Managing Supply Chains During the Covid-19 Pandemic

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Abstract

Purpose: The Covid-19 pandemic disrupted the lives of people and organizations, including supply chains (SC). Therefore, this study aims to explore concepts, methods, and tools for managing SC during the Covid-19 pandemic.

Methodology: The main research methods were systematic and grey literature reviews, supported by 5W2H and 20/80 methods.

Findings: Three research gaps were identified, supported by concepts, methods, and tools for managing SC during the Covid-19 pandemic with other related findings.

Limitations: Short research horizon because the Covid-19 pandemic started two years ago, which precluded us from performing full results verification.

Implications: This study updates and enriches supply chain management theories, especially regarding resiliency, disruption, and risk SC management. One of the fifteen research criteria was related to applied concepts, methods, and tools, which thus can be used by SC managers to implement them into practice.

Originality/Value: Compared to the literature review, a systematic literature review is performed according to a structured procedure. This comprehensive study will enable researchers/managers to understand the problem and prepare measures against the pandemic in SC.

Keywords: supply chain management, Covid-19, pandemic.

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Introduction

The outbreak of the Covid-19 pandemic in 2019 has changed the world economy. This pandemic is primarily a humanitarian crisis, but it also entails significant economic consequences, including the likelihood of a global economic crisis (Demirbaş *et al.*, 2020). Published global economics scenarios estimate total GDP loss (in billions of dollars) for 24 industrialized countries in terms of the total cost of the Covid-19 pandemic from a minimum of $283 billion to a large cost of $9.2 trillion (McKibbin and Fernando, 2020). The pandemic affects the economy in two areas: demand and supply. In the former, the best example is the changes in demand for crude oil (e.g. less demand for transport) and oil prices. However, the pandemic's impact on the supply side of the economy is more important, as it causes product shortages in many industries, including medical, pharmaceutical, food, automotive, and electronic (Bhaskar *et al.*, 2020; Chiffoleau and Dourian, 2020).

Numerous initiatives have been launched to meet the urgent needs and adapt to the pandemic conditions, both at government and industry levels. At the level of government or even international agreements, vaccine availability programs were launched. At the industry level, manufacturers accelerated the production process to meet the demand. Many of them changed their production profile to combat the impact of the pandemic (Bhaskar *et al.*, 2020). Despite the current initiatives and various efforts to mitigate the risks caused by the pandemic, much depends on the coordination, integration, and efficient management in SC (Fonseca and Azevedo, 2020; Francis, 2020). Proper SC operation in the conditions of a pandemic can significantly minimize its economic and even social effects.

Due to the importance of the pandemic, the phenomenon has become the subject of much research in the fields of medical, social, technical, and natural sciences (Almeida, 2021). Although each of them can be directly or indirectly referenced to supply chains due to their critical role in supply, production, distribution, and utilization, publications analyzing the impact of the Covid-19 pandemic on SC and methods of SC management during a pandemic deserve attention (Adobor, 2020; Agarwal *et al.*, 2020; Çetindaş and Öztürk, 2020; Kumar and Mishra, 2020; Chowdhury *et al.*, 2020). The last systematic literature review on supply chains in the Covid-19 pandemic situation known to us is the publication by Chowdhury *et al.* (2021), albeit its research horizon ends in 2020.

Therefore, in response to the recommendations of many authors regarding the need for further research, this study explores concepts, methods, and tools for managing SC during the Covid-19 pandemic with other related issues, and the article presents the

study results in a systematized and structured form. Therefore, the method of systematic literature review (SLR) is applied following other studies of this type. Nevertheless, this study's novelty in comparison to other studies is the adoption of 15 criteria of literature assessment based on the 5W2H method for the detailed final analysis of 196 articles, whose results are not treated equally but in accordance with the 20/80 method: group "A" of the most important results is selected from them, which constitutes only about 20% of all articles, but they represent about 80% of the results obtained under each of the 15 assessment criteria, additionally verified by results of grey literature research. The findings are cross-sectional and systemic, so we may propose recommendations for SC management. Therefore, the added value of this publication is a comprehensive picture of possible solutions for managing SC during and after the Covid-19 pandemic (detailed in Appendices 1 and 2).

The structure of the article is as follows. The theoretical part introduces the problem and explains its importance, thus constituting a theoretical basis, providing research context, identifying problem areas, and contributing to the state of the art. The methodological part describes the method of systematic literature review by detailing the stages of the research procedure, along with the methods and tools used at each of the stages. Next, the findings section presents the outcomes obtained from the SLR, especially those that may serve as specific concepts, methods, and tools for managing supply chains during and after the pandemic. Then, the discussion section includes opinions and critical comments on the findings. Finally, the conclusions section summarizes the main results of the study, presents its limitations, and recommends future research.

Theoretical Background

The scientific discipline that forms the basis for the planned SLR is supply chain management (SCM). Multiple definitions of the SCM and related terms can be found in the literature, as it is described as, for instance:

- the act consisting in delivering goods with related information on the route from the place of shipment to the place of destination in accordance with the terms of delivery (Christopher, 2016);
- the activities involved in the production of goods or providing services, from raw materials to delivery to the consumer, aimed at making the entire process effective in terms of costs, using resources, while meeting the requirements of those involved (Golwelkar, 2020);

- a series of procurement and supplies management activities coordinated by an organization (Fonseca and Azevedo, 2020);
- an umbrella construct incorporating supplier and sourcing in a network, as well as managing demand, value chain, and entire logistics (Croom *et al.*, 2000).

Considering the above definitions, this study understood supply chain management (SCM) as a system of stakeholders involved in moving resources from their points of acquisition to their destinations in accordance with the agreed terms of delivery.

The structure of the research areas covered by the concept of SCM was multifaceted and most frequently divided by supply chain management activities. According to the Global Supply Chain Forum, the core of SCM is made by the eight key processes (Cooper *et al.*, 1997):

- managing relations with customers,
- managing customer service,
- managing demand,
- order fulfillment,
- managing manufacturing flows,
- procurement,
- developing and commercializing the product,
- managing returns.

The wide range of issues covered by the above SCM concepts has allowed the development of more specific research directions: Supply Chain Risk Management (SCRM; Manuj and Mentzer, 2008), Agile Supply Chain (ASC; Christopher, 2000), Sustainable Supply Chain (SSC; Seuring and Müller, 2008), and Resilient Supply Chain (RSP; Christopher and Peck, 2004). All the mentioned SCM research directions aim at answering the fundamental question: How can supply chains function effectively under changing environments and the occurrence of various events, disruptions, and threats, including events such as terrorist attacks, wars, or pandemics (Ishida, 2020)?

The above concepts scrutinize the issues of managing SC during a pandemic by:

- the identification of disruptions and risks of threats in the SC environment that have or may have an impact on SC (Veselovská, 2020),
- risk management in supply chains (Althaf and Babbitt, 2020),
- agile supply chains (Chen *et al.*, 2020),
- value creation in the supply chain (Dilyard *et al.*, 2020),

- sustainable supply chains (Seuring, 2013),
- creating supply chain resilience (Adobor, 2020).

Although the above concepts do include a lot of propositions for managing supply chains to stay resilient, agile, or sustainable under unfavored conditions – including the Covid-19 pandemic – they also call for further study of this area due to the domination of disruptive conditions in the economy. Therefore, we are motivated to follow these calls with the aim to update and enrich the SCM theory related to the Covid-19 pandemic.

Methods and Materials

The SLR should follow a robust, well-defined research framework that allows for repetition in the future (Piper, 2013). The review must include not only articles but also books, reports, and other materials relevant to the studied topic. In this article, the review will have more than one outcome (a three-in-one review), as it will simultaneously be (a) an evaluative review, (b) a syncretizing review, and (c) a gap review. Thus, we needed to first the state of the art should be assessed first to discover the literature gaps that require a transparent methodological approach (including stratified selection).

The research framework presented in Figure 1 resulted from merging a PRISMA diagram (2020) with the approach of Denyer and Tranfield (2009). The PRISMA diagram was modified in the last stage of preparing final results through grey literature analysis to validate the SLR results or supplement them and by the 5H2W method for the selection of 15 review criteria, supported by 20/80 method to identify class A of the most important findings. In all stages, we used MS Excel and Mendeley Desktop software.

Because the pre-search stage was already performed, the next one began by searching the literature. The following keywords and conditions to search literature databases were used:

- "supply chain management" or "scm" or "managing supply chain" in the abstract;
- "Covid-19" or "coronavirus" or "2019-ncov" or "sars-cov-2" or "cov-19" or "pandemic" in the abstract;
- published from 2020 to 2022 (including possible volumes and issues approved for 2022 but not officially published);
- accepting "in press" articles and articles;
- English-language sources;

Figure 1. Systematic literature search and review procedure
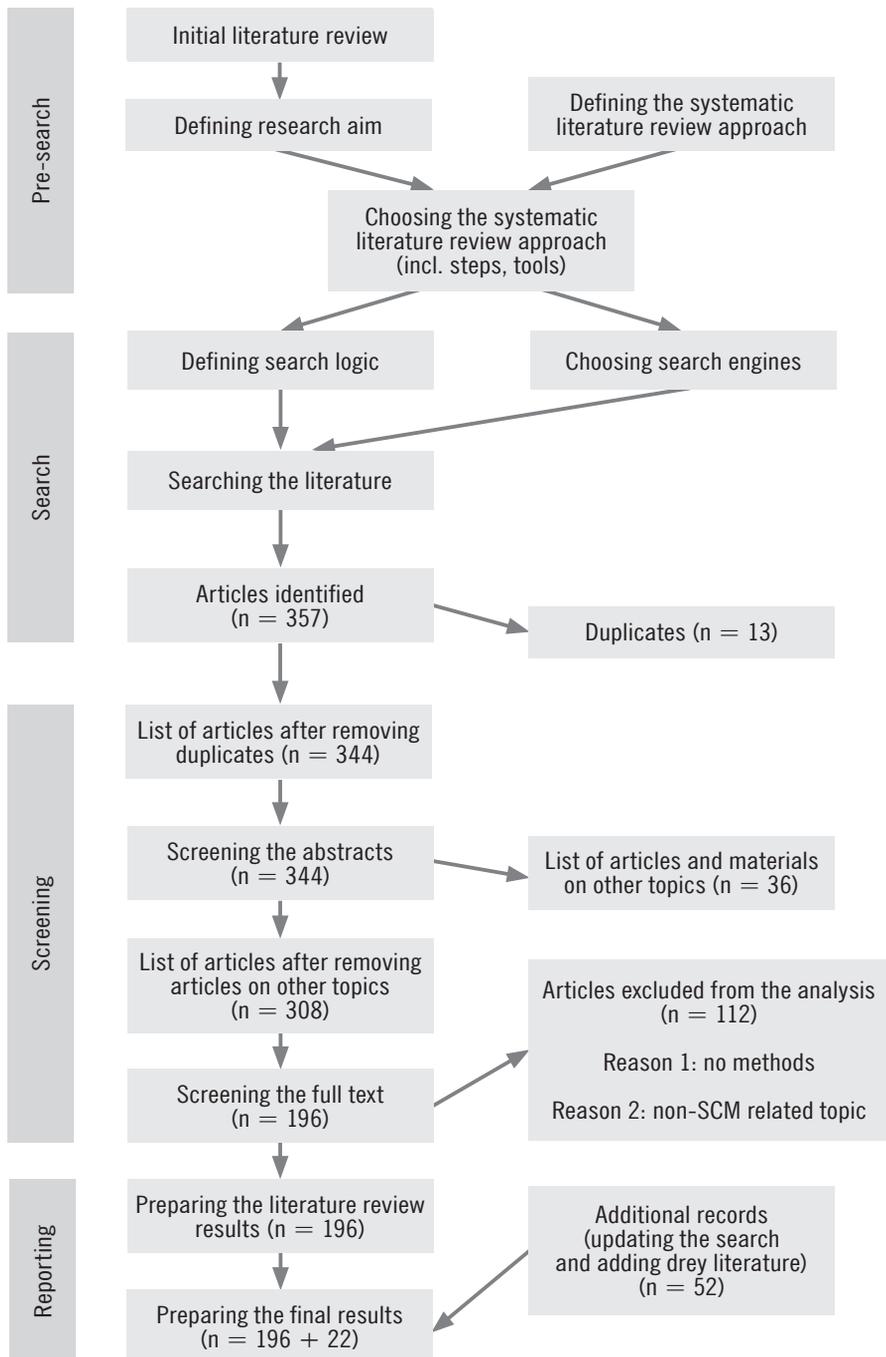
Source: own elaboration based on the PRISMA diagram (2020), Denyer and Tranfield (2009).

- only full-text records (with access to engines subscribed by the academic institution);
- PDF files only.

First, the *Central European Management Journal* database was explored, which revealed two articles on Covid-19 but with no relation to supply and four articles on supply but unrelated to this pandemic. The same search was done on nine academic search engines: DOAJ, EBSCOhost, Emerald, Google Scholar, JSTOR, ScienceDirect, Scopus, Springer, Taylor and Francis. A total of 357 articles were found after the review. After removing duplicates, the remaining 344 articles (titles and abstracts) were checked for their coherence with the topic of the research. After excluding 36 articles, 308 articles were identified for the next round of research, namely text analysis.

After text analysis and consultations between research members, 196 articles were qualified for the main study. The reasons for excluding individual articles were most often that SCM was only briefly mentioned or was only one of the aspects of the impact of the pandemic, and it was not more extensively described further in the article, namely only in the abstract and the introduction in a few sentences. However, the literature review did not omit articles that dealt with SCM directly but presented them as one part constituting at least one subsection.

A crucial part of the research framework was to identify and select the criteria for literature analysis. In articles using the SLR method, the identification and selection of criteria for evaluating the researched object usually happens based on the subjective researcher's judgment. To minimize this unwelcome bias effect and increase the objectivity of the assessment – also to avoid omitting significant results – we implemented the 5W2H approach. The 5W2H method is widely used in economics and management (Bies, 2019; Siwiec and Pacana, 2020). According to the literature above, this questioning technique contains the following elements:

- What is the problem?
- Why did this problem occur?
- Where did the problem occur?
- When did the problem occur?
- How did the problem occur?
- How important is it and what is the scope of the problem?

This study applied the above questions to identify 15 research criteria for the purpose of SLR in the form presented in Table 1.

Table 1. The application of the 5W2H approach to identify 15 research criteria for SLR

5W2H element	Question	15 Criteria
WHAT	What problem or area should be analyzed?	Main research problem/topic/aim
	What SC area is critical to be addressed by strategies and concepts within the pandemic? In what part of SC did the problem occur?	SC process/area
	What commodity or resource is the main focus in the analyzed supply chain?	Flow object
	What strategies and concepts should be implemented?	Theoretical concepts, methods, and tools
WHEN	When the new concepts/methods/tools should be implemented (e.g. according to phases of the pandemic, but also weak signals of other disruptions)	Conditions of implementation of concepts/ methods/tools
WHERE	Where (in the geographical sense) was the problem observed?	Country
	Where did the outcomes of the pandemic occur and if they need to be addressed in future actions?	Industry
	In what part of the supply chain should they be implemented? In what sector should they be implemented?	Application area (also sector)
WHY	Why is there a need to identify the methods and tools for managing supply chains during a pandemic? Why were the methods and tools necessary to be applied?	Disruption factors
WHO	Who should implement new actions within logistics strategies and concepts to minimize the impact of the pandemic on supply chains? Who will benefit from the implemented solutions, concepts, or tools?	Beneficiaries/ Receivers
HOW IMPORTANT, HOW MUCH	What will the financial and non-financial impact of implementing the concept in logistics be on SC?	Theoretical or applied concepts in SC
	What will the financial and non-financial impact of implementing the concept be for the further environment?	Theoretical or applied concepts in SC environment
HOW	How were the impacts of the pandemic identified?	Main research method
	How were the impacts of the pandemic measured? How were the effects of SC concepts measured/validated/ diagnosed?	Data analysis method
	In what way, according to what plan should they be implemented?	Applied concepts, methods, and tools in practice

Source: own elaboration based on Bies (2019), Pinheiro *et al.* (2016), Siwiec and Pacana (2020).

These 15 criteria were used to examine in detail each of the 196 articles, starting from the main research problem and ending with concepts, methods, and tools applied in practice.

The 5W2H method is supplemented by the operational spreadsheet using 20/80 analysis (Nie, 2011). For every criterion of 15 criteria, the occurrence of identified keywords was counted, which enabled us in turn to identify the most important group of keywords in the analyzed literature, namely class A (Kheybari *et al.*, 2019). We had to calculate the cumulated number of keywords in the sum of all keywords in relation to the cumulated frequency of keyword occurrences in all the analyzed articles. One keyword could occur in multiple articles, and one article could be assigned to more than one keyword (n:n relation), which meant the total number of keywords could be higher than the number of articles. All the results are presented in the next section and detailed in Appendices 1 and 2.

The systematic literature review was supplemented by grey literature sources in order to strengthen, confirm, and verify the SLR findings (Paez, 2017). The sources were obtained from well-known and reliable business data search engines: Statista and EMIS. The search logic was more straightforward than in SLR: exact keywords were used but as single words in the search process or in many combinations. Then, all the results were refined to 22 sources included in the final content review.

Findings

Systematic Literature Review Results

While browsing full texts by keywords we reviewed 308 articles, of which 112 we deemed unfit for the requirements specified for this study. The excluded articles were mainly related to personal protection equipment (PPE) and production technology, rather than supply chain operations and management. As the 196 articles analyzed were incomplete, not every one of them could have values assigned to all 15 criteria (see Figure 2 and Table 1). Nevertheless, for all the 196 (100%) analyzed articles, we could identify the main research problem, the SC process described, and the leading research method. For more than 90% of the articles, we were able to extract the disruptive factor, the proposed theoretical concepts with their effects, and the main beneficiaries (see Appendices 1 and 2 for more details). However, for the three criteria, only a 20% share was recorded, thus discovering three main research/literature gaps that should be covered by this or further research (Figure 2). One of them was a methodological gap related to a weakness of data analysis methods, and two of them were explicitly connected with

supply chains: (a) concepts, methods, and tools applied to manage supply chains during the Covid-19 pandemic; (b) application conditions for the conceptions, methods, and tools. This meant that study results and literature contents on how SC are managed during a pandemic in these three aspects are neglected, thus requiring further research.

Figure 2. Share of 15 criteria identified in the analyzed literature
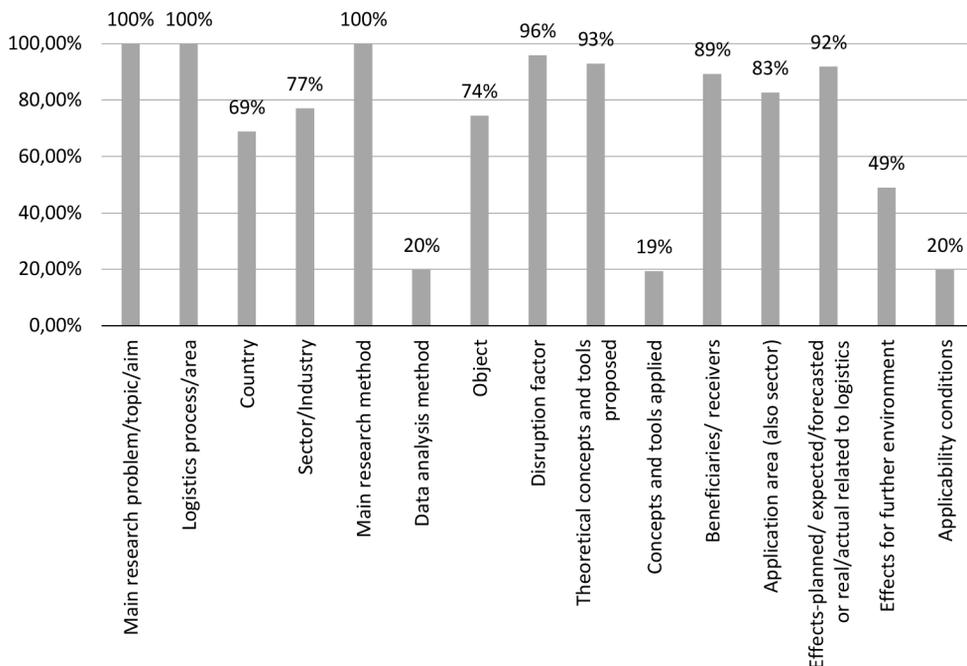
Source: own elaboration.

Figure 2 contains only general data. For example, 100% of the articles showed information about research problems, but it was unclear what kind of problems they are. With that in mind, an in-depth analysis of articles according to the 15 criteria was performed to identify what problems, industries, disruption factors, conceptions, methods, tools, and conditions were included in the analyzed articles, together with their frequency of occurrence.

The first criterion was the main research problem addressed in each article. In the analysis, 345 different problems were identified (generally named as keywords). The 20/80 method allowed for specifying a group of 78 keywords representing 23% of the sum of all 345 keywords (having three occurrences or more, see Appendix 2). This 23% quantitative cumulant corresponds to as much as 73% of the frequency cumulant

of all the 1254 keywords (see Appendix 2). For example, the keyword "chain" occurred 121 times, "supply" – 117 times, and Covid-19 – 90 times. This meant that the problem of the impact of the Covid-19 pandemic on SCM was very well represented at the full-text analysis stage.

Although supply chains are most often global, some exist and operate locally (e.g. in the food industry). Therefore, we should scrutinize the structure of the countries (second criterion) whose situation was described. As many as 252 research indications for 70 countries were identified as some of the articles did not indicate any country, and some of them focused on several countries. The highest percentage was found for the USA: 13.10% of all the 252 identified cases. A similar share (10.32%) was recorded for China and the global economy in general. Many studies focused on Southeast Asia, not only China but also India (7.94%), Bangladesh, and Indonesia (3.17%). Relatively few studies were devoted to European countries – six articles, each analyzing the situation in Italy and Germany – which is in fact a research gap that should be filled by future research. Although many supply chains contained elements located in Asia, the highly developed countries were the main consumers of final goods, and they suffered the most from the shortages in the supply of products in individual sectors. Thus, another research gap emerged at this analysis stage: the lack of studies for some geographical areas, particularly Europe and Australia.

The 20/80 analysis supported the identification of the industries that had to respond first to disruptions (third criterion). The top industry was obviously healthcare (16.5% of all 206 industries listed), and the food sector (13.11%), but they were mostly described for Asian countries or the USA. As with the other criteria, there was a significant number of publications on the overall effects on the world economy in this regard (12.14%, "all industries"). Other sectors flagged as occurring more frequently in the analysis included medicine (approx. 7.3%), agriculture (approx. 6.8%), logistics (3.9%), transport (3.4%), automotive (2.4%), e-commerce (2%), manufacturing (2%), and retail (2%). In some, the pandemic engendered positive changes (e.g. transport, e-commerce, medical, and pharmaceutical sectors), while in others, it brought negative changes (especially production and retail). The effects of the pandemic on the flow of resources in supply chains first appeared in the industries supplying essential products, therefore they were described in the literature promptly. The remaining ones concerned the impacts resulting from changes in consumer behavior (e.g. in online shopping). At this stage of the analysis, a research gap emerged in the absence of studies on the response of some industries to the pandemic (e.g. petrochemicals, tourism, hospitality, construction, and luxury goods).

The SC or logistics processes and areas described in the analyzed literature (fourth criterion) were mainly related to SCM: over 62.4% of all areas mentioned 226 times in the analyzed articles. Importantly and in line with the current development of logistics, information logistics was the critical factor (3.98%) and so were stockpiling (3.98%) as well as transportation (3.98%) and distribution (3.54%). Manufacturing was analyzed in seven articles, so 3.1% of the total. Therefore, the main SC areas that emerged as the most vulnerable to disruption were listed as areas worth changing or considering in the design of new SCM strategies (Mchopa *et al.*, 2020; Stentoft and Mikkelsen, 2020; Zhu *et al.*, 2020).

All the analyzed literature items were based on some research method or methods (fifth criterion). Reviews of literature and other sources were overwhelmingly dominant (50% of all the identified methods including literature review in 31.78%), review of other sources (11.02%), systematic literature review (3.39%), report analysis (2.54%), content analysis (0.85%), and grey literature review (0.42%). They were prepared since no empirical data were observed in the first wave of the pandemic and only some fragmented information made it possible to initially assess the scope of changes in supply chain management made ad hoc. Gathering those dispersed data could allow us to catch the fresh effect of supply chain changes because of the pandemic (Friday *et al.*, 2021). Nevertheless, experiences from previous pandemics (non-Covid-19) were assessed as improper since the characteristics, duration, geographical coverage, and scope of changes significantly differed between the Covid-19 pandemic and previous ones (Farooq *et al.*, 2021; Kumar *et al.*, 2020). Then, the previous methods could not be proper for recommending the SCM during the Covid-19 pandemic (Bolislis et al., 2020; Marzantowicz et al., 2020). Therefore, case studies were the prevalent approaches for obtaining new data about the pandemic and SCM (30 articles, 12.71% of all used methods) and catching the specifics of SCM changes (Chowdhury *et al.*, 2020; Gereffi, 2020; Handfield *et al.*, 2020).

Although data analysis methods (sixth criterion) were not widely observed in the analyzed literature, the most popular methods for examining the impacts of the pandemic in SCM were multiple linear regression analysis (MLRA; 10.87%), structural equation modeling (SEM; 10.87%), factor analysis (6.53%), followed by anyLogistix simulation software, cluster analysis, decision-making trial and evaluation laboratory (DEMATEL), and principal component analysis (PCA), which accounted for 4.35% each.

Interestingly, the number of flow objects (seventh criterion) identified by text analysis was twice more than the number of 196 articles analyzed. The flow object or objects were usually strongly related to the sector identified by the third criterion. In this

category, numerous studies were observed that did not focus on specific objects ("all products" with 40 observations, 20.62%). As mentioned above, adequate to the sectors considered in the analyzed literature, of prime interest were food (also meat, a total of 17.1%) and healthcare-related goods (a total of 17.6%) including PPE (6.7%) and vaccines (2.6%; McKenzie, 2020). Thus, the previously mentioned flow objects could be categorized as basic necessities in times of disruption, as they were needed for combating the symptoms of the crisis caused by this event (Li and Chiu, 2020; Paul and Chowdhury, 2020; Bhardwaj *et al.*, 2021; Ma *et al.*, 2020).

The reviewed articles usually mentioned the Covid-19 pandemic as the most important disruption factor (eighth criterion), which was obvious and resulted from the literature search process. However, the analyzed articles did not describe the specific disruptions resulting from the pandemic but rather the overall impact. The direct impacts mentioned in the analyzed literature were supply shocks (1.6%), demand shocks (3.13%), stock shortages (1.6%), lockdown (1.6%), and other crises (1.17%). Of all disruption factors, 0.78% of occurrences were identified as the lack of resilience or recovery plans in the supply chain. The remaining mentions identified in the review were different kinds of disruptions (very fragmented) taming the flows in supply chains. According to Gupta (2020), the lack of defining the exact disruption makes it difficult to tackle its effects on SCM and find the right solutions to reduce its negative effects on all SC stakeholders. There is also a need for adjusting the solution to the disruption and create the proper scenarios to be prepared for many possible situations (Farias *et al.*, 2020; Perdana *et al.*, 2020; Sinha *et al.*, 2020; Wang *et al.*, 2020; Zhu and Krikke, 2020).

A critical issue and outcome from the systematic literature review was the group of theoretical concepts, methods, and tools (ninth criterion) recommended for implementation in supply chains in case of events and disruptions caused by Covid-19 and the like. It was one of the broadest criteria in the entire analysis (a total of 231 different propositions). In this broad group, 56 were identified as significant (indicated twice or more) as a result of the 20/80 analysis. The most popular concepts that were prominent in the review and addressed the disruptions were resilient supply chains (4.83% of all indications of any keyword), risk management (3.86%), blockchain (2.66%), IoT (Internet of Things) and increasing inventories (each 2.42%, see Figure 3). As the first two of them were relatively well known, the concepts referring to blockchain and IoT emerged as quite new, so there is no wonder that 60% of organizations plan to invest in SC digitization, usually, in the form of automation, robotics, artificial intelligence, augmented reality, and cybersecurity. The other concepts categorized as necessary to implement in the supply chains during the pandemic were mainly related to increasing supply chain resilience and agility, flexibility, and quick response to a disruptive

factor. Therefore, supply sources should be diversified, and SC should be shortened, integrated, digitized, and stabilized. Furthermore, information should be shared with SC members, staff should be trained to solve complex problems, and innovative technologies implemented as soon as possible, including e-platforms, cloud computing, real-time data monitoring, and robotics. Business analytics (e.g. predictive models, business intelligence, and artificial intelligence) should be robust and reliable. Significant importance should be assigned to publications indicating the vital role of the IoT concept in combating the effects of the Covid-19 pandemic. Selected articles focused on the role of industry 4.0 in that process. The strategies for production could be changed towards reshoring, collaboration, additive manufacturing, and core technologies like 3D printing. It is essential to keep the SC efficient when preparing contingency or business continuity plans, anticipating different unexpected changes or types of events and scenarios for dealing with obstacles in SC operations and returning to stability before the event. All the concepts, methods, and tools were described in more detail in Appendices 1 and 2.

Figure 3. The map of keywords for the nineth criterion "theoretical concepts, methods, and tools proposed to manage SC during Covid-19"

Source: own elaboration.

As mentioned above, only about 20% of the analyzed articles were based on primary data. Some conceptions, methods, and tools were applied in practice (tenth criterion), but it was only 23 concepts mentioned 32 times. In the 20/80 analysis, only methods mentioned two or more times were indicated as significant – adapting SC to restrictions (e.g. social distancing), logistics rerouting, exchanging information, IoT, reshoring and stockpiling, and accounting – which stood for a total of 46.88% of all the applied methods. Nevertheless, there appeared a substantial gap in primary data analysis.

The sectors in which the concepts were applied (eleventh criterion) corresponded closely to the industries listed previously in the third criterion. Those were mainly sectors involved in supplying companies and residents with the materials and products, which were basic necessities in times of the Covid-19 pandemic, mostly food (7.33%) and medical or healthcare products industries (18.84%); response to these disruptions had to be quick. Therefore, the application areas addressed by theoretical or applied concepts, methods, and tools previously mentioned fall mainly into the food, medical, and SC management sectors (23.04%). In the first one, the food industry and agriculture (sometimes combined as agri-food industry) accounted to 14.1% share. In the second, the main area was healthcare (12.04%). The third one can be divided into two subcategories:

- general supply chain management: SCM, global supply chains, logistics, SC in various industries, manufacturing (planning and execution), SC risk management, and transportation;
- sector-specific supply chain management: food SC, healthcare SC, humanitarian SC, and pharmaceutical SC.

Considering all the abovementioned findings, the question arose: Who benefits from implementing SCM concepts, methods, and tools during the Covid-19 pandemic (twelfth criterion)? There were 49 different recipients of the benefits mentioned 208 times in total. The most significant groups in this regard are stakeholders (28.85%) or decision-makers (SC managers 12.02%), while governments together with policymakers constitute 9.62%. The remaining beneficiaries are members of SC, such as producers (11.54%), suppliers, (5.77%), retailers (4.33%), distributors (2.4%), and very surprising – only 1.92% of the total occurrences mentioned logistics operators. Interestingly, there were very few mentions of healthcare-related or pharmaceutical-related SC as the recipients of solutions, which were the most frequently cited industries affected by the Covid-19 pandemic.

The next very important outcome of the systematic literature review was the identification of the results in the abovementioned theoretical or applied conceptions, methods,

and tools of managing SC during the Covid-19 pandemic (thirteenth criterion). The results showed (see Appendix 2) that one solution dominates the findings, namely the achievement of a higher level of SC resilience. It was mentioned in 34 articles as the most suitable concept for pandemic SCM (17.8%). The other concepts qualified in the analysis as the most significant were the ability to mitigate risk (5.76%) and severity of the disruption, lowering costs, increasing security, efficiency, and reliability of SC, as well as traceability, visibility, and product availability (2–3%). Besides, on the operational level, decision-makers were to implement solutions for enhancing the service offer and make decisions to relocate facilities and reduce lead times. Among the less significant outcomes of the review, the higher level of agility, stability, flexibility, and competitiveness of SC were cited as results of managing SC during the Covid-19 pandemic as well as early intervention (connected to the ability to identify weak signals).

Implementing the supply chain management concepts mentioned before should also cause positive results in SC environment (fourteenth criterion), especially in the area of:

- politics: better decisions of policymakers (7.35%);
- healthcare: healthcare sovereignty, increasing healthcare capacity and protection of lives (7.35%);
- business: business recovery, better business position, better economic forecasting, business sustainability, faster time-to-market (5.88%);
- other issues: food safety and security as well as food importance awareness, survivability after the pandemic, better services for society, and social sustainability.

To implement the concepts in SC, some conditions were needed to increase the chances for implementation success (fifteenth criterion). Those presented in the literature can be divided into internal and external determinants for SC. The internal ones identified in the analysis were the cooperation of SC stakeholders, sharing information, digitization, and monitoring, which together with one external one – namely smart public policy – stood for the five main determinants (22.73% in total) of the successful SC management during Covid-19. Although they were only five of the all twenty-two conditions identified in the literature, they were mentioned most often, reaching the frequency about 57% of all occurrences (see Appendix 2).

Verification of SLR Research Findings: Grey Literature Review Results

Research done by Fortune 1000 confirms the SLR data reporting that China was the country with the highest level of supply chain risk exposure as well as the country that was most affected by supply disruptions, followed by Thailand, Hong Kong, and

Singapore (Grubel-Lloyd Index). At the beginning of 2020, at least 51,000 companies around the world had a minimum of one direct or Tier-1 supplier in the impacted region, and over 5 million companies – a minimum one Tier-2 supplier (Business impact of the coronavirus, 2020; Global trade impact of the coronavirus (Covid-19) epidemic, 2020). Not only suppliers suffered from overstocking during the pandemic. On the opposite side of the chain, retailers struggled with demand shocks during the lockdown. In 2020, almost two-thirds of retailers calibrated their supply chain to the development of e-commerce, 28% experienced shortages and out-of-stocks, 28% had to find other supply sources than current ones, and 56% had to renegotiate contracts (Supply chain changes faced by retailers due to the Covid-19 pandemic worldwide in 2020, 2020).

The impact of Covid-19 on supply chain operations and strategies was indisputable, because it was confirmed by 42.1% of the respondents (n=300) in 2020 (Will you change your shipping and supply chain strategies because of your experience with the coronavirus pandemic?, 2021). This impact was multidimensional, but 32% of business leaders stated that demand volatility is the most significant condition in this field, which confirms the SLR finding about different kinds of shocks experienced by SC during the pandemic. The other significant causes of SC vulnerability were mainly related to supply: single sourcing (28%) and just-in-time (27%) do not seem to be good solutions in the time of disruptions (Which conditions make businesses most vulnerable to value chain disruptions, including Covid-19?, 2020). Those results supplement the SLR findings, which were not detailed in the specific supply changes area due to SC redesign. What is more, approx. 42% of the respondents declared that they considered changing SC strategies after the end of the pandemic (Will you change your shipping and supply chain strategies because of your experience with the coronavirus pandemic?, 2021). 55% of the respondents (users of logistics and freight transport services) in another study said that they prepared a risk management plan to avoid or minimize the adverse effects of a pandemic outbreak (Do you have any risk management plan to handle the coronavirus outbreak? 2020). This confirms that some theoretical strategies identified in the SLR could be used for empirical verification by implementation in practice.

As outlined above, the observed concentration of risk was not only geographic but also sectoral and depended on the place in SC (the classical, well-known, and expected bullwhip effect appeared). The only universal solution was to create a business continuity plan (Goenka and Shetty, 2020). A comprehensive analysis in this regard was made by Gaul and Kumar (2020).

The grey literature analysis confirmed the SLR results about sectoral disruption effects. Next to healthcare, the food industry experienced the most significant obstacles, especially in cold chain area, also because of the short time in the dates of consumption of vegetables, fruit, dairy products, or meat (Top three challenges faced by cold chain businesses as a result of Covid-19 in 2020, by business type, 2020). For food production, the most significant changes were managing the fear of contracting Covid-19 (40.5%) and supply chain disruptions (56.5%).

Even 68% of all organizations believe that the pandemic forced or encouraged them to change their business models and strategies. One main finding appears from the previous content: resilience and risk management are the main elements of SCM in the Covid-19 crisis. The course of global supply chain shocks (demand shocks, supply shocks, and capacity shocks) suggested that one consequence of this pandemic could be an acceleration in offshoring, reshoring or nearshoring, especially in some industries that were highly disrupted by the pandemic like international trade and shipping (The effects of Covid-19 on trade and global supply chains, 2020).

How did the supply chains adapt to the changes? Almost 50% of the surveyed respondents from various sectors admitted that their contingency plans were sufficient to address the challenges that arose during the pandemic (Was your plan sufficient to cover the supply chain issues that arose from Covid-19?, 2020). However, 37% stated that they experienced partial SC shutdown and significant delays, while 36% said that those delays were incidental and lasted a few days. Finally, 8% had to deal with a complete shutdown of SC (How adaptable have your shipping and supply chain been during the outbreak?, 2020). Thus, the only solution to survive the pandemic and the post-pandemic time was to create strategies or plans to mitigate risks and enable recovery. Only 6.3% of SC members will not change anything in their SC operations (see Figure 4).

These propositions depended on the sector and products themselves. When a product portfolio was complex (Alicke *et al.*, 2020), there was a possible shift towards outsourcing and building complex global production networks with localized supply chains. Nevertheless, supplier diversification and supplier risk management strategies occurred in all SC cases (Kaufmann *et al.*, 2021). Those findings agreed with the SLR results, especially when referring to risk mitigation. Resilience and risk management were the two concepts mentioned in the SLR most often. Nearly 62% of surveyed supply chain members stated that pandemic-related crisis highlighted resilience as a key priority after the pandemic. Resilience should be built in seven areas: contingency planning, location, diversification, sustainability, agility, end-to-end transparency,

and visibility. Only 4% of the 1000 surveyed organizations declared their potential in all those areas. The most significant problems in building resiliency were observed in visibility and end-to-end SC monitoring (*Fast forward…*, 2020; Vita *et al.*, 2020).

Figure 4. Proposed concepts, methods, and tools for Covid-19 post-pandemic time
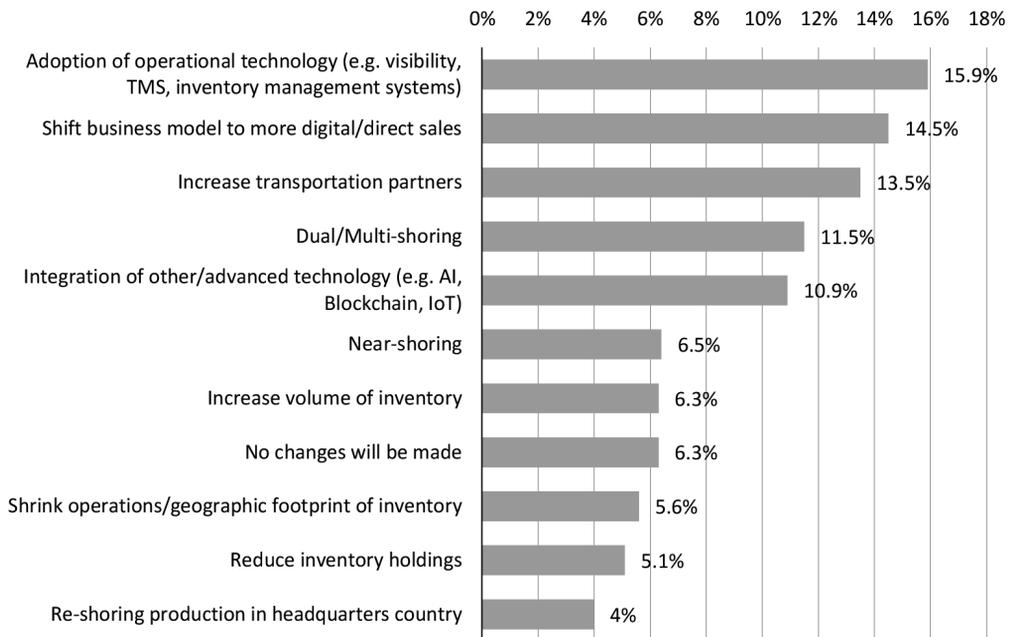
Note: the survey was worldwide from September to December 2020 with 1206 respondents who were SC industry professionals.
Source: Which of the following are you likely to implement in order to create more resilience within your supply chains?, 2020.

According to Kilpatrick and Barter, (2020), a new supply chain model – resistant to disruption and providing resilience – should be the digital supply network (instead of traditional SC). In 2020, the pandemic was the biggest complication and barrier for SC in building resilience (56%), followed by budget limitations (36%), the market (32%), and legal regulations (30%). In March 2020, scholars recommended building a resilient supply chain by (Bohn, 2020; Building a More Resilient ICT Supply Chain, 2020; Dohrmann *et al.*, 2020):

- proactive risk classification,
- mapping the supply chain in detail,
- broadening the supplier network and local and regional footprint,
- enhanced business analytics,

- planning buffers in the inventory,
- planning alternatives in logistics and transportation (scenario planning).

The alternative for delivering added value to the SCM-related areas in building resilience is providing a new service, risk-management-as-a-service (Bohn, 2020). This viewpoint was interesting and supplements the SLR results by indicating new directions for the development of SC services because it was not addressed in the analyzed literature.

On the other hand, business reports presented the shortcomings of implementing resilience in supply chains. In a survey by Capgemini (*Fast forward…*, 2020), 69% of supply chain members experienced barriers in supply planning (e.g. because of lack of adequate information or delays in receiving it) and demand planning as it was changing very fast. Delayed shipments and parts shortages were experienced by almost three-fourths of respondents. Rapid scaling of production and its reconfiguration was a problem for almost 70% of companies, and the same was true for finished product inventory balances in the distribution channel. The rapid transition to online sales channels was a problem for 71% of the respondents. End-to-end monitoring of the processes carried out in the chain, for the reasons mentioned, was very difficult and even impossible for 72% of companies (*Fast forward…*, 2020). Thus, a crucial component of the new SC strategies is location. The above report states that 83% of organizations consider enabling their structures to flexibly switch between make-or-buy through subcontracting.

One of the concepts in the SLR for managing the effects of the Covid-19 crisis in SC was to abandon just-in-time deliveries. Before Covid-19 (December 2019), 39% of respondents stated that they would be using this approach, whereas in March 2020 it was only 29% (*Fast forward…*, 2020). The previous findings also confirm that most of the surveyed organizations plan to widen the current data sharing in the SC (McKenzie, 2020). The Covid-19 pandemic accelerated the decisions to invest in technology and digitization (see Figure 5), with 60% of organizations planning to invest in digitization, usually automation, robotics, IoT, artificial intelligence, augmented reality, and cybersecurity.

The SLR did not properly address the use of a control tower since this solution was mentioned only in very few articles. Using the control tower in the supply chain is highly recommended, as is having crisis teams. The suppliers were identified as the most critical part of the supply chains that should be monitored and managed. The situation of SC should be monitored and recovery plans should be made separately for different regions in the same company (scenario-based modeling). Other solutions in this regard can be supply chain mapping, understanding of "black swan" events, and their effects (Aylor *et al.*, 2020; Covid-19 Supply Chain System, 2020). Only about 57% of organi-

zations had their control tower (20% planned to invest in one), and only 27% had a control tower enabling end-to-end SC monitoring (*Fast forward…*, 2020).

Figure 5. Adoption plans for managing SC during the Covid-19 pandemic in the area of digitization
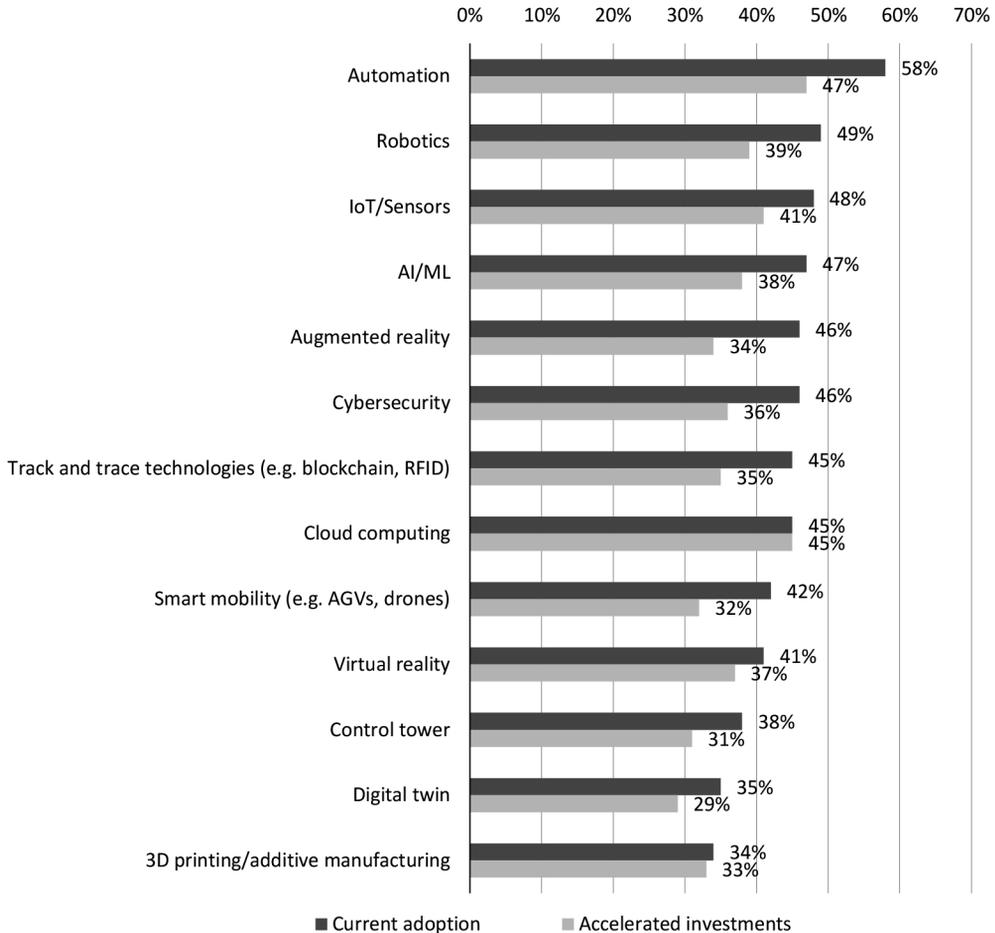
Source: *Fast forward. Rethinking supply chain resilience for a post-Covid-19 world*, 2020.

Allow us to present some final results to sum up all the findings from both SLR and grey literature. The SLR results provided a great amount of information that generally outlined the problems of managing SC affected by the Covid-19 pandemic and ways of solving their issues (theoretical and practically implemented). The grey literature analysis enriched earlier results by providing information on the opinions and actions of decision-makers and managers in supply chains during the pandemic period. Gene-

rally, the economic slowdown, together with the lockdown, changed the spending habits of end-users and the general situation in many sectors. In terms of restructuring SC into pandemic-resilient SC, they should be transparent (end-to-end visibility), flexible (in terms of transactions between SC members), and focused on the elimination of bottlenecks (through the quick change of locations or other concepts). Some of the countries were more affected (especially South Asia) and so were some sectors (depending on whether their products were basic necessities or not). Generally, according to the overall findings, the concept of a resilient supply chain (inevitably including an element of risk management) was the most suitable recommendation for managing SC during Covid-19.

Discussion

The Covid-19 pandemic remains a global threat to the functioning of socioeconomic systems, including SC (Carlson-Szlezak *et al.*, 2020; Fernandes, 2020). The research initiated in this area is of pioneering nature. Never before has the world encountered a disruption of this kind and with such a magnitude of impact on SC. Certainly, one should also agree with van Hoek (2020) that research of this kind is a moral obligation for SC researchers.

There are a lot of studies – usually based on the case study method or SLR – describing the impact of the Covid-19 pandemic on SC chains in different countries, industries, conditions, etc. (Dalton, 2020; Dragan *et al.,* 2020; Gautam *et al.,* 2020; Farooq *et al.,* 2021). However, the academic output presented in this article is a novelty due to its structuralized and comprehensive research. Thus, the above analysis of a wide range of views supported by theoretical and practical recommendations of concepts, methods, and tools for managing SC during the Covid-19 pandemic can be viewed both in terms of their originality and scientific added value. The results of the analyses presented in this study may constitute a particular reference map of the situation together with solutions that can be used by all stakeholders of SC, especially SC managers.

We are aware of the limitations of their research resulting primarily from the narrow research horizon (two years) resulting in the inability to consider the full extent of the impact of the pandemic on SCM. Nevertheless, the value and advantage of this study is that it considers both scientific literature and grey literature, thus diversifying data sources. By following this approach, we wanted to obtain the broadest possible view of the analyzed problems, not only from the perspective of researchers but also from the view of SC participants.

Therefore, we agree with Yogaananthan (2020), who outlines three possible strategies to build a resilient SC, especially considering the implications of the Covid-19 crisis for SCM:

- diversification of suppliers (multi-sourcing): increasing supply reliability and flexibility by working with many suppliers for the same commodity;
- establishing circular supply chains: maximization of the number of renewable (raw) materials or semi-finished products, maximizing product shelf life and total product lifetime, and maximizing the ability to recover or reuse by-products, spare parts, and waste to make new materials and products, e.g. by remanufacturing;
- building (and improving) supply chain visibility: implementing solutions (also digital) to monitor the whole supply chain (or network), risks, and signals about disruptions.

The results obtained as part of the study identified specific research gaps in relation to data analysis methods, concepts, methods, tools applied in practice, and application conditions. Therefore, these can be proposed as prospective directions for the further research.

Conclusions

The purpose of this study was to explore conceptions, methods, and tools regarding SCM during the Covid-19 pandemic. The main value of the study and its original quality was the structured and comprehensive research in this area, which provides researchers and professionals with detailed findings (see Appendices 1 and 2). These include an overview of solutions that can be implemented to make SC resilient against the Covid-19 pandemic: digitization methods and tools are foreseen as the right propositions to detect pandemic threats and take a set of anti-Covid decisions. Referring to the theoretical and practical implications of this study, the archived results contribute especially to the discipline of SCM, which can be applied by SC managers to overcome difficulties in managing SC during the Covid-19 pandemic.

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