Managing supply chains during the Covid-19 crisis: synthesis of academic and practitioner visions and recommendations for the future

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Markus Kohl, Andreas Habl, Khalil Kallali, Jakob Puff and Johannes Fottner
Chair of Materials Handling, Material Flow, Logistics, Technical University of Munich, Munich, Germany, and
Raphaël Oger, Matthieu Lauras and Jiayao Li
Centre Génie Industriel, IMT Mines Albi, Université de Toulouse, Albi, France

Abstract

Purpose – The Covid-19 pandemic has created an environment of high uncertainty and caused major disruptions in supply chains. The new normal that has emerged during the pandemic is leading to a need to identify new solutions to improve supply chain crisis management in the future. Practitioners require adapted recommendations for solutions to implement. These recommendations are laid out in this paper.

Design/methodology/approach – A combination of a systematic literature review (SLR), qualitative semi-structured interviews and a questionnaire survey of supply chain practitioners is applied. The interviews provide insights into supply chain practitioners' views of their approaches and, together with the solutions proposed in the literature, provide future recommendations for action for supply chain managers.

Findings – During the pandemic, companies experienced disruptions in supply, production and demand, as well as interruptions in transportation and distribution. The majority of the solutions proposed in the literature, coincide with the opinions of practitioners. These include collaborative risk management, real-time monitoring and information sharing, supply network management, scenario planning and "what-if" simulations.

Research limitations/implications – Although the number of interviews conducted and questionnaires completed is limited, they still serve to supplement the SLR with important practical insights and recommendations.

Originality/value – This paper presents a review of recent academic literature focusing on the impact of Covid-19 on supply chains and the existing solutions to mitigate that impact and manage future crises. It has been expanded to include industry perspectives and experiences. The findings of this study present recommended practices and strategies for better managing supply chains during a crisis.

1. Introduction

Covid-19 is a disease caused by the SARS-CoV-2 virus, which first appeared in Wuhan, China in late 2019. Over the course of several months, the disease quickly spread all over the world

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and was declared a global pandemic by the WHO on March 11, 2020 (Lai *et al.*, 2020). It is considered the worst pandemic outbreak since the Spanish flu that occurred between 1918 and 1920 and it triggered the worst economic crisis since at least the Great Recession of 2008 (Coveri *et al.*, 2020). Fonseca and Azevedo (2020) describe the Covid-19 outbreak as a crisis with a high degree of ambiguity and a potentially severe adverse outcome. In this context, Ivanov and Das (2020) consider the Covid-19 pandemic as a low-frequency, high-impact event.

From a business perspective, very few companies profited from the crisis and increased their sales, while the majority were negatively affected as they declared considerable losses. In fact, companies that had globalized and adopted lean structures were more vulnerable to the crisis (Ivanov, 2020). Over the last few years, production has been vertically fragmented on a global scale, which has accelerated the trend of global value chains. When the Covid-19 crisis occurred, global supply chains (SCs) were the first channel that the pandemic hit (Coveri *et al.*, 2020). It can be stated that the Covid-19 pandemic was breaking multiple global SCs, such as the healthcare supply chain (Sriyanto *et al.*, 2021). Besides, Covid-19 has exposed the fragility, vulnerability and low resilience of global SCs (Vanany *et al.*, 2021). This crisis was unique, because it was global, spread quickly and affected supply and demand simultaneously (Fonseca and Azevedo, 2020). Given this uniqueness, companies reacted in different ways, some more successfully than others. In such a highly uncertain environment, there were no clear guidelines to follow and no clear solutions to implement. Companies responded differently, but there is also no consistent picture in the literature of how supply chain managers should respond to the challenges of Covid-19. There is therefore a growing need to identify the most relevant practices, strategies and solutions to mitigate not only the impact of Covid-19 but also of future crises in SCs. The aim of this study is, thus, to identify and formulate recommended solutions and associated actions for better managing SCs during crises in the future.

To identify the most relevant solutions, it is important to consider not only academic literature, but also the industry's perspective, as it is possible that a gap exists between the two. Accordingly, best practices should be identified and specified along the process chain. Especially for a new type or scale on the supply chain, it is particularly necessary to include the direct assessment from the practice of supply chain managers and their accumulated experience. The recommended actions should also be clear, understandable and distinguishable. In this context, a possible categorization can be conducted in the context of the supply chain operations reference (SCOR) model. According to the Association for Supply Chain Management (ASCM), formerly APICS, the SCOR model consists of the following six management processes: *plan, source, make, deliver, return* and *enable*. It mainly describes business activities for which all phases contribute to the satisfaction of customer demand (APICS, 2017).

After considering the aforementioned aspects, this study aims to satisfy the stated research needs. It aims to identify the best solutions for managing SCs in the context of Covid-19 and of crises in general, from the perspective of both the industry and academic literature, and to formulate recommendations for solutions to help companies better cope with SCs crises in the future. The applied methodology, which is a combination of a systematic literature review (SLR) and an empirical approach, is explained in Section 2. The findings of the SLR and the empirical component are presented in Section 3. These findings are then discussed and analysed in Section 4, in which recommendations are formulated based on the findings, and limitations of the study are discussed. Section 5 concludes the paper by summarizing the outcomes and making suggestions for future research.

2. Research methodology

The methodology adopted in this paper combines an SLR and an empirical approach, as presented in Figure 1. The SLR covers the impact of Covid-19 on SCs and suggested solutions by authors in the literature for dealing with and recovering from the crisis. However, given the recency and the dimensions of the pandemic, there is a potential discrepancy between the industry and the current literature. To assess this issue, we employed an empirical approach consisting of semi-structured interviews, followed by a questionnaire. Interviews were conducted with SC practitioners in Europe to discover their opinions about Covid-19, its impact, the short- and long-term solutions adopted and possible paths to recovery. Afterwards, the interviewees were asked to respond to the questionnaire to obtain a quantitative assessment of the importance they attach to the solutions identified in the SLR. The combination of SLR and empirical methodology reduces their weaknesses, combines their strengths and increases the quality of the research (Mentzer and Flint, 1997) without losing any practical relevance.

2.1 Systematic literature review

We used an SLR to assess the existing literature covering the Covid-19 pandemic from an SC perspective. SLRs are a well-established tool and provide an effective framework for identifying and selecting literature from multiple databases to answer defined research questions. This way, a consistent and comprehensible literature review is created that can help advance research in the field of supply chain management (Durach *et al.*, 2017). SLRs also enhance practices and produce reliable knowledge (Tranfield *et al.*, 2003). The following section describes how the SLR was conducted.

2.1.1 Definition of research questions. Research questions (RQs) are formulated to set appropriate research boundaries (Durach *et al.*, 2017). The following two RQs were determined for the literature component of this study:

RQ1. What impact has Covid-19 had on global SCs?

RQ2. What recommendations and actions does the literature propose for coping with the effects of Covid-19 crisis and for being better prepared in the event of any future disruption, and to which process of the SCOR model can they be attributed?

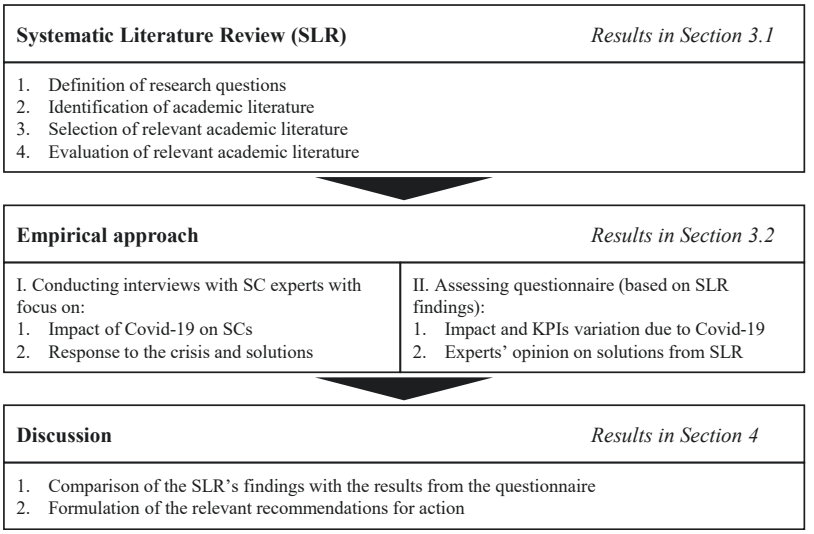

Figure 1.
Overview of the research methodology

2.1.2 Identification of academic literature. To find answers to the proposed research questions, suitable academic literature had to be identified. For this purpose, literature related to the topic was scanned for potential keywords. The preliminary list of keywords was finalized into a set of words and synonyms to be searched for in reliable databases. The primary keywords for this SLR are *supply chain, management* and *Covid-19*. Combinations were formed using Boolean operators and then used to search the following databases: Scopus, Science Direct, IEEE and Springer Link. Depending on the number of results in the databases, the synonyms *coronavirus* and *crisis* were added as keywords to either broaden the search or narrow down the results. A large number of articles were found at Science Direct and at Springer Link, so further filters were added with a focus on "Business and Management," "Economics," "Engineering" and "Social Sciences." This resulted in 747 articles (Science Direct) and 396 articles (Springer Link). Via Scopus 244 articles and via IEEE 27 articles were identified. As a result, the search found a total of 1,414 articles.

2.1.3 Selection of relevant academic literature. To identify relevant articles, duplicates were first eliminated and then inclusion and exclusion criteria were applied to this list, using the focus of the article and its contribution to the research topic as decision criteria. A total of 1,068 papers were classified as not relevant based on exclusion criteria. Articles considered relevant either focused on the impact of Covid-19 on SCs or featured a set of requirements or recommendations for action to help SCs cope with or recover from the Covid-19 pandemic. In the event of doubt, the abstract was used to further assess the relevance of a specific article. Publications not matching these criteria were excluded, such as papers focusing on environmental or policy aspects. Following this step, 131 articles remained as potentially relevant.

Based on the previously defined RQs, two clusters were created, with Cluster (1) focusing on the impact of Covid-19 on SCs (RQ1) and Cluster (2) on the solutions and recommended actions (RQ2). In this step, the articles identified in the previous step as potentially relevant were reviewed to determine those that were indeed relevant for answering the RQs. Cluster (1) did not include literature describing only one impact of the pandemic. Here, at least two or more individual impacts had to be described, demonstrating that the article attached sufficient relevance to the aspect of disruption. Cluster (2) included articles that outlined at least two solutions, recommendations and/or future trends with a focus on SCs for coping with or recovering from the Covid-19 crisis or that contributed to being better prepared for future disruption events. To ensure a cross-process view, articles also had to address at least two areas of the SCOR model.

Cluster (1): Impact of Covid-19 on SCs (38 papers).

Cluster (2): Solutions and recommendations for action (36 papers).

These clusters are independent from one another. The articles identified can be found in one or both clusters (20 articles), depending on whether they match the given criteria. The articles from the SLR are marked with an asterisk in the bibliography.

2.1.4 Evaluation of relevant academic literature. Following the selection process, the publications were fully reviewed. To answer RQ1, the impacts of Covid-19 on SCs were assigned to their respective disruption type, following the suggestion by Chowdhury *et al.* (2020), who classified disruption types as supply-side disruptions, production disruptions, transportation and distribution disruptions, demand-side disruptions or a combination of two or more of these types. The results are presented in Section 3.1.1.

To assess RQ2, a structural framework was defined on the basis of the SCOR model. This model was chosen because it is well-known, widely used and thus well established in the scientific community. Key recommendations and requirements identified in the literature were thus assigned to the respective SCOR process. This allowed recommendations

presented in different papers to be put into an SC perspective and given a uniform structure. The framework and results are discussed in Section 3.1.2.

2.2 Empirical approach

One year after the beginning of the Covid-19 outbreak, a considerable amount of academic literature has been written about the impact of the pandemic and the best countermeasures for SCs and SC players. The opinion of SC practitioners is crucial to ensure an accurate reflection of the SLR perspective in industry.

The empirical approach aims to answer the following research questions:

RQ3. According to practitioners, how has Covid-19 impacted the performance of their companies in regard to their key performance indicators (KPIs)?

RQ4. According to practitioners, how helpful would the solutions proposed in academic literature be to manage supply chain crises in the future?

To answer RQ3 and RQ4, we divided the empirical approach into two parts. The first involved conducting semi-structured interviews with SC practitioners with the purpose of identifying the problems that companies encountered and the solutions that they implemented during the Covid-19 crisis. The second part consisted of a questionnaire based on the results of the SLR, which aimed to verify the alignment of the solutions suggested in the literature with the practitioners' opinions.

2.2.1 Semi-structured interviews. First, interviews were conducted with SC practitioners from industrial partners in France and Germany who specialize in either consultancy, technology or manufacturing. Eleven interviews were conducted between January and February 2021 with interview partners consisting of supply chain managers and executives with years of professional experience and knowledge in their respective field in the period. Each interview lasted one hour. The purpose of the interviews was to identify problems that SCs faced and are still facing one year after the outbreak of the pandemic in Europe and to discuss the solutions that they have implemented or are planning to implement either to mitigate the impact of the current crisis or to prepare for future ones. The companies interviewed are classified as either consulting [Cons], technology [Tech] or manufacturing [Manu] partners.

The interview was structured in three sections. The first section focuses on the impact of the Covid-19 crisis on SCs. The second section concentrates on the short- and long-term solutions that companies have implemented or intend to implement as countermeasures. Solutions based on the SCOR model and the dimensions of supply chain resilience (SCRE) are discussed. Finally, the practitioners are asked about any previous major disruptions that they have faced during their careers and any aspects that these shared with the current Covid-19 crisis.

The SCOR model focuses on all customer interactions, physical material transactions and market interactions. It was designed primarily to support SCs with different complexities and across various industries (APICS, 2017). However, the dimensions of SCRE add a time factor to the framework. The practices and measures are classified according to the timeline of the evolution of the crisis. Chowdhury and Quaddus (2016) define SCRE as the ability of an SC to develop the required level of readiness, to respond quickly and to recover. Therefore, the three dimensions of SCRE are readiness, response and recovery. Ponomarov and Holcomb (2009) emphasize the importance of the pre- and post-disruption aspects of SCRE. Readiness refers to pre-disruption aspects, response focuses on short-term post-disruption aspects, while recovery concentrates on long-term ones.

After the first interviews were conducted, the framework was adjusted accordingly. It was found that the SC practitioners were not able to compare the Covid-19 crisis to any previous

crises, given its length and global impact. Only one dimension of SCRE – the response – was discussed in any detail. The majority of the companies were not prepared for such a major disruption and are still so focused on ensuring the continuity of their daily business that they have no concrete recovery plans yet. The *return* process of the SCOR model was also discarded, as no solutions or measures were suggested in this category. We should, however, point out that questions were still asked about previous crises and the SCRE dimensions.

2.2.2 Questionnaire. The second component of the empirical approach consisted of a questionnaire based on the findings of the SLR, which aimed to verify the alignment of the solutions identified in the literature with the industry, quantify the variation of the KPIs after the Covid-19 outbreak and review the SC practitioners' opinions of some of the most popular solutions and strategies in the literature. Overall, the questionnaire was focused on completing the semi-structured interviews for answering RQ3 and RQ4.

In line with this objective, on the one hand, the questionnaire was specifically issued to the practitioners performing the interviews. The practitioners' answers were given on a 5-point Likert scale in response to how different KPIs were affected after the Covid-19 outbreak (ranging from "1: greatly decreased" to "5: greatly increased") and how much the solutions cited in the literature would be or would have been helpful in mitigating the impact of the current crisis or future crises (from "1: not helpful at all" to "5: very helpful"). To prevent their answers from being influenced during the actual interview, the questionnaire was sent out to the interview partners only once the interviews had been conducted. Regarding the solutions part, some were reformulated to help practitioners answer and, in addition, of the 13 identified during the SLR, 3 additional ones were identified during the interviews and added to the questionnaire. A total of 10 answered questionnaires have been received over the 11 interviewees.

On the other hand, in order to gather more opinions, the questionnaire was also developed as an online survey to gather results over a broader spectrum of supply chain practitioners in a variety of countries and industries. The questionnaire consists of two sections. One concerns the profile of respondents, including business type of company, size of company, the continents where the company operates, years of work experience, etc. Another section was dedicated to gathering opinions about how much the proposed solutions would be helpful to manage supply chain crises. A 10-point Likert scale was adopted, ranging from 1 to 10 by level of relevance (from "1: not helpful at all" to "10: extremely helpful"). The questions about the solutions proposed in academic literature were the same in both questionnaires so that results could be easily aggregated. 15 new responses to the questionnaire were received, bringing the total number of responses to 25.

3. Findings

3.1 Results of the SLR

This section presents the results of the SLR. Since all results and recommendations presuppose an underlying problem, the following Section 3.1.1 gives an overview of the impact of Covid-19 on the SCs. Section 3.1.2 then outlines the requirements and recommendations identified from the literature.

3.1.1 Qualitative evaluation of the impact of Covid-19 on SCs. To answer RQ1, we evaluated the 38 papers identified in Cluster (1). All authors agree that Covid-19 triggered multiple disruptive impacts on global SCs, posing unseen challenges for businesses, which are still struggling to resume normal operations to this day. One of the causes of disruption during the initial phases of the outbreak was the inability of many businesses to source necessary parts or raw materials from suppliers in China due to the discontinuation of Chinese and East Asian production (Ivanov, 2020; Ivanov and Dolgui, 2021; Li *et al.*, 2021; Remko, 2020). This had a cascading effect onto other manufacturers in (at that time) less-affected countries (Belhadi

et al., 2020), who soon found themselves in a similar situation, facing closures or limited operations of their own facilities and trading partners due to the continued global spread of the virus (Chowdhury *et al.*, 2020; Kumar *et al.*, 2020). This resulted in a disruption of the global availability of supplies, with a shortage of raw materials and spare parts (Karmaker *et al.*, 2021; Shafi *et al.*, 2020; Xu *et al.*, 2020; Zhu *et al.*, 2020). In particular, the medical sector was unable to acquire necessary supplies such as medical masks, medical equipment and hand sanitizers (Cai and Luo, 2020; Sharma *et al.*, 2020a; Xu *et al.*, 2020). Travel bans and closed borders further slowed the movements of goods and introduced distribution bottlenecks due to increased controls, time-consuming inspections and delays in customs clearances (Workie *et al.*, 2020; Xu *et al.*, 2020). Consumer buying behavior changed rapidly, leading to panic buying and stockpiling of sanitary products, food and daily necessities, which created additional pressure on manufacturers and retailers (Kumar *et al.*, 2020). At the same time, the automobile, crude oil and transportation sectors saw a sharp decline in demand (Belhadi *et al.*, 2020; Rapaccini *et al.*, 2020; Sharma *et al.*, 2020a). Businesses across all sectors faced simultaneous disturbances in supply, demand and the logistics and transportation infrastructure as a whole (Ivanov, 2020; Rapaccini *et al.*, 2020). These sequential supply and demand disruptions had a ripple effect, which quickly propagated forward and backward through the SC, triggering failures along all stages of the network (Ivanov and Dolgui, 2021; Li *et al.*, 2021). This intensified the stress on global SCs and further exacerbated the impact that companies were experiencing. To this day, the global supply situation is facing continuous disruptions caused by the ongoing spread of infection and is still struggling to find its way out of the crisis.

3.1.2 Qualitative evaluation of literature on SC requirements and recommendations after the Covid-19 outbreak. A total of 36 publications were identified in Section 2.1 which contained solutions and recommendations to help SCs cope with or recover from the crisis. These publications are used in this section to answer RQ2. The recommendations identified were assigned to the most appropriate SCOR processes (see Table 1). We define a relevant recommendation as a suggested solution that appears in the academic literature sample at least ten times.

Regarding the *plan* process of the SCOR model, three main recommendations were identified in the literature. The first of these is *real-time monitoring and information sharing,* and it is the most commonly proposed approach overall. With most companies encountering shortcomings in their SC visibility, real-time monitoring and processing of relevant data are proposed as a solution by such authors as Shen *et al.* (2020), Karmaker *et al.* (2021) and Sheng *et al.* (2020). The required visibility is attained with the aid of digital tools, which transform traditional SCs into digital supply networks with a free flow of information and end-to-end visibility (Zhu *et al.*, 2020). The application of digital tools is also suggested by Liu *et al.* (2021). Another frequent recommendation is *quick decision making*. The literature identified the ability to make timely decisions as a key factor in mitigating uncertainty and increasing responsiveness during times of crisis (Okorie *et al.*, 2020). This includes the ability to make joint and coordinated decisions together with other SC stakeholders, which promotes a collaborative and transparent decision-making approach (Ahlqvist *et al.*, 2020). The third recommendation proposed in the literature is the implementation of *collaborative and data-driven demand forecasting* (Karmaker *et al.*, 2021; Paul and Chowdhury, 2020). The ability to anticipate and consider potential changes in consumption is of vast importance, especially during times of crisis (Siebert *et al.*, 2020) and the communication should include customers, suppliers and other SC stakeholders, to enable appropriate demand–supply synchronization strategies to be established (Sharma *et al.*, 2020b; Xu *et al.*, 2020).

For improving the *source* process, a total of five recommendations were identified. Several authors call for diversification to reduce reliance on single suppliers by adopting strategies such as *multi-sourcing and supplier diversification* (Sarkis *et al.*, 2020; Xu *et al.*, 2020).

SCOR process	Identified recommendation	Number of papers	References
Plan	Real-time monitoring and information sharing	28	Zhu *et al.* (2020), Belhadi *et al.* (2020), Sarkis *et al.* (2020), Li *et al.* (2021), Guo *et al.* (2020), Queiroz *et al.* (2020), Cai and Luo (2020), Okorie *et al.* (2020), Remko (2020), Kumar *et al.* (2020), Sharma *et al.* (2020a, b), Xu *et al.* (2020), Ivanov (2020), Deshmukh and Haleem (2020), Shen *et al.* (2020), Paul and Chowdhury (2020), Karmaker *et al.* (2021), Li *et al.* (2020), Shao *et al.* (2021), Liu *et al.* (2020), Fonseca and Azevedo (2020), Ahlqvist *et al.* (2020), Schiele *et al.* (2020), Sarkis (2020), Yang *et al.* (2020), Sheng *et al.* (2020), Al-Mansour and Al-Ajmi (2020)
	Quick decision-making	19	Zhu *et al.* (2020), Belhadi *et al.* (2020), Sarkis *et al.* (2020), Guo *et al.* (2020), Ishida (2020), Queiroz *et al.* (2020), Cai and Luo (2020), Okorie *et al.* (2020), Xu *et al.* (2020), Sharma *et al.* (2020b), Deshmukh and Haleem (2020), Khurana *et al.* (2021), Shen *et al.* (2020), Li *et al.* (2020), Ahlqvist *et al.* (2020), Sarkis (2020), Yang *et al.* (2020), Sheng *et al.* (2020), Al-Mansour and Al-Ajmi (2020)
	Collaborative and data-driven demand forecasting	14	Siebert *et al.* (2020), Cai and Luo (2020), Kumar *et al.* (2020), Sharma *et al.* (2020a, b), Xu *et al.* (2020), Ivanov (2020), Shen *et al.* (2020), Paul and Chowdhury (2020), Karmaker *et al.* (2021), Li *et al.* (2020), Schiele *et al.* (2020), Sarkis (2020), Sheng *et al.* (2020)
Source	Multi-sourcing and supplier diversification	11	Zhu *et al.* (2020), Sarkis *et al.* (2020), Gurbuz and Ozkan (2020), Okorie *et al.* (2020), Remko (2020), Sharma *et al.* (2020a, b), Strange (2020), Liu *et al.* (2020), Gereffi (2020), Fonseca and Azevedo (2020)
	Alternative and backup suppliers	13	Zhu *et al.* (2020), Ishida (2020), Queiroz *et al.* (2020), Okorie *et al.* (2020), Remko (2020), Sharma *et al.* (2020a), Xu *et al.* (2020), Ivanov (2020), Shen *et al.* (2020), Paul and Chowdhury (2020), Karmaker *et al.* (2021), Fonseca and Azevedo (2020), Yang *et al.* (2020)
	Localization, regionalization and reshoring	21	Zhu *et al.* (2020), Belhadi *et al.* (2020), Sarkis *et al.* (2020), Guo *et al.* (2020), Gurbuz and Ozkan (2020), Ishida (2020), Hobbs (2020), Siebert *et al.* (2020), Cai and Luo (2020), Remko (2020), Sharma *et al.* (2020a), Xu *et al.* (2020), Ivanov (2020), Deshmukh and Haleem (2020), Moutray (2020), Strange (2020), Liu *et al.* (2020), Gereffi (2020), Fonseca and Azevedo (2020), Sarkis (2020), Sheng *et al.* (2020)
	Supplier collaboration and strategic partnerships	20	Belhadi *et al.* (2020), Sarkis *et al.* (2020), Guo *et al.* (2020), Gurbuz and Ozkan (2020), Hobbs (2020), Siebert *et al.* (2020), Remko (2020), Kumar *et al.* (2020), Sharma *et al.* (2020a, b), Xu *et al.* (2020), Paul and Chowdhury (2020), Karmaker *et al.* (2021), Li *et al.* (2020), Shao *et al.* (2021), Liu *et al.* (2020), Schiele *et al.* (2020), Sarkis (2020), Yang *et al.* (2020), Al-Mansour and Al-Ajmi (2020)
	Adaptive warehouse capacity	13	Zhu *et al.* (2020), Belhadi *et al.* (2020), Hobbs (2020), Queiroz *et al.* (2020), Remko (2020), Kumar *et al.* (2020), Sharma *et al.* (2020a), Xu *et al.* (2020), Ivanov (2020), Gereffi (2020), Fonseca and Azevedo (2020), Yang *et al.* (2020), Al-Mansour and Al-Ajmi (2020)

(*continued*)

Table 1. Relevant recommendations identified for managing the Covid-19 crisis

SCOR process	Identified recommendation	Number of papers	References
Make	Cyber-physical systems and automation	19	Zhu *et al.* (2020), Belhadi *et al.* (2020), Sarkis *et al.* (2020), Guo *et al.* (2020), Gurbuz and Ozkan (2020), Queiroz *et al.* (2020), Okorie *et al.* (2020), Remko (2020), Kumar *et al.* (2020), Ivanov (2020), Deshmukh and Haleem (2020), Khurana *et al.* (2021), Shen *et al.* (2020), Moutray (2020), Karmaker *et al.* (2021), Li *et al.* (2020), Shao *et al.* (2021), Liu *et al.* (2020), Sarkis (2020)
	Adaptive production	14	Zhu *et al.* (2020), Sarkis *et al.* (2020), Guo *et al.* (2020), Gurbuz and Ozkan (2020), Ishida (2020), Queiroz *et al.* (2020), Okorie *et al.* (2020), Sharma *et al.* (2020a), Ivanov (2020), Deshmukh and Haleem (2020), Khurana *et al.* (2021), Paul and Chowdhury (2020), Karmaker *et al.* (2021), Fonseca and Azevedo (2020)
Deliver	Flexible delivery routes and alternative delivery options	11	Belhadi *et al.* (2020), Queiroz *et al.* (2020), Siebert *et al.* (2020), Okorie *et al.* (2020), Kumar *et al.* (2020), Sharma *et al.* (2020a, b), Paul and Chowdhury (2020), Karmaker *et al.* (2021), Liu *et al.* (2020), Fonseca and Azevedo (2020)
Enable	Scenario development and simulation	17	Belhadi *et al.* (2020), Sarkis *et al.* (2020), Guo *et al.* (2020), Gurbuz and Ozkan (2020), Queiroz *et al.* (2020), Cai and Luo (2020), Kumar *et al.* (2020), Sharma *et al.* (2020a, b), Shen *et al.* (2020), Moutray (2020), Karmaker *et al.* (2021), Li *et al.* (2020), Liu *et al.* (2020), Fonseca and Azevedo (2020), Sarkis (2020), Sheng *et al.* (2020)
	Active and collaborative risk management	17	Zhu *et al.* (2020), Belhadi *et al.* (2020), Li *et al.* (2021), Gurbuz and Ozkan (2020), Hobbs (2020), Siebert *et al.* (2020), Cai and Luo (2020), Sharma *et al.* (2020a, b), Xu *et al.* (2020), Karmaker *et al.* (2021), Strange (2020), Gereffi (2020), Fonseca and Azevedo (2020), Ahlqvist *et al.* (2020), Yang *et al.* (2020), Al-Mansour and Al-Ajmi (2020)

Table 1.

Similarly, *alternative and backup suppliers* are recommended so as to reduce the supply-side risk of plant closures during a crisis event (Remko, 2020) and to help overcome sourcing difficulties during times of disruption (Okorie *et al.*, 2020). The most frequent suggestion regarding the *source* process, however, was the recommendation of *localization, regionalization and reshoring*. Remko (2020), for example, proposes a local sourcing approach that includes more local and nearshore suppliers and plants in the SC. Belhadi *et al.* (2020) also call for an increased local and regional focus in the sourcing process, arguing that in the event of a disruption, the emerging risk could be contained in one area, without it affecting other regions. Sheng *et al.* (2020) further argue that global value chains will be re-evaluated, with the possibility of them becoming shorter, more regional and national, in order to build future resilience. Another recommendation is *supplier collaboration and strategic partnerships,* which involves actively working together with suppliers and increasing stakeholder communication in order to establish cross-tier partnerships. This suggestion is backed by authors including Schiele *et al.* (2020), Kumar *et al.* (2020) and Sarkis *et al.* (2020), who all propose a collaborative approach based on an intensive communication structure between SC members and customers as one of the main measures to increase SC resilience. A fifth recommendation is *adaptive warehouse capacity*. The adoption of lean management strategies in recent years has inevitably led to inventories, capacities and safety stocks reduced to minimum operational levels. To manage this situation, several solutions have been

identified under the collective term of "adaptive warehousing," which focuses on aspects such as safety stocks, reserve capacity, flexible inventory management and resource allocation (Remko, 2020; Sharma *et al.*, 2020b).

For the *make* process in the SCOR model, two main suggestions were identified. *Cyber-physical systems (CPS) and automation* are possible solutions for moving towards a more digital manufacturing process, enabling the use of automation and Industry 4.0 technologies, such as smart manufacturing, cloud computing and IoT (Queiroz *et al.*, 2020; Sarkis, 2020; Zhu *et al.*, 2020). Examples of such applications are provided by authors, including Shen *et al.* (2020) who propose a collaborative, intelligent manufacturing framework that includes cloud manufacturing, digital twins and IoT solutions to support process and factory automation. With the aid of *adaptive production*, companies can pursue a flexible manufacturing approach that allows them not only to adjust production capacities and processes, including manufacturing repurposing, but also to change product specifications such as variety, size or standardization. This enables companies to dynamically adapt products or processes that can be of advantage not only to recovery but also in preparing for future disruptions (Okorie *et al.*, 2020).

With regard to the *deliver* process, *flexible delivery routes* and *alternative and supplemental delivery options* are recommended as solutions. In fact, Siebert *et al.* (2020) list ensuring delivery capacity as one of the business objectives identified in the time of the Covid-19 pandemic. Belhadi *et al.* (2020) further highlight the importance of lifeline maintenance as a reactive response strategy, pointing out that the loss of the transportation system would affect the entire manufacturing SC.

Finally, two suggestions were identified for the *enable* process. *Scenario development and simulation* are proposed to help companies understand what impact different pandemic scenarios would have on their businesses and how managers could be supported in operating their SCs during crises. To enable and support the development of this scenario, the use of digital technology including data analytics and simulation is proposed. Liu *et al.* (2020), for example, suggest using predictive models that consider risk factors in the proactive scheduling of supply. Sheng *et al.* (2020) share the same view, outlining the need for new analytical methods to help managers make sense of their environment. In order to increase SC resilience and to be better prepared for future crises, the authors in the literature suggest pursuing *active and collaborative risk management* strategies, which include continuous risk assessment and the establishment of contingency plans. Belhadi *et al.* (2020), for example, suggest an integrated SC risk management approach, working with SC partners towards a collaborative risk management effort throughout the SC. Ahlqvist *et al.* (2020) also point out the increased need for inter-organizational collaboration in order to evaluate, handle and manage diverse risks and uncertainties. Xu *et al.* (2020) highlight the importance of a collaborative risk management approach, recommending that companies develop congruent risk management practices with their strategic partners.

3.2 Empirical findings

The aim of this section is to present the findings of the empirical component of our study. It contains the opinions of SC practitioners regarding the impact of Covid-19 on their respective SCs and the solutions and strategies that helped – or could have helped – them during the first year of the pandemic. It is divided into two sections: first, a section that answers RQ3 describing the practitioners' vision about the impact of the Covid-19 crisis and their companies' performance. Second, a section that answers RQ4 describing practitioners' vision about how helpful the solutions proposed in academic literature would be to manage supply chain crises in the future.

3.2.1 Impact of the Covid-19 crisis on company performance. The majority of the companies interviewed have been negatively impacted by the Covid-19 crisis, some more than others. Manufacturing companies from the automotive and aeronautics fields have

faced the greatest problems. They have been forced to shut down for an extended period of time and demand for their products has fallen drastically. Pharmaceutical companies that focus on producing disinfectants, masks and other pandemic-related products have witnessed an increase in demand and have been able to produce continuously throughout the pandemic. However, other production areas such as cosmetics have been negatively affected. Consulting companies have had a turbulent phase as well, as many projects have been cancelled or postponed. Only technology companies that provide visibility, software support or automation services have profited from the crisis, as demand has increased due to the new trend in digitalization.

The SC practitioners stated (in answers ranging from "1: greatly decreased" to "5: greatly increased," including "3: stable") how the following KPIs have been affected by the pandemic: lead times, demand, on-time deliveries, costs, cash flows and inventory levels.

The findings from the ten questionnaires completed by interviewees reveal that companies have mostly had low cash flow levels during the Covid-19 crisis (min = 1; mean = 2.2; median = 2.5; max = 3). In fact, [Manu2] describes cashflow difficulties as the biggest challenge of the crisis, especially in the first months. [Manu4] had to take loans from the government to cope with the cashflow bottleneck, while [Cons3] stated that the governmental help was insufficient to solve cashflow problems, especially for aeronautics companies. The majority of companies also witnessed a decrease in demand (min = 1; mean = 2.6; median = 2.0; max = 5). However, technological and medical companies profited from the crisis and witnessed an increase in demand, which explains the high standard deviation SD (SD = 1.58) for this KPI. Actually, the demand for the products of [Tech2] and [Tech3] slightly increased after the pandemic outbreak, which led to an increase in turnover. The demand for pharmaceutical and medical-related products of [Manu2] slightly increased. Nevertheless, their overall turnover was negatively affected because of the drop in revenue from their other, cosmetics products. According to the interviewed practitioners, other KPIs such as lead times, on-time deliveries, costs and inventory levels have not been clearly affected by the Covid-19 crisis.

3.2.2 Solutions that could help to better manage the SC crisis. Companies have reacted in various ways to the Covid-19 outbreak, each having different problems to cope with and having to take individual respective measures. Nevertheless, one year after the outbreak of the pandemic in Europe, they agreed that certain strategies and solutions helped or could have helped them during the crisis, and more specifically could help to manage supply chain crises in the future. After identifying the solutions most frequently cited in the literature, 10 interviewed SC practitioners were asked through the first questionnaire to assess how helpful they think these solutions are to manage the supply chain crisis. The practitioners answered on a 5-point Likert scale (from "1: not helpful at all" to "5: very helpful"), indicating how they perceived each solution. Then, a second questionnaire was sent through social networks such as LinkedIn to broaden the scope of respondents. 15 practitioners mainly from Europe and Asia completed this second questionnaire. The findings from the 25 completed questionnaires, which provide the answer to RQ4, are synthesized in Table 2.

The solution "*active and continuous risk management and collaborative risk management with suppliers and customers" w*as pointed out by practitioners as the top one to deal with a supply chain crisis. Interviewed SC practitioners considered it to be a very helpful countermeasure against the impact of Covid-19 on SCs. This consensus is evidenced by the fact that this solution has the highest mean and median as well as the lowest standard deviation (see Table 2). [Tech3] greatly focused on this point during the interview, considering risk assessment and constant communication with suppliers of critical parts about inventory levels and financial situations to be very important for the survival of the SC.

Moreover, *"collaborative and rapid alignment solutions with SC partners" and "real-time monitoring of SC partners and information sharing"* are also both frequently mentioned by

Suggested solutions	Boxplot	Mean	Median	Standard deviation	Number of papers in SLR
Active & continuous risk management / collaborative risk management with suppliers and customers		4.50	4.50	0.53	17
Collaborative & rapid alignment solutions with supply chain partners		4.30	5.00	1.25	20
Demand-driven & adaptive flow management		4.25	4.00	0.71	Solution identified during interviews
Real-time monitoring of supply chain partners and information sharing		4.00	4.00	0.94	28
Quick decision-making		3.85	4.00	1.06	19
Multi-sourcing & supplier diversification		3.75	4.00	1.28	11
Alternative & backup suppliers		3.56	4.00	1.18	13
Flexible production processes and strategies		3.29	4.00	1.25	14
Planning scenario development & what-if simulations		3.50	4.00	1.12	17
Non-deterministic planning systems		2.95	3.75	1.36	Solution identified during interviews
Adaptive warehouse capacity		3.33	4.00	1.41	13
Predictive and data-driven planning & forecasting systems		3.25	3.50	1.28	14
Cyber physical systems & automation		3.13	3.50	1.13	19
Localization, regionalization and/or reshoring		3.22	3.00	1.09	21
Flexible delivery routes, alternative and/or supplemental delivery options		2.71	2.00	1.38	11
Flexible manufacturing technologies		2.44	2.50	1.24	Solution identified during interviews

Table 2.
Questionnaire findings for the solution component

practitioners and characterized by a high mean and a high median and are thus considered among the best countermeasures against the Covid-19 crisis and the supply chain crisis. The statements made by the SC practitioners reinforced support for these solutions. In fact, [Cons2] increased the focus on collaborations with key suppliers in order to enable aligned solutions and counter the bullwhip effect. They also considered collaborations with customers an important factor and attempted to integrate them in the SC design, using methods such as value stream mapping. The importance of collaboration was also emphasized by [Manu1, Manu2, Manu3, Manu4]. Furthermore, the lack of visibility was a problem shared by many of the companies interviewed [Cons1, Cons3, Tech3, Manu1, Manu2, Manu4], which is why the majority searched for real-time monitoring and information sharing to improve SC visibility.

Next are *"demand-driven and adaptive flow management"* and *"alternative and backup suppliers,"* respectively in fourth and fifth position. Even if slightly lower than the previous ones, these solutions also have high mean and median and so are considered by interviewed practitioners as among the best solutions to deal with the supply chain crisis. During interviews, [Manu4] stated that both their demand-driven operative model, involving switching from a push to a pull strategy, and demand-driven material requirements planning helped them considerably during the first year of the pandemic. In addition, companies faced various problems with suppliers during the first year of the Covid-19 outbreak, such as delays, huge price increases and inability to deliver [Cons2, Cons3, Tech3, Manu1, Manu3, Manu5]. This explains the practitioners' interest for alternative and backup suppliers.

The five following solutions ranked from the 6th to the 10th were not always mentioned, but still pointed out as relevant by several practitioners: *"planning scenario development and 'what-if' simulations,"* "*multi-sourcing and supplier diversification," "quick decision making,"* "*localization, regionalization and/or reshoring"* and "*predictive and data-driven planning and forecasting systems."* For the use of "what-if" simulations and planning scenario development during the Covid-19 crisis, [Manu4] implemented a decision-making process in which they examined three potential crisis evolution scenarios (worst, middle and best case) and adopted the middle one. They stated that scenario planning and "what-if" simulations would have helped them a lot if they had implemented such tools before the Covid-19 outbreak. For multi-sourcing and supplier diversification, the explanation was similar to that for *"alternative and backup suppliers."* For quick decision-making, both [Cons3] and [Manu4] implemented this practice in the early stages of the crisis and were satisfied with their results. In fact, the more time that passed without a decision, the less relevant the missing information would become. However, some practitioners do not view localization and reshoring as particularly helpful. Thanks to globalization, even local suppliers would have to rely on certain raw materials and products from overseas. It would take a lot of money and effort to build a completely independent regional supply network and it may prove not to have been worthwhile in the long run.

Finally, even if remaining solutions identified in the literature were either less interesting or more controversial from the practitioners' point of view, they were all graded with a mean and median above 2.5 over 5.

3.3 Comparison between SLR and empirical findings

In order to identify and explain the most relevant solutions, the findings of the SLR and the empirical component will now be analysed and compared to show that the majority of the solutions mentioned in the literature are consistent with the practitioners' opinion.

The most popular solutions, both in the literature and from the practitioners' point of view, for mitigating the impact of the Covid-19 crisis and managing supply chain crises are the following: *"Active and continuous risk management and collaborative risk management with suppliers and customers," "collaborative and rapid alignment solutions with SC partners,"*

"real-time monitoring of SC partners and information sharing," "planning scenario development and 'what-if' simulations," "quick decision making" and *"localization, regionalization and/or reshoring."* These solutions focus on three major aspects. The first is collaboration and frequent communication with all SC players. The success of each company in overcoming the crisis is dependent on the success of the SC as a whole, and it is therefore in their best interest to help each SC node as much as possible. This help can be manifested in actual collaborations and partnerships, or it can be limited to a high level of communication and information sharing. The second aspect is time. During major disruptions, time is an important factor. In fact, a quick reaction can mitigate the impact of the crisis significantly. However, decisions should be based on a firm foundation (facts and logical reasoning) and not only on velocity. The third aspect is risk management. The emphasis has been put on performing risk management in collaboration with supply chain partners and also on performing SC planning based on scenarios and "what-if" simulations analysis.

Some solutions were not cited as frequently by practitioners during interviews as they are in the literature, but questionnaire findings showed that they are still recognized as important to practitioners. Among these solutions are the following: *"alternative and backup suppliers," "multi-sourcing and supplier diversification"* and *"predictive and data-driven planning and forecasting systems."* Suppliers are a critical element of the SC. When the borders closed and supply from East Asia was temporarily suspended, suppliers worldwide faced many problems. Many companies' strategies were based solely on goods costs and transportation costs, and they did not consider there to be any risk associated with sourcing from these countries. However, such a risk manifested itself during the recent Covid-19 outbreak, as the transport cost for a container from China to Germany tripled [Tech3], the borders closed and goods prices increased drastically. This caused chaos in the market, as stated by [Cons3]. The problem with these solutions is the availability of reliable suppliers. It also takes a lot of time to trust new suppliers and build strong networks.

Other solutions, such as *"cyber-physical systems and automation," "flexible production processes and strategies," "adaptive warehouse capacity"* and *"flexible delivery routes, alternative and/or supplemental delivery options"* featured heavily in the literature sample but are not recognized to be as helpful by the interviewed practitioners. The SC practitioners are of the opinion that solutions linked directly to production are not so helpful during the Covid-19 crisis, since the manufacturing process was not the problem they were dealing with.

Regarding solutions identified during interviews, *"demand-driven and adaptive flow management"* is the one seen by practitioners as very helpful in managing the SC crisis, while the interest in *"non-deterministic planning systems"* and *"flexible manufacturing technologies"* is more controversial even if globally helpful.

From the point of view of the SCOR model, both the SLR and the interviews focused mainly on the *plan*, *source* and *enable* processes. In these categories, the solutions that were suggested in the literature and approved by the practitioners aimed at solving major problems caused by the Covid-19 outbreak. In fact, companies need to have plans in place to enable them to mitigate the impact of major disruptions or else they must be able to devise practical plans in a short time. Therefore, the most popular solutions are those that aim to increase visibility and flexibility across the SC. Communication between the SC players is also seen as an important point of discussion. In addition, companies should integrate their risk management practices, not only internally but also with their suppliers and customers. In contrast, solutions referring to *make* and *deliver* processes are viewed by the practitioners as less relevant or merely "nice to have." There are limited solutions for both of these categories in the literature and, according to our interview partners, they are not perceived as the main problem.

4. Discussion

4.1 Research contributions

Since the start of the Covid-19 pandemic, researchers have been publishing their studies on plenty of SC topics prompted by the pandemic. Although these recent works have made significant contributions to SC disciplines, two important knowledge gaps motivate this research.

First, a variety of studies have been conducted to propose measures, strategies or best practices as a response to the pandemic impacts. Most of them work on this subject by adopting simulation (Ivanov, 2020; Singh *et al.*, 2021) and secondary data analysis (Sharma *et al.*, 2020a, b), while others generally prefer to use empirical methods such as case study (Chowdhury *et al.*, 2020; Handfield *et al.*, 2020) and survey (Okorie *et al.*, 2020). To the best of our knowledge, there has been almost no systematic literature review of both the impacts on SCs and the implemented solutions in the context of Covid-19 provided by existing research. This means that there is no synthesized insight into understanding and formulating meaningful recommended actions in times of crisis.

Secondly, despite the fact that there has been a boom in the number of articles in the context of the Covid pandemic, more attention has been placed on identifying and assessing Covid-19 impacts and the resulting managerial insights (Al-Mansour and Al-Ajmi, 2020; Ivanov, 2020; Liu *et al.*, 2020; Queiroz *et al.*, 2020; Xu *et al.*, 2020). It is definitely important to discuss the implications of epidemic outbreaks, including challenges and opportunities. However, we argue that a gap exists between the research findings on conclusive viewpoints and the industrial efforts of SC practitioners. Although plenty of studies gather practitioners' opinions from companies, many proposed strategies are dedicated to one specific industry sector, such as manufacturing (Cai and Luo, 2020; Okorie *et al.*, 2020), food and beverage (Chowdhury *et al.*, 2020) or automobile and airline (Belhadi *et al.*, 2020). This hardly provides an overall structured guideline for SC practitioners to deal with the present situation.

Accordingly, in order to bridge these research gaps, the study systematically reviews recent literature covering the Covid-19 pandemic from an SC perspective. The findings and recommendations are synthesized and clustered with a structural framework based on the SCOR model. Scholars can take advantage of the comprehensive overview of available evidence on the topic of resilience solutions in the domain of supply chain risk management with impactful research. Moreover, to fill the gap in combining the academic literature and industrial vision on recommended solutions, this work employs an empirical approach to evaluate the relevance of the solutions synthesized from SLR in practice. As a result, SC practitioners can identify the most relevant solutions to manage impacts and recovery.

4.2 Practical implications

As already mentioned, the main contribution of this study lies in identifying and formulating the best countermeasures from both the academic and the industrial perspective to help SCs better respond to crises. Specifically, the recommendations for action are suggested for supply chain managers as follows, based on the practitioners' opinions and the relevant solutions from the SLR and the questionnaire. Figure 2 synthesizes the recommendations for companies to improve their capabilities to manage SC crisis. It structures recommendations according to the SCOR model processes. Then, the following paragraphs describe the recommendations with more details.

4.2.1 Plan. Integrate more agile practices, find a balance between leanness, agility and flexibility and invest more in risk prevention and mitigation strategies in the future. Actually, very few companies were prepared for the crisis. In general, companies had a lean approach before the Covid-19 outbreak and lacked flexibility and agility, because the costs of the latter two were not deemed justified by the top management prior to the crisis. The same problem is

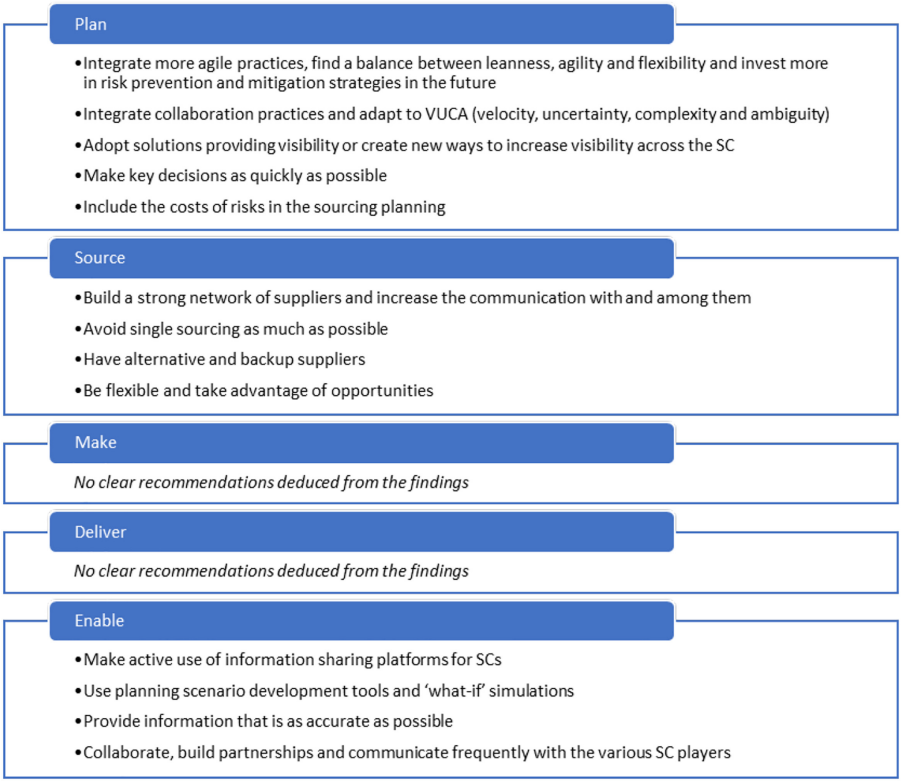

Figure 2.
Synthesis of the recommendations for companies to improve their capabilities to manage SC crisis, structured according to the SCOR model processes

always brought up when major disruptions occur, but it is quickly deferred or even ignored as soon as companies recover, stated [Tech3].

Integrate collaboration practices and adapt to VUCA (velocity, uncertainty, complexity and ambiguity). Actually, SC entities must accept crises and catastrophes as normal situations and increase their SC risk management significantly. Furthermore, they should adapt their decision-support systems to be able to consider disruptions as regular inputs, regardless of their size. Moreover, collaboration should be extended to all entities of an SC. Therefore, concrete tools allowing these entities to share vital information in order to increase visibility, ensure synchronization of material flows and align management of emergencies and use of critical resources must be developed and constantly used.

Adopt solutions providing visibility or create new ways to increase visibility across the SC. Companies faced a huge lack of visibility across the SC after the Covid-19 outbreak, which helped to exacerbate the already high uncertainty of their SC environment. Visibility can be increased with the aid of software or technologies such as Track and Trace. Nevertheless, the costs of these solutions can be high.

Make key decisions as quickly as possible. Over the course of the pandemic, companies found themselves in a position where they needed to make decisions quickly, despite lacking some necessary information. They all agreed on the importance of decision-making velocity in mitigating the impact of the crisis. A major problem, however, is the accuracy with which the information is assessed, as discarding some information in the decision-making process so that it can be performed on time could lead to inaccurate decisions, which could in turn lead

to an even worse situation. The ability to prioritize certain information and assess the risk of disregarding other information is crucial in this context. In addition, decision-making processes would be more effective if the solutions could enable companies to perform their decision-making quickly without disregarding available information.

Include the costs of risks in the sourcing planning. Companies not only have to consider part prices, but they must also include *total logistical costs* and risk prevention and mitigation costs (such as flexibility costs), when planning their supply strategy. In fact, companies are more flexible when they source locally, even though the costs might appear lower when sourcing globally. The risk of global sourcing is greater than that of local sourcing, as borders can close, transport costs may increase and there may be significant delays that affect production. Thus, it is important to take the cost of this risk into consideration in the planning process.

4.2.2 Source. Build a strong network of suppliers and increase the communication with and among them. This can be achieved only through trust and by maintaining good relationships with suppliers. Within this network, suppliers are perceived as collaborators and not as competitors. Nevertheless, a huge coordination effort is needed.

Avoid single sourcing as much as possible. Dependency on one supplier would have an immediate and drastic impact as soon as the supplier is affected by any major disruption. There are some components that can be provided only by a limited number of suppliers. If there is no possibility of dual- or multi-sourcing, consider *building up safety stocks of the critical materials and/or parts.*

Have alternative and backup suppliers. In the event of problems with the main suppliers, a backup supplier can temporarily substitute for them and ensure continuity. The problem with this solution is the uncertain availability and reliability of such suppliers. Given the risks of borders closing and increased transport costs, it is preferable to *have regional sourcing backup alternatives.* However, high costs and questionable reliability could be an obstacle.

Be flexible and take advantage of opportunities. SCs should become more opportunity-oriented and flexible enough to build agreements on the fly, which would potentially lead to exceptional results. Nevertheless, this implies changing the mindset of a great majority of SCs' governance which are based on long-term agreements, by considering paradigms such as Servitisation (Vendrell-Herrero *et al.*, 2017) or Hyperconnectivity (Montreuil, 2011). Ideally, SC entities should be able to mobilize any relevant partner on-demand, according to the current needs, potentially far from their usual business.

4.2.3 Enable. Make active use of information sharing platforms for SCs. The platforms are created for the benefit of all SC players. The more users there are, the better it is for the SC. Platforms for information sharing already exist, but very few SC players use them, possibly due to a lack of trust or familiarity or failure to understand the importance of the platforms. Companies therefore need to be made more aware of the importance of such platforms. They should invest in increasing employees' trust in them, use them to incentivize and train their employees to use them properly.

Use planning scenario development tools and "what-if" simulations. Many companies were not ready for the pandemic and lacked preparedness. Although it is hard to predict a global effect such as the one caused by Covid-19, it is still possible to reduce the complexity of the situation and facilitate the decision-making process based on potential crisis evolution scenarios. The accuracy of projected scenarios is a major obstacle, although it might be overcome by finding solutions that enable decision makers to consider the multitude of uncertainties while comparing decision-making alternatives.

Provide information that is as accurate as possible. While information sharing is an important aspect of increasing SC visibility, it serves its purpose only when the shared data is also accurate. In fact, it can sometimes occur that information is interpreted differently at different SC stages or nodes, which can lead to the adoption of conflicting measures and strategies. Thus, SC players should agree on a common method of checking the accuracy of

shared information. This can be done through a trusted third party who checks the legitimacy of the shared data or else potentially by software. [Cons3] emphasized that focusing on information sharing across the SC alone is not enough, as the accuracy of the shared information is sometimes inconsistent.

Collaborate, build partnerships and communicate frequently with the various SC players. Once you perceive the problems of other SC nodes as your own problems and you actively try to help solve them, the whole SC has a better chance of overcoming the crisis and in a shorter period of time. The problem is the high level of complexity that comes with considering the problems of the SC partners. Increased coordination is also needed. Furthermore, some SC players could be less involved and rely passively on help from other SC nodes.

4.3 Limitations

The limitations of this study, despite the extensive expertise of the interviewees, can be observed in the small number of interviews conducted ($N = 11$) and questionnaires completed ($N = 25$), as they are not enough to enable quantitative conclusions to be drawn. An extended survey should be conducted in the future to verify the reliability of the results of this limited sample. Furthermore, the industry practitioners were exclusively from German, French and Chinese companies. Thus, it is not yet possible to generalize the findings of this study to the rest of the world, as further research is needed. Finally, the Covid-19 crisis is ongoing. At the time of writing, companies are still focused on the daily survival of their business. More analysis will be needed when and if Covid-19 has been globally contained. After assessing the problems that companies have faced during the crisis, future research should focus on solving the problem of the insufficient accuracy of shared information across the SC as well as on the difficulty of building trust and communicating online with potential new customers. Developing newer and cheaper ways to increase SC visibility will also be an important issue in the future. In addition, the literature analysed for answering RQ1 does not contain enough information to deduce a comprehensive analysis of the impacts of the Covid-19 crisis structured for each industry sector. Therefore, additional business analysis would be required to produce such a comprehensive analysis.

5. Conclusions

Covid-19 has had a significant impact on companies' business activities, making smooth operations impossible and bringing production and SC processes to a sudden stop (Shen *et al.*, 2020). Thus, the need to formulate recommendations for action for companies to mitigate SC risks is greater than ever.

The methodology proposed in this study consists of a combination of an SLR structure around the SCOR model and semi-structured interviews with practitioners along with a questionnaire. This methodology covers the perspectives of both academic literature and real-world practice. First, solutions and strategies most suggested in the academic literature for mitigating the impact of the Covid-19 crisis and managing supply chain crises were identified. Secondly, identified solutions were discussed during interviews with SC practitioners from consultancy, technology and manufacturing companies in France and Germany. Thirdly, identified solutions were further validated by a questionnaire sent to interviewed practitioners as well as additional practitioners from Europe and Asia.

The impact of the Covid-19 outbreak on SCs has been such that the majority of companies have witnessed a decrease in cash flow and a drop in demand. Based on the adopted methodology, the most important solutions identified in the literature and confirmed by practitioners are "*active and continuous risk management and collaborative risk management with suppliers and customers,*" "*collaborative and rapid alignment solutions with SC partners,*" "*real-time monitoring of SC partners and information sharing, quick decision making,*"

"demand-driven and adaptive flow management," "alternative and backup suppliers," "planning scenario development and 'what-if' simulations," "multi-sourcing, supplier diversification," "quick decision-making," "localization, regionalization and/or reshoring," and "predictive and data-driven planning and forecasting systems."

From a SCOR model perspective, the findings showed a focus on the *plan, source* and *enable* categories. The recommendations for action regarding the *plan* process aim to increase visibility, ensure a certain degree of flexibility and take into account the time factor. Regarding the *source* process, the focus was on diversifying the supply alternatives and building a strong network of suppliers through trust and communication. As for the *enable* process, the suggested recommendations for action concentrate on collaborations, communication and information sharing across the SC. Most recommendations are associated with managing risks and improving risk-management practices.

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Corresponding author
Andreas Habl can be contacted at: andreas.habl@tum.de