.1016/j.ijpe.2008.01.006

Xu, S., Zhang, X., Feng, L., & Yang, W. (2020). Disruption risks in supply chain management: a literature review based on bibliometric analysis. *International Journal of Production Research*, *58*(11), 3508–3526. https://doi.org/10.1080/00207543.2020.1717011

Yarger, H. R. (2006). *Strategic Theory for the 21st Century: The Little Book on Big Strategy*. Strategic Studies Institute, U.S. Army War College.

Yazdani, B. (1999). Four Models of Design Definition: Sequential, Design Centered, Concurrent and Dynamic. *Journal of Engineering Design*, *10*(1), 25–37. https://doi.org/10.1080/095448299261407

Zsidisin, G. A. (2003). A grounded definition of supply risk. *Journal of Purchasing and Supply Management*, *9*(5–6), 217–224. https://doi.org/10.1016/j.pursup.2003.07.002

Zsidisin, G. A., Ellram, L. M., Carter, J. R., & Cavinato, J. L. (2004). An analysis of supply risk assessment techniques. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 397–413. https://doi.org/10.1108/09600030410545445

Zsidisin, G. A., & Ritchie, B. (Eds.). (2009). *Supply Chain Risk: A Handbook of Assessment, Management, and Performance*. Springer Science+Business Media.