

# Information value for disruption management in supply chains

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## ABSTRACT

Supply chains (SC) are vulnerable to unpredictability and uncertainty. In the year of 2020, the biggest disruption in SC emerged – the globally-spread virus COVID-19, which is a highly unpredictable, long-term threat. Such disruptions cause unwanted propagations, i.e. the ripple effect. In order to mitigate disruption risks, certain measures can be taken. Supply chain management can be defined as a set of approaches utilized to integrate all SC members in order to perform efficiently and satisfy customer demand. However, the literature about supply chain management (SCM) so far did not focus on information sharing during disruptions. Therefore, this paper aims to prove that information sharing in SC disruption management is a crucial factor. The results of this paper are twofold. This paper recommends a list of key performance indicators (KPIs) that could be exchanged between SC partners in order to mitigate uncertainty. The list includes KPIs such as service level, delivery time, lead time and other valuable indicators. Moreover, this study offers a list of effective disruption risk mitigation strategies, such as collaboration, visibility, digitalisation and flexibility. The findings of this research were gathered by performing a systematic literature review (SLR), collecting insights from SCM webinars and obtaining information from an interview. This research could help decision-makers to identify, prevent and reduce disruption risks in SCs.

## Keywords

Supply chain, disruption risk management, ripple effect, COVID-19, epidemic outbreak, information sharing.

## 1. INTRODUCTION

Supply chain networks have been troubled by unexpected disruptions in recent decades. Disruption risks are unpredictable events caused by 1) natural catastrophes, such as hurricanes, earthquakes, floods by 2) man-made threats, such as terrorist attacks, labour strikes or by 3) epidemic outbreaks, pandemics. Such events have low probability, but high (negative) impact. They are too irregular, unpredictable to be identified and forecasted well. The most recent disruptive outbreak is the highly infectious COVID-19 virus (novel coronavirus or Severe Acute Respiratory Syndrome Coronavirus-2) that emerged in

December 2019. The virus soon became a globally-spread threat, posing a challenge to supply chains. The pandemic has caused numerous disturbances in SCs – it has paralyzed certain industries (i.e. the airlines, electronics, healthcare, etc.) [24] and negatively affected the global economics [9]. Intertwined supply networks have become immensely complex due to globalization, for this reason, the flows of goods and information have been exposed to disruption propagations such as the ripple effect.

Ripple effect defines a vast spectrum of changes in the structure and dynamics of supply chains due to the impact of a disruption. The effect ripples through the whole supply network – failure at a single business unit can cause failure and/or damage to several other businesses. The breadth and duration of the ripple effect depends on a few different factors, for example, **robustness** and post-disruption recovery measures. But there is also another fundamental concept to protect SCs – **resilience**. According to SC trend watchers, resilience began gaining more attention among scholars and companies [18]. To swiftly diminish the rippling across the whole network, SCs need to be robust and resilient to be able to withstand disturbances, maintain their functionality as well as be able to adapt in case of a disruption in order to accomplish planned performance [10].

A robust SC is defined as being able to absorb disturbances and continue achieving the set goals with minimal impact on the performance [10], [14]. Robustness is concerned with proactive redundancies such as back-up suppliers or risk mitigation inventory, that are alternative sources that can be used during failure or disruptions. Contrary, resilience is concerned with the system's ability to endure and restore its performance and functionality while following the changes in the environment conditions and the system. According to SCM experts, resilience could be divided into individual areas, one of them being collaboration. Collaboration between partners can provide crucial data and key performance indicators (KPIs), therefore increasing SC resiliency [17]. That being said, information sharing could be the key for supply networks to survive and overcome disruption risks. The current pandemic naturally obtained the attention of many academics (Ivanov 2020; Queiroz et al. 2020; Chowdhury et al. 2020), yet a research gap exists concerning the value of sharing information between SC actors in the matter of disruption management.

### 1.1. Research Questions

In order to fill the gap in SCM literature in regards to **information value in disruption risk management**, the aim of this paper is to answer the following research questions:

**RQ1:** What kind of information could be exchanged and measured between SC actors?

**RQ2:** What proactive and reactive strategies can be taken to reduce the negative impact of disruptive events?

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The contributions from this study are twofold:

- 1) An analysis and conclusion of key performance indicators that can be shared between SC partners;
- 2) An investigation and conclusion of successful disruption risk mitigation strategies.

The outcomes of this study contribute to the literature by highlighting the value of information sharing in the supply networks during disruptions. Additionally, the paper proposes disruption risk mitigation strategies that can be used by practitioners and decision-makers.

## 1.2. Methodology

Regarding the methodology, this study had adopted the Systematic literature review (SLR) approach, elaborated in Section 2. Moreover, to provide a practical perspective, insights from webinars had been collected and data from an interview with the Director of New Product Development from a company in the SCM field was obtained.

## 2. SYSTEMATIC LITERATURE REVIEW

Systematic literature review (SLR) is a form of research that is concerned with existing publications and follows a systematic methodology for analysing data that is already published [6]. This rigorous method allows the research questions to be answered with evidence, minimizing bias and bringing transparency. [6], [24]. Denyer and Tranfield [6] propose five steps to perform an SLR. The steps are visualised in Figure 1.

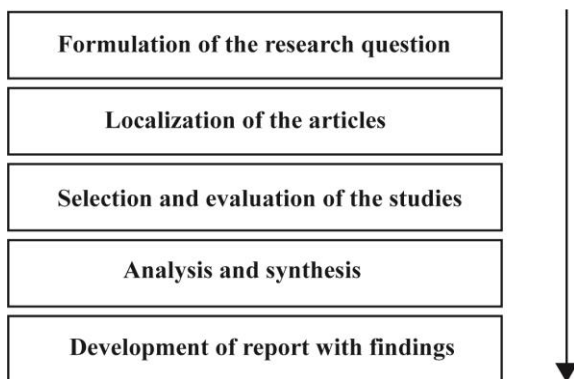


Figure 1. Steps of systematic literature review by Denyer and Tranfield (2009)

The SLR format provides robust evidence by investigating high-quality research articles, therefore, it has been practiced in the supply chain field successfully due to its reliability. In like manner, this paper adopted this research technique to draw clear and non-biased conclusions about the matter of concern – significance of information sharing in SC disruption management. The study had been carried out by following the SLR steps proposed by Denyer and Tranfield.

The search had been carried out by using keyword strings in Scopus, ScienceDirect and Informs PubsOnLine databases. The **keyword strings** were such:

- "ripple effect" AND "disruption risk\*" AND "supply chain\*";
- "Information sharing" AND "supply chain" OR "supply chain management" OR "disruption risk management";
- "disruption\*" AND "risk management" OR "supply chain risks" OR "resilience" AND "supply chains";

- "disruption" OR "disruption risk" AND "supply chain risks" OR "resilience" OR "mitigation" AND "supply chains" AND "COVID-19" OR "pandemic" OR "outbreak".

The use of several, divergent and detailed keyword strings had benefited the search with a vast yet quite reliable selection of papers. The localization resulted in 71 article that had a potential to be correlated with this study. The number of included papers subsequently had been reduced to 18 papers. Within limitations, the final collection of articles is relatively scarce due to the said gap in research concerning the value of sharing information prior, during and post-disruptions. To specify the assessment, criteria for inclusion and exclusion had been designed. The following **criteria** were designed in order to select articles which:

- 1) Address supply chain disruption risk management;
- 2) Address information value and/or KPIs;
- 3) Suggest or propose disruption risk mitigation strategies.

In order to filter the selection of 71 paper, the factors for exclusion depict articles which:

- 1) Are not in the English language;
- 2) Are prior to 2003;
- 3) Do not include supply chain disruption risk management;
- 4) Do not address information value and/or KPIs;
- 5) Do not suggest or propose disruption risk mitigation strategies.

Therefore, articles that purely address, for example, operational risks had been discarded. The articles which satisfied each criterion had been prioritized, however, some exceptions had been made due to limitations. Papers, which satisfied 2 out of 3 criteria were still considered. However, such articles were, after all, of high-quality and relevancy. In Figure 2, the process of selection and evaluation is visualised.

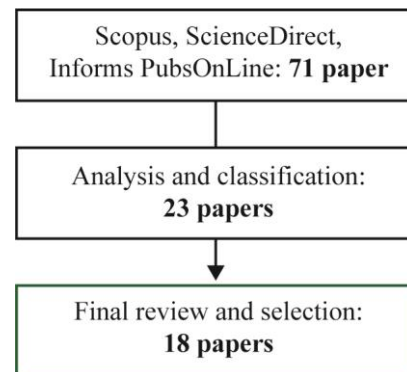


Figure 2. Process of selection and evaluation of literature

## 2.1. Paper Overview

After concluding the selection and evaluation step, as mentioned before, 18 papers are left to be used in the steps of analysis and development of findings. In Table 1, the final selection is presented. In the following subsections, the selection of articles is examined by analysing the year and the journals, in which the articles had been published.

**Table 1. Final selection of articles for the review**

Ref. no.	Title of the Article
[1]	Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries
[2]	Supply Chain Thinking in Healthcare: Lessons and Outlooks
[4]	A case study on strategies to deal with the impacts of COVID-19 pandemic in the food and beverage industry
[5]	Information sharing and coordination mechanisms for managing uncertainty in supply chains: a simulation study
[7]	Managing relationships in the Tourism Supply Chain to overcome epidemic outbreaks: The case of COVID-19 and the hospitality industry in Spain
[8]	A critical review on supply chain risk – Definition, measure and modelling
[9]	Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case
[11]	A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0
[12]	Disruptions in supply chains and recovery policies: state-of-the art review
[13]	Supply chain design with disruption considerations: review of research streams on the Ripple Effect in the supply chain
[14]	Ripple effect in the supply chain: an analysis and recent literature
[15]	Information sharing across multiple supply chain tiers: A Delphi study on antecedents
[16]	Supply chain disruption by avian flu pandemic for U.S. Companies: A case study
[19]	Critical factors affecting information sharing in supply chains
[20]	A Resilient and sustainable closed-loop supply chain using multiple sourcing and information sharing strategies
[22]	Strategies for Managing the Impacts of Disruptions During COVID-19: An Example of Toilet Paper
[24]	Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review
[25]	Assessing the value of information sharing and its impact on the performance of the various partners in supply chains

### 2.1.1. Years of Publications

The selection of papers, overall, is relatively current and up-to-date, as the novel coronavirus stimulated the research community to draw more attention to disruption risks. 11 (61%) of the selected articles had been published in the year of 2020 – 8 out of the 11 papers focused solely on COVID-19 and epidemic outbreaks. The earliest publication of the selected papers dates back to 2010. Other articles had been published in 2011 (6% of papers), 2015 (17%), 2016 (6%), 2017 (6%), 2018 (6%).

### 2.1.2. Journals

The majority of articles (89%) were represented by operations management, logistics, production and engineering journals. Moreover, the list contains a journal which is concerned with social, environmental, technological factors (Technological Forecasting and Social Change), along with a journal that covers the trends and developments related to management in the hospitality industry (International Journal of Hospitality Management). Both of these journals had a single paper per journal and combined for the remaining 11% of the papers. The Table 2 displays the journals and the number of papers published by each journal.

**Table 2. Number of selected articles for each journal**

Source	Articles
International Journal of Production Research	2
Production Planning & Control	2
International Federation of Automatic Control	2
Transportation Research Part E	1
Journal of Cleaner Production	1
International Journal of Production Economic	1
Computers & Industrial Engineering	1
Technological Forecasting and Social Change	1
Annals of Operations Research	1
Omega	1
Global Journal of Flexible Systems Management	1
Operations Management Research	1
Transportation Journal	1
Manufacturing & Service Operations Management	1
International Journal of Hospitality Management	1

## 2.2. Paper Analysis and Synthesis

The articles have been classified and analysed by clustering them in six following categories: industry; methodology; type of disruption; findings; strategies; key performance indicators. This method allowed to retrieve applicable data and synthesize the main findings. Moreover, the technique had assisted in dismissing the articles that did not meet the criteria for inclusion. In the following sections discussion of the listed categories is presented – general overview along with the analogy and correlations between the selected articles.

### 2.2.1. Industry

Classifying the industries addressed in the articles had been a beneficial category whilst performing SLR. Including the type of industry had served the selection of the articles in behalf of

relation to SCs, diversity of industries and exclusion of articles which address very specific industries not correlated to SCs. The diverse industries of the selected articles are such: Tire industry, Automobile and Airline industries, Food industry, Healthcare industry, Hospitality industry, all combine in a total of 28%. However, some articles do not refer to a particular industry, they combine for the remaining 72%. For example, Paul and Chowdhury's research [7] was motivated by the panic buying of toilet paper due to COVID-19, yet the study investigated strategies for high-demand and essential items during a disruption in general. Some industries highlighted the importance of **information sharing** and **collaboration**. Automobile and Airline industries [1], Healthcare industry [2], Hospitality industry [7] and Tire industry [20] had recognised information sharing as a crucial factor for disruption risk management. For instance, a hospital in Finland is able to achieve high clinical, operational, as well as financial levels, because it had integrated information sharing with SC actors (i.e. provision of electronic health records) along with other SCM strategies [2]. Therefore, it is safe to say, that in any case (or any industry), information sharing among SC parties can be considered as an effective disruption risk mitigation strategy.

### 2.2.2. Methodology

Regarding the main approaches of the selected papers, a few leading methods had been observed: Literature review/SLR, Optimization/simulation/mathematical models, Case-studies. Literature review had been used in 17% of articles. However, it has been used in 83 % of papers along with other methods (i.e. mathematical models and case-studies). SLR as a main method had been used in 11% of the selected articles. Different mathematical approaches had been used in 22% of the papers, such as simulation-based analysis, stochastic programming and other case-study based mathematical calculations. Mathematical approaches and models had been observed to be used in order to propose certain disruption risk mitigation strategies and to forecast and/or analyse the behaviour of SCs. Furthermore, case-study had been recognized as a regnant method used in half (50%) of the selected articles. This method seeks to understand a specific situation or a problem in-depth, as well as it allows to interpret the meaning of it [4]. Information is gathered by conducting interviews or empirical surveys, by investigating a certain sector/industry or by designing and simulating a SC.

### 2.2.3. Type of Disruption

This research was motivated by the COVID-19 pandemic and its impact on SCs. As expected, the novel coronavirus (SARS-2) outbreak instantaneously grasped the attention of many scholars and practitioners, resulting in a generous amount of articles (44%) focusing on the recent globally-spread virus. The pandemic had stimulated the research society to direct more focus on disruption risk mitigation and most importantly information sharing which, as observed, had been neglected by researchers and surpassed by other matters. The type of SC risk that a pandemic such as COVID-19 creates could be distinguished by long-term disruption continuance, as well as its unforeseeable scaling, coexisting disruption propagation (i.e., the ripple effect) and further simultaneous disruptions in the supply, demand, logistics infrastructure. It is different compared to other disruptions, as the disruption caused by a pandemic starts small, yet tends to scale fast and spread over several geographic regions, leaving a lot of unknowns, which makes it challenging to fully observe the impact and severity of the disruption on the SC and come up with the right measures to cope with it. Furthermore, the selection contains papers

which do not have any particular focus on a specific type of disruption (39%) – such papers had a broader approach on disruptions. That means that the paper mentions several disruptions, such as natural disasters, man-made catastrophes, etc. Moreover, only a single article (6%) with focus on Avian influenza had been selected, whilst 2 (11%) did not mention disruption risks nor specifically focused on operational risks.

### 2.2.4. Findings of the articles

The findings of selected papers are diverse, yet rather analogous. As the main focus of this research is information value in SC disruption management, naturally, papers which provide material and relatable outcomes on this topic had been recognized as a priority. Overall, the majority of selected papers proposed certain SC disruption risk mitigation strategies. Moreover, a portion of papers presented managerial insights or introduced certain optimization models such as Ivanov's simulation model for predicting SC behaviour during disruptions [9]. Referring to information value, for example, Mehrjerdi and Shafiee's study [20] revealed that information sharing along with multiple sourcing had been the most effective resilient strategies in the tire industry. Thus, the selection offers observations, insights and evidence on the value of information sharing – such findings had been considered as a priority in this research.

### 2.2.5. Key performance indicators

Key performance indicators can be used to assess behaviour of supply networks to disruptions. The majority of selected articles had offered several fitting indicators, that can be measured during a disruption. KPIs such as service level; delivery time; lead time; inventory level; production capacity and other financial KPIs had been mentioned in most papers. Moreover, Ivanov et al. (2016) [12] mentioned disruption costs and recovery costs, which should be considered when designing a SC. Service level has been observed to be the most frequently mentioned KPI, which is worth observing. Some studies [9], [20], [22] include service level as a measure in their optimization models. According to Ivanov et al. [14], the SC is at its most resilient condition when the SC achieves maximal service level at minimal possible costs during a disruption. KPIs in each industry may slightly vary. However, it is important that SC managers and decision-makers identify the financial and operational performance indicators that are crucial to observe during disruptions.

### 2.2.6. Strategies

One of the two contributions of this research is a conclusion of proactive and reactive disruption risk mitigation strategies. Proactive strategies build protection against a possible disruption, whilst reactive approaches adjust to the unexpected events [12]. In order to achieve this objective, whilst conducting SLR, proactive and reactive strategies that highly applied to the criteria were selected. Therefore, the majority of selected articles includes equivalent strategies that can lead to a conclusion, which answers the second research question (RQ2). The most frequently addressed strategies are such: information sharing, collaboration and visibility; flexibility; digitalisation among other recently proposed mitigation strategies.

A more distinct example would be a paper by González-Torres et al., as it had highlighted the value of information sharing between partners [7]. The paper presents a case study on the management of relationships in the hospitality industry in Spain during the pandemic. The collected data and insights from the respondents gave prominence to information sharing and collaboration. According to this study, rivalry and competition

increases the time of recovery of the whole SC. Therefore, in order to survive, businesses must collaborate.

### 3. COLLECTED INSIGHTS

#### 3.1. Interview insights

To support the SLR findings, observations had been synthesized from a practical point of view. Firstly, a Director of New Product Development of an online SC optimization platform shared insights about measures the company pursued during the COVID-19 outbreak. The company shared that that it had to shift to sea transportation due to airfreight cancellation caused by the COVID-19 pandemic. Although it has led to longer lead times, on the other hand, it is a more robust way of transportation during disruptions. The respondent also indicated, that the company is keeping a back-up inventory. This strategy is suggested by several studies and it was proven to at least slightly lessen the impact of disruption risks [1]. After earlier disruptions, such as SARS outbreak in 2002-2003 or Japan's earthquake and tsunami in 2011, companies tend to have a risk mitigation inventory, although it serves only for about 30 days [9]. Therefore, it can be led to a conclusion, that back-up inventory might not be the ultimate solution. Furthermore, the company had collaborated with its SC partners. **Collaboration** (or it can also be referred as coordination or cooperation) is proven to be an effective strategy for mitigating **disruption risks** among a few studies i.e. [1], [7], [25]. For this reason, it can be assumed that collaboration can be one of the most effective disruption risk mitigation strategies. The respondent reported that in the future, the company will not make drastic changes to the design and structure of the SC, however, implementation of automation and certain SC strategies as well as the design of an emergency plan for disruptive events are expected in the future.

#### 3.2. Webinar insights

Another source for collecting insights were webinars on SCM. Moderators of one webinar [18] conducted an empirical survey about supply chain management, precisely concentrating on **visibility**. The survey involved 142 manufacturing companies in Europe. The study revealed that the largest part of companies solely depended on back-up inventory and experienced a lack of visibility of demand and capacity of suppliers. Subsequently, the moderators conducted an additional survey among 106 manufacturing companies. The respondents were particularly asked if they would invest in visibility and SCM. It was observed that companies, which happen to be more stable and developed, would invest in end-to-end SC visibility and SC disruption risk management. Considering this, companies come to be more aware about the importance of visibility between SC partners. Furthermore, another webinar had been attended [17]. The presenter proposed eight areas of resilience – collaboration being one of them. It was suggested that a lot of focus should be put into collaboration, because it can provide important data, which can assist in assuring better performance across other seven areas. Moreover, a new SC track and tracing program had been introduced during the webinar. The program is designed to ensure end-to-end SC visibility as well as it alerts the user about disruptions in the SC in real time. Such type of digitalisation had been proposed by the name of “digital twin” by well-known scholars [10], [11]. It can be assumed that digitalisation in the current, technological times could be an effective approach to monitor SCs in real time.

## 4. RESEARCH FINDINGS

The main focus of this study is the importance of information sharing in SCM during disruptions. The selection of articles certainly acknowledged information sharing, yet this study **prioritises** the exchange of information during disruptions. The following subsections answer both of the research questions – KPIs that could be exchanged between SC partners are presented in Section 4.1. (RQ1) and disruption risk mitigation strategies are presented in Section 4.2. (RQ2).

### 4.1. Key Performance Indicators

The act of sharing information among SC actors had been observed to be a crucial characteristic of SC resilience. Therefore, this research offers a list of recommended KPIs that could be exchanged in the supply networks during or even pre-disruptions. Information sharing could act as both proactive and reactive approach in order to prevent and survive disruption risks. Information sharing mitigates uncertainty, therefore bringing balance to the SC. It is important to acknowledge that measurable information in each industry and supply network can be different. Accordingly, decision-makers of the SCs should evaluate, which KPIs are suitable to observe and share. Naturally, companies may experience misinterpretations and confusion whilst sharing data. However, harmonising KPIs [15] and sharing the same goals between SC entities could be the solution to such obstacles. Table 3 offers the recommended indicators that could be exchanged in the supply networks.

**Table 3. Key performance indicators that could be exchanged between supply chain partners**

Reference numbers	Key performance indicators
[5], [8], [9], [12], [14], [22], [25]	Service level
[2], [5], [7], [9], [15], [16], [19]	Inventory level
[2], [11], [19], [20]	Delivery time
[1], [9], [11], [12]	Profit, revenue
[5], [11], [14], [16]	Sales, order amount
[5], [9], [15], [19], [20]	Production capacity
[9], [15], [25]	Lead time
[12], [20]	Fixed, variable costs

In the following subsections, elaboration of five recommended, most **effective KPIs** is presented. The KPIs could be exchanged between the SC partners, in order to prevent and mitigate **disruption risks**. The remaining KPIs could as well be shared, however, they can serve as indicators that can be observed individually.

#### 4.1.1. Service level

Service level is a KPI, which measures performance and quality of work flow. It is a rather flexible indicator, because service level depends on the type of service or product provided. This KPI can become extremely crucial to monitor and exchange during disruptions such as the global pandemic – not only for the sake of business, but for the sake of customers. During a disaster such as COVID-19, SC actors must take the responsibility of satisfying **customer demand** for (especially

essential) items and services. Although, companies would like to stay competitive, they are obligated to cooperate and share information during disruptive events [7], [22]. Exchanging service level indicator between the parties in SCs could be beneficial as it would inform each partner (upstream and downstream) about changes in customer demand. Sharing such information could prevent shortage of raw material and halts in production. As a result, it would be a robust way to clear uncertainty caused by disruptions, such as epidemic outbreaks.

#### 4.1.2. Delivery time

Delivery time is the period within the seller transports goods to the buyer. Delayed deliveries may cause the ripple effect, resulting in degradation of the service level, productivity and revenue [9]. On-time-delivery during disruptions such as COVID-19 can be crucial in numerous situations. For example, delivery of vaccines is vitally important – long delivery time may cause expiration of the vaccine and can cause other unwanted circumstances. Furthermore, due to the movement restrictions caused by the pandemic, an increase of online shopping developed [2]. This means, that companies face the risk of delayed deliveries and overall loss of performance. To prevent this, SC partners should collaborate. Sharing information such as delivery time, had been observed to help companies achieving stability in performance and financial costs [19]. For this reason, SC partners could minimize the impact of the ripple effect if they shared KPIs, such as delivery time.

#### 4.1.3. Production capacity

Production capacity is a KPI that measures the capability of the output that the SC partner is able to produce. Sharing and being aware of this KPI helps other partners in reaching efficient and effective coordination in the SC [19]. It can be also exchanged with the aim of improving supply chain resilience, as all parties benefit from the lower levels of **uncertainty**. Therefore, being aware of the partner's production capacity allows for uncertainty to lessen, as well as provides with a better ability to forecast the efficiency of the SC [5]. Using the knowledge gained by this KPI, a SC actor might be warned to start using a SC strategy, such as backup capacity, multiple sourcing [20], in order to avoid or reduce damage of a potential disruption. Therefore, sharing this KPI is important for timely measures to be taken in the SC.

#### 4.1.4. Lead time

Lead time indicates the period between the initiation and completion of a process. Due to the novel coronavirus, companies had faced increased lead times. However, increased lead time can sometimes be the only option. As mentioned before, the interviewed company stated, that due to airfreight cancellation (caused by the pandemic), the company had to shift to sea transportation. This resulted in a longer lead time, however, it is a more robust way of transportation during disruptions. To increase the robustness of SCs, This KPI could be beneficial to share between the members of SC. It has been argued, that sharing lead time between SC partners could help avoid losses in logistic costs [1], which could be seen as a benefit during already stressful periods, such as pandemics. Although only few studies focus on lead time as a KPI that is worth sharing between SC members [1], it is a significant indicator during disruptions, which alter the dynamics of SCs. Therefore, theoretically, sharing lead time (and even other transportation related KPIs, i.e. transportation costs) between SC members could result in reduction of the ripple effect.

#### 4.1.5. Inventory level

Inventory level refers to the total of all goods and materials a SC partner has in stock. Sharing this KPI with other SC partners allows them to be aware of the partner's available inventory. The KPI is sometimes shared on a daily or weekly basis with an aim to reduce cycle time and to improve asset utilisation and customer services [19]. Such daily or weekly reviews on inventory level can also be beneficial with reducing the inventory costs, improving logistic resources allocation [15]. Regarding disruptions, sharing inventory level KPI with other SC parties grants them with the possibility of indicating any shortages that may arise, thus increasing the coordination between the SC partners, which is crucial during disruptions [19]. Before the disruption occurs, inventory level can be used to detect the weak signals of the SC that may affect the performance and allows to act up on them [5], minimizing the damage the disruption may cause.

### 4.2. Disruption Risk Mitigation Strategies

The results of this study offer a list of disruption risk mitigation strategies, both proactive and reactive. The selected strategies had been proven to be effective whilst managing disruption risks. Moreover, the strategies can build a resilient and a robust SC. **Robustness** and **resilience** include a spectrum of strategies and methods into their definitions. Robust (proactive) strategies, such as digitalisation, are practiced in order to absorb the threats a possible disruption may cause. Resilient (reactive) strategies, such as flexibility, are designed in order to adapt to the situation during a disruption. However, the selected strategies can be both proactive and reactive. For example, simulation technologies can be beneficial at the pre-disruption phase, as well as during [9]. Moreover, information sharing and collaboration (or coordination) can both be performed all-year round, as it could ensure a high-level of robustness and mitigate uncertainty. Table 4 proposes disruption risk mitigation strategies, which could be applied in the (re)design of SCs.

**Table 4. Disruption risk mitigation strategies**

Reference numbers	Mitigation strategies
[1], [4], [5], [7], [8], [15], [19], [20], [25]	Information sharing
[1], [11], [20]	Visibility
[1], [8], [15], [19], [22], [25]	Collaboration
[2], [7], [12], [15]	Coordination
[4],[5], [12], [13], [14], [20], [22]	Flexibility
[1], [9], [11], [24]	Digitalisation, simulations

The following subsections elaborate four recommended disruption risk mitigation strategies that could be considered **most effective** for mitigating **disruption risks**.

#### 4.2.1. Information sharing and collaboration

In this subsection, information sharing and collaboration (along with coordination) are combined, as information sharing cannot be executed without collaboration and vice versa.

Information sharing and collaboration had been discussed and proven to be rather effective strategies for mitigating SC operational and disruption risks. However, during disruptions

these strategies become vitally important, due to the uncertainty caused by disruptions, such as the long-lasting COVID-19 outbreak. Information sharing can weaken the uncertainty and reduce further risks. It offers better coordination between the SC members – information sharing can help to avoid production planning and control failures [20]. Furthermore, information sharing provides the SC with **visibility** and transparency [11], [17], [20]. As mentioned before, rivalry and competition increases the time of recovery in SC during disruptions [7], therefore, in order to effectively recover from the damage disasters cause, SC members must be willing to collaborate. An example from real-life can be considered the insights from the interviewed company – the Director of New Product Development had shared, that they collaborate with other SC actors in order to mitigate disruption risks. Although, it can be assumed that sharing information with other members might cause troubles such as lack of trust, will and responsibility. However, SC partners could assess and discuss their values, goals and concerns – this way, the companies could reach a consensus of this matter. Finally, information sharing and collaboration should be performed continuously, because both of these strategies can be considered long-term [1].

#### 4.2.2. *Visibility*

During disruptions, such as the recent coronavirus outbreak, increasing visibility is crucial in order to manage SCs. Visibility can be achieved by sharing information between the parties in a supply chain. Information sharing can be seen as an activity and visibility is the outcome of the activity [26]. Each SC member holds valuable information not only about its processes but also about its upstream (i.e. suppliers) and downstream (i.e. consumers) operations. Collecting this information in a central information system, where information is accessible by all parties, allows a quicker and more effective response to disruptions [23]. During a disruption, a lack of visibility can result in a major threat to a company. Many supply chain interruptions could have been avoided or negative effects mitigated if firms had succeeded in possessing end-to-end visibility [1]. For this reason, investing in visibility could be beneficial for the management of multi-tier SCs [1], [17]. For instance, visibility, along with collaboration mitigates the uncertainty, thus reducing the time of recovery [7]. Moreover, visibility improves resilience [11]. High levels of integrity between all the supply chain actors induce a high efficiency in controlling the disruptions. Such collaboration and transparency can help establish mutual goals between the SC parties and managers, thus it can help to reconfigure the SC [26]. However, unless trust between the supply chain partners is available, sharing information can be disadvantageous for some [21].

#### 4.2.3. *Flexibility*

Flexibility is a proactive SCM strategy that revolves around the ability to adjust and change processes and structures, according to the situation as a reaction to disruptions [12], [14]. Flexibility considers re-allocation of inventories, capacities and sourcing facilities in the SCs [14]. It was found that using flexibility can result in reduction of the total cost of SC. Moreover, it can have a positive impact on service level [14], [20]. Besides that, it is also related to better coordination in SCs and refers to concepts like collaborative planning, forecasting and replenishment [14].

One of the critical capacities of a resilient SC is recovery and adjusting tactics and operations for recovering from disruptions is essential [14], [22]. Flexibility is a common disruption recovery strategy, that is also categorized as an adaptive SC

recovery strategy [22]. Therefore, it is fundamental to implement in order to build a resilient SC and it should be considered by SCs for the means of disruption recovery.

#### 4.2.4. *Digitalisation*

Digitalisation is a proactive SCM strategy of converting the SC into a digital SC version. This approach can eliminate the need for basic things such as paper and face-to-face interactions, which can be particularly helpful during disruptions such as the pandemic. During the times of the novel coronavirus outbreak, it is suggested to include digitalisation, as it could improve the quality of the response to outbreak-related disruptions, by enhancing the **flexibility** under the pandemic circumstances [24]. During disruptions, technologies such as digital twin provide great potential to improve SC resilience through its high connectivity, accuracy, transparency and visibility [1], [11]. The digital version of a SC is a computerized model that represents SC's states for any given moment in real time [11]. That greatly contributes to lower levels of uncertainty, allowing the SC partners to make more informed decisions and manage the situation more effectively. After having to deal with the disruption of COVID-19, for example, automotive industry identified the lack of real-time visibility across the SC to be their major weakness [1]. Moreover, simulation technologies can be an another approach that can lead to better decision making. Simulations can allow to forecast the behaviour of SCs during a disruption – specifically, it can predict the information and material flows [9]. This method can increase visibility and supports decision-makers. Therefore, such information management systems can be defined as frameworks for **decision support systems** [10]. However, it is still a rather new concept to SCs. In the current years, especially during COVID-19, when physical contact is limited, a need for information systems in SCs. As mentioned before, digitalisation can provide the SC with transparency and real-time visibility. For this reason, it can be assumed that the implementation of digital technologies could solve the issue of uncertainty and lack of real-time visibility prior, during and post-disruptions.

## 5. CONCLUSION

The purpose of this research was to highlight the value of information during disruptions in SCM. The study found that information sharing is a crucial factor in disruption risk management in SCs. Exchanging information with SC partners can help prevent and mitigate disruption risks and uncertainty, thus making the SC robust and resilient. This research had been carried out by performing SLR, which provided this study with strong evidence by investigating high-quality research papers. This research contributes by filling the literature gap that exists concerning the importance of information sharing during disruptions in SCM. Moreover, this research provides a list of KPIs, that could be shared between SC members and provides a list of mitigation strategies, that can help reduce the negative impact of disruptions. Finally, this research can be considered one of the first articles, which prioritise information sharing during extraordinary disruptions, such as COVID-19.

### 5.1. Discussion

The findings of this research can be considered rather successful, considering the said gap in the literature. Although, the recommended KPIs had been mentioned and variously used in the selected articles, more depth about the KPIs and their benefits was expected. Furthermore, a lot of KPIs found (i.e. inventory level, fixed costs) during the SLR are related to operational risks, therefore a need for disruption risk oriented KPIs emerged during this research. Concerning the disruption

risk mitigation strategies, a lack of unification of terms has been noticed. For example, collaboration had been often referred as cooperation or coordination, although the concepts are very much alike. Another possible literature gap can be identified as a lack of research on SCs in Information Management (IM). Whilst conducting SLR, the search strings did not come across papers, that were published by IM journals, for example, Information Systems Journal. However, the selection of articles had provided applicable data, therefore, the outcomes can be viewed as sufficient, considering the limitations.

## 5.2. Limitations

This paper was done with no prior background or knowledge on supply chains, as well as no prior experience on performing the SLR or conducting research. That caused a loss in efficiency when conducting this research, as the time was rather limited. Moreover, adapting to this topic consumed a portion of time. The limited amount of background and knowledge might have also affected the outcomes of this research. Finally, the literature gap concerning the value of information in disruption management had influence on the findings. In many cases, information sharing and KPIs were not disruption-risk oriented and were often addressed rather vaguely.

## 5.3. Future work

The main goal of the future work should be to further explore the exchangeable, disruption risk oriented KPIs and mitigation strategies. As mentioned before, some of the KPIs are only very vaguely used or researched. As for the strategies, the importance of information sharing and collaboration could be explored more in-depth. In addition, management of SC relationships should be investigated – how to avoid misinterpretations, conflicts between SC partners and abuse of information. Finally, in the future, a deeper exploration of digital technologies and their implementation to SCs should be done. Information systems and technologies could provide SCs with visibility, real-time data tracking and information sharing.

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