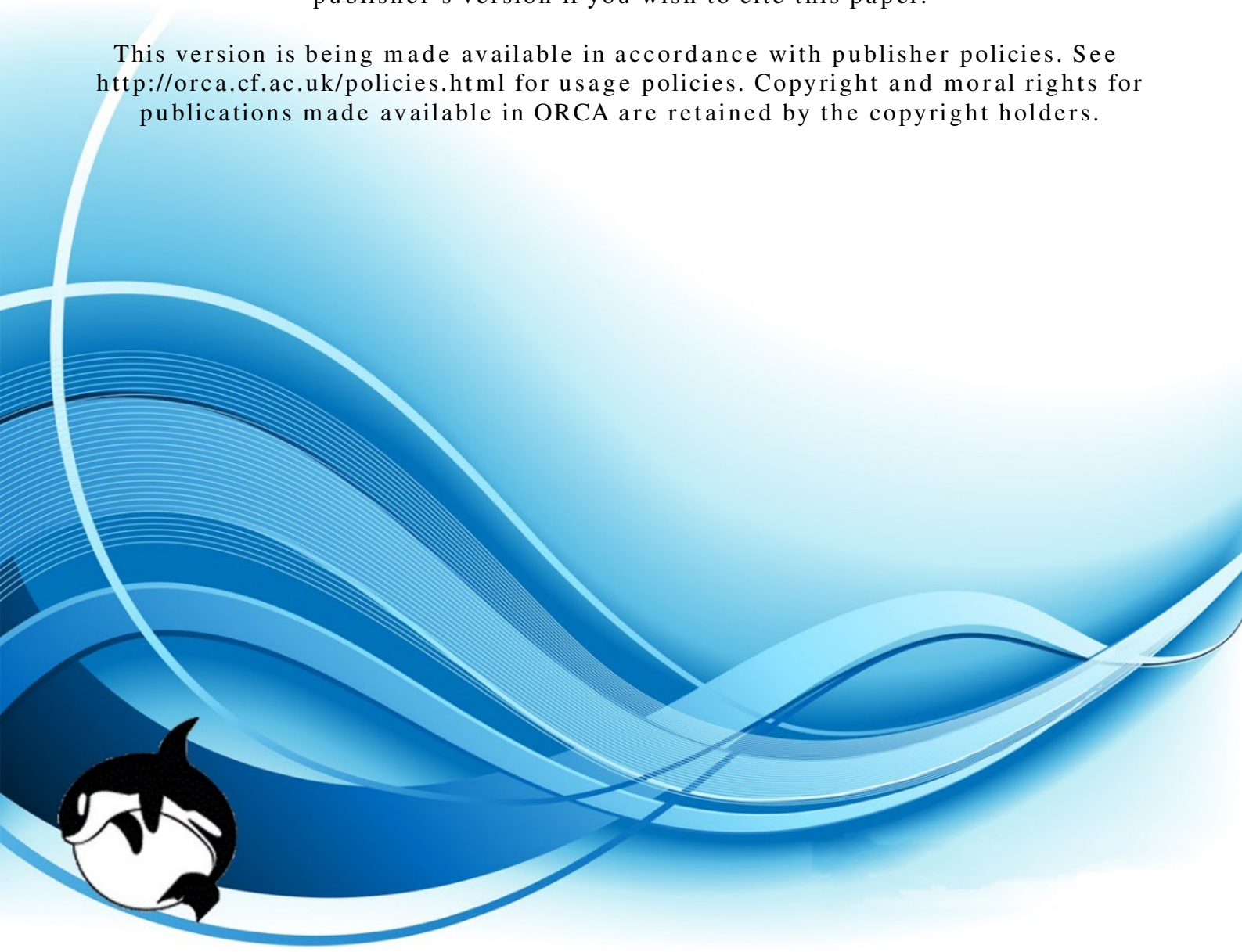


Food Supply Chain Resilience in Major Disruptions

Abstract

Purpose – Corona Virus Disease (Covid-19) is a global pandemic that emerged at the end of 2019 and caused disruptions in global supply chains, particularly in the food supply chains that exposed the vulnerability of today's food supply chain in a major disruption which provided a unique research opportunity. This review explores the current research direction for food supply chain resilience and identifies gaps for future research in preparing for future major global pandemics.

Methodology – This article presents a review of food supply chain resilience followed a systematic literature review of the business and management-based studies related to the food supply chain in Covid-19 published between December 2019 – December 2021 to identify the immediate issues and responses that need to be addressed in the event of future disruptions in food supply chains due to new global health threats.

Findings – The study revealed the need for more literature on food supply chain resilience, particularly resilience to a major global pandemic. The study also uncovered the sequence of events in a major pandemic and identified some strategies for building resilience to potential future risks of such an event.

Limitations - Firstly, the selection of databases is not comprehensive. Due to time limitations, authoritative publishers such as Springer, Emerald, Wiley, and Taylor & Francis were not selected. Secondly, a single author completed the literature quality testing and text analysis, possibly reducing the credibility of the results due to subjective bias. Thirdly, the selected literature are the studies published during the immediate event of Covid-19 and before January 2022, other research studies may have been completed but were still in the state of auditing at this time.

Originality – This paper is the first study that provides a detailed classification of the immediate challenges to the food supply chain faced in both upstream and downstream nodes during a major global disruption. For researchers, this clearly shows the immediate difficulties faced at each node of the food supply chain, which provides research topics for future studies.

Keywords – Covid-19, Pandemic, Food Supply Chain (FSC), Supply Chain Resilience, Major Global Disruptions

1. Introduction

Supply chain resilience (SCR) has been defined by several disciplines (Ponomarov and Holcomb, 2009), and researchers such as Pettit et al. (2013). Recently, Katsaliaki et al. (2021) studied the impact of several significant disruptions on SCR. Pettit et al. (2013) developed an assessment tool to evaluate SCR.

The risk of major disruptions has increased considerably due to globalisation, long and interconnected networks and the impacts of them, have needed to be better understood as they can often be only understood after the event (Fiksel et al. 2015). The outbreak of Covid-19 in late 2019 posed multiple challenges to food supply chains (FSCs) worldwide that exposed their fragility in the face of global disruption. Studying the immediate effects of Covid-19 can be used to inform research and practice in preparation for potential future disruptions.

As governments implemented strict lockdowns and social distancing measures to curb the spread of the pandemic, consumers' buying habits also changed accordingly. The phenomenon of panic buying occurred worldwide (Wang and Na 2020; Yoshizaki et al. 2020). One study in China found that consumers were willing to pay a 60.5% premium (Hall et al., 2021). Such extreme consumption led to empty shelves; which led to shortages of necessities in remote communities (Singh et al. 2021a; Boyacı-Gündüz et al. 2021). Panic buying influenced companies' market perceptions and affected materials, production, and transport planning. Also, the food industry's labour-intensive nature challenged food processing regarding staff attendance. Staff sickness, self-isolation, and restricted mobility caused by Covid-19 reduced the speed of food processing lines and affected capacity (Hobbs 2021; Larue 2021). All the above factors contributed to the food shortage in supply.

Due to the profound impact of the pandemic on supply and demand, the concept of food supply chain resilience (FSCR) has moved to the forefront of discussion. SCR is interpreted as the ability to leverage a company's flexibility, risk awareness, redundancy, early warning, and integration capabilities to withstand, adapt, recover and even enhance operations when faced with a supply chain disruption or suspension (Ali et al. 2021). Admittedly, a global crisis like this is difficult to predict, and it is difficult for SMEs to plan as this affects their cash flow and increases costs. In Covid-19, there were extended supply disruptions in the early stage of the outbreak (Chenarides et al., 2021). The shift of some US-based food producers from traditional sales models to e-commerce is estimated to have increased by 63% compared to 2019 (Thilmany et al., 2021). This aggressive strategy has opened distribution and sales channels for producers, providing them with a broader market.

Previous research contributed to improving the resilience of the FSC. Typical examples include Singh et al. (2021a), who developed a public distribution system's simulation model capable of re-scheduling transport plans to meet daily supply based on constantly updated travel restrictions. The cross-use of data-driven technologies such as blockchain, big data and digital twinning has also become one of the methods scholars use to explore the possibility of enhancing FSCR (Zheng et al. 2021; Sengupta et al. 2021; Ivanov 2021; Naz et al. 2021).

Overall, the outbreak aroused the attention of companies and researchers on FSCR. The research results are helpful in mitigating the ongoing pandemic and, more importantly, in guiding future crises. For example, pre-positioning additional inventory is more resilient than alternate suppliers (Moosavi & Hosseini. 2021); Cost optimisation and government support can maximise supply chain flexibility (Das et al., 2021). Integrated management and information transparency among nodes in the supply chain are essential drivers for maintaining resilience (Demirci 2021; Shen and Sun 2021). These outcomes are valuable lessons for dealing with recurring outbreaks and other crises that may arise in the future. After referring to these best practices, enterprises can enhance SCR and mitigate the impact of the crisis by adjusting their operational strategies according to their conditions. However, there are no literature review studies available in the extant literature looking at these best

practices and recommendations for future major disasters. The scope of this systematic literature review (SLR) focuses on all nodes in the FSC from upstream to downstream. The study is not country-specific; therefore, food industry practitioners, decision-makers, policymakers, and researchers can widely refer to it.

The primary aim of this review is to explore the resilience of the FSC in the event of a significant global disruption to identify potential recommendations to mitigate future risks. Infectious diseases are among the top 10 global risks identified by the World Economic Forum (2020). Covid-19 is an example of a recent global infectious disease that has affected most countries with severely disrupted FSCs.

The "Farm to Fork" FSC is highly complex, interconnected, volatile and long. The nature of food, often comprising many short-life products, is vulnerable to disruptions but can also be resilient, provided the land can recover.

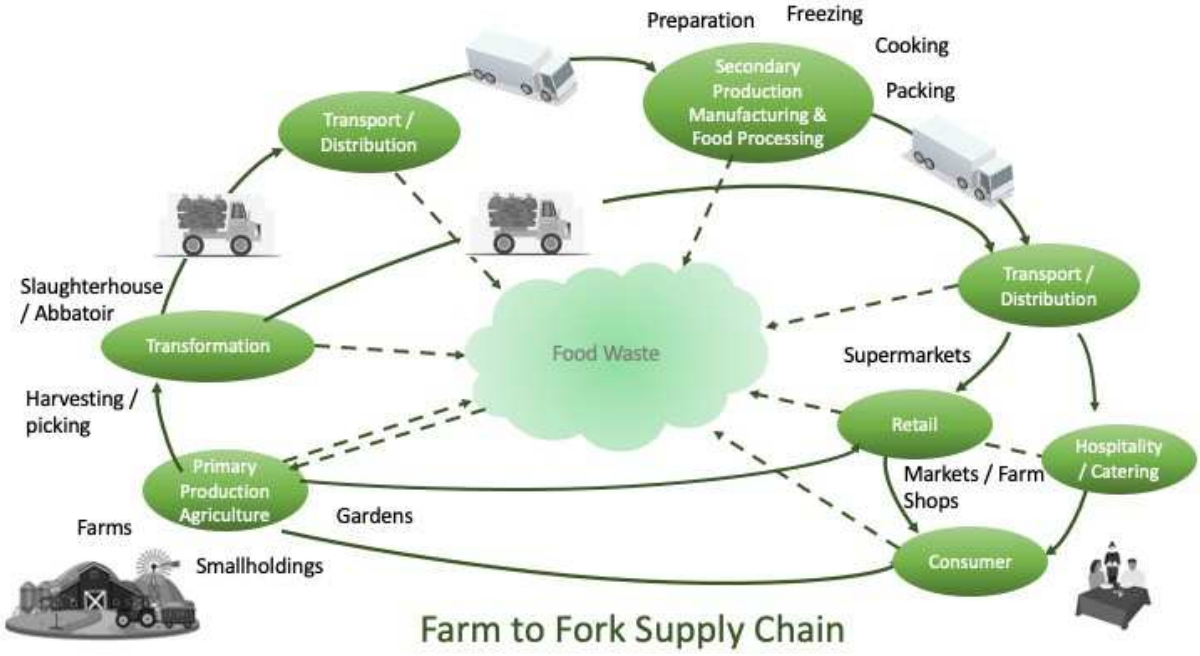


Figure 1– Farm to Fork Food Supply Chains

Take in Figure 1 - Farm to Fork Food Supply Chains

Farming is one of the biggest industries, with over 570 m farms worldwide, providing over 80% of global food consumption. The remainder is from smallholdings and gardens. The farms range from <1 hectare to >1000 hectares (Ritchie and Roser, 2021).

The Farm-to-Fork FSC consists of agricultural primary production, the growing of crops and livestock, and secondary production, where the crops are harvested or slaughtered and on to food processing or direct to market. Direct-to-market can include farm gate sales to consumers, farmer markets and farm shops directly to consumers or restaurants/caterers. The FSC logistics includes distribution and storage to food processors or retail and hospitality/catering.

The following research questions will be answered to achieve this aim:

RQ1 - How were the FSCs affected by global pandemics like Covid-19?

RQ2 - What solutions and recommendations were proposed to prepare for future major global pandemic disruptions?

RQ3 - What are the gaps in research of FSCs in the event of a major global pandemic disruption?

This study adopts a two-phase approach with a narrative overview of the FSCR literature to identify models and frameworks of FSC resilience. This review is followed by a systematic literature review (SLR) to evaluate specific articles on the FSCs that were published during the immediate Covid-19 period of 2020-21 to determine how the impact of a global pandemic fits with existing resilience literature and whether any new gaps emerged to drive future research.

The rest of the paper is structured as follows. A review of the FSC resilience is introduced in section 2 to identify current models and frameworks for FSC. The research methodology for the SLR of Covid-19 is discussed in the 3rd section, including the content analysis. A review of the literature on Covid-19 and the findings are discussed in the 4th section, and the 5th section is dedicated to the discussion. The study and future research opportunities conclude in the 6th section.

2. Food Supply Chain Resilience (FSCR)

The FSCs have unique characteristics like seasonality, supply spikes and perishability, which make them more complex than any other supply chains like manufacturing or automobile. The changing consumer demands, climate change, price volatility and animal or crop diseases are the major uncertainties of agriculture food (Behzadi et al. 2018). This section focuses on some key relevant studies about FSCR and discusses the research gaps and highlights the need for a review of the literature review.

Recently, Azizsafaei et al. (2021) conducted a narrative review of relevant FSC risk management and suggested considering Artificial Intelligence for future research. A comprehensive systematic review examining the sources and resilience factors of the agri-food supply chain was done by Zhao et al. (2017). They emphasised the need for more research on the relationship between risk sources and resilience factors. This review paper advised more research on perishability modelling, multi-period planning, low-probability high-impact events modelling and demand side disruptions.

A business resilience risk assessment framework considering ready, respond, and recovery phases were proposed for the FSC organisations to establish and enhance the strategic resilience for internal and external risk factors (Manning and Soon 2016). The agility, adaptability and alignment in supply chain processes help to combat demand and supply uncertainties. Hendry et al. (2019) discussed the importance of vertical and horizontal collaboration between the FSC actors in the context of Brexit. Along a similar line, Leat and Revoredo-Giha (2013) showed how the supply chain vulnerability was reduced after a horizontal and vertical collaboration of Scotland's pork supply chain actors. The resilience elements should develop the supply chain's ability to support food security rather than the growth of an individual company's performance (Stone and Rahimifard 2018). Most authors explored sustainability risks in the FSC context. However, Choirun et al. (2020) analysed the

sustainability of the agri-food industry from multiple dimensions, i.e., economic, environmental, social, technical and institutional.

The previous papers clearly showed that there has been research going on FSCR for many years. However, scholars and practitioners started demonstrating more interest after the supply shortages and demand spikes for food items caused by Covid-19 lockdown measures. The economics of scale was good for standard times, whereas investments in adaptability and flexibility can help enhance resilience during abnormal times like Covid-19 for FSC (Hobbs 2021). The UK's food system was weakened because of a lack of domestic food production, JIT supply chain and labour issues. The collaboration and adaption to IT technologies helped to make resilient regional FSCs during the pandemic in the US (Marusak et al. 2021). The significance of SC digital twins and end-to-end visibility, along with resilient demand, inventory, and capacity management, was discussed by Burgos and Ivanov (2021) using a simulation model.

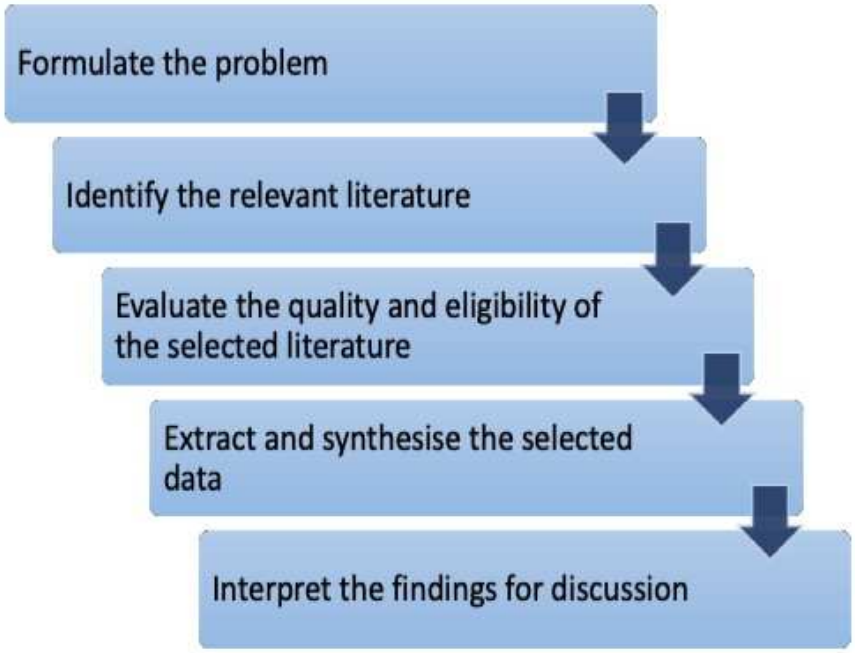
Additionally, Garnett et al. (2020) acknowledged that the developing redundancy and variety in the food system was critical for resilience in Covid-19 recovery. A summary of the key review papers on FSCR is reported in below Table I. Limited systematic literature review studies are available on FSCR in major disaster events (Choirun et al., 2020). The supply and demand side risks were only considered for long-life and perishable products with robust and resilient strategies (Behzadi et al. 2018). Furthermore, Siddh et al. (2017) reviewed the papers on Agri-fresh FSC quality without looking at the supply chain resilience. Perdana et al., (2022) did not look at the specific set of journals in their systematic literature review. Many authors suggested various typical resilience strategies such as flexibility, agility, collaboration, redundancy and visibility to improve the FSCR without any strong practical justifications or quantifying the resilience strategies (Ali et al., 2021, Kumar and Singh, 2021, Sharma et al. 2021, Mishra et al. 2021). Due to the above limitations, there is a dire need to conduct SLR of FSCR considering major disasters.

Take in Table I – A Summary of the Key Literature on FSCR

3. SLR Methodology

In Bourcet (2020), SLR refers to selecting literature within the scope based on a protocol established in advance and its use as a basis for summarising and analysis. It is a systematic and comprehensive description and review of the research results, existing problems, and new trends in the field of study over a certain period (Nichols and Stahl 2019).

Implementing the SLR methodology for Covid-19 literature demands an orderly, rigorous, and scientific manner. Thus, the following steps (Figure 2) were followed:



Source: Khan et al. (2003)

Figure 2 – The SLR Process

There are several phases of this review. Firstly, the problems need to be defined clearly to set the review questions of the study. Secondly, finding relevant data is key to ensuring the quality of the SLR. Thirdly, the initial shortlist is assessed for quality by reading the full text to determine the final data selection. Fourthly, the data are extracted, entered, and summarised, and, fifthly, the findings are presented in textual and graphical form to provide evidence for the final discussion.

Following Khan et al. (2003), data collection requires an initial search through various retrieval systems and incorporating a designed protocol to limit it to exclude irrelevant data. The research protocol clearly states whether a study can be included. The research protocol is shown in Table II

Take in Table II

Table II – Research Protocol

Scopus is used in this study as the primary search tool. Meanwhile, Web of Science and EBSCOhost, as specialised academic databases, is chosen as complementary search tools to guarantee the completeness of the data (Malabanan and Bayeng 2019; Birkle et al. 2020). As this study is to explore the immediate aftermath of Covid-19, insufficient academic and empirical data would not be available during the timeframe. So grey literature is included to encompass more data, and, for the same reason, grey data retrieval databases, Base and NDLTD, are utilised.

The main keywords are “Covid-19”and “Food Supply Chain” and “Resilience”. The synonyms of “Covid-19”, such as “Coronavirus *”, “Pandemic”, are included in the search terms to include more relevant literature, and the term “Food Supply Chain” was also expanded, as shown in Table II.

As many types of literature as possible are selected to accurately explore the field's trends and state of research. Therefore, doctoral theses, postgraduate dissertations, articles, conference papers, notes, letters, and editorials are also considered.

In addition, literature whose primary intent is to ease the FSC is also considered. It is important to note that types not related to upstream and downstream activities are excluded. What is more, if the research object of the literature is not related to business and management, it is also excluded. In addition, studies on specified food categories are also excluded because they are unrepresentative. Only full-text literature is included.

To further limit the scope to identify the most relevant and valuable literature, the Title, Abstract, and Keywords of the results are read after the keyword search is completed. This step determines whether the literature fits the designed research protocol. Afterwards, the literature that meets the requirements is read thoroughly. In this step, the literature is assessed for quality according to the Quality Assessment (Appendix A) to determine the final data.

However, using only keywords with Title, Abstract, and Keywords as Search Type can limit the retrieval (de Vries et al. 2020; Bramer et al. 2018). To ensure the comprehensiveness of the data to answer the research aim effectively, the snowballing method was utilised to expand the existing literature.

The snowballing method uses the starting article as a reference. It effectively increases the sample size of the study data based on its related publications or citations. The snowballing method applied in this study follows the procedure described by Wohlin (2014). Forward and backward snowballing are implemented after identifying the starting articles. Backward and forward snowballing refers to identifying studies associated with the initial article by looking up the reference list and citation. As with keyword searching, the snowballing method also requires filtering articles. Each time an additional article is selected, it is necessary to repeat the previous stage's actions to achieve saturation, where no new article is found.

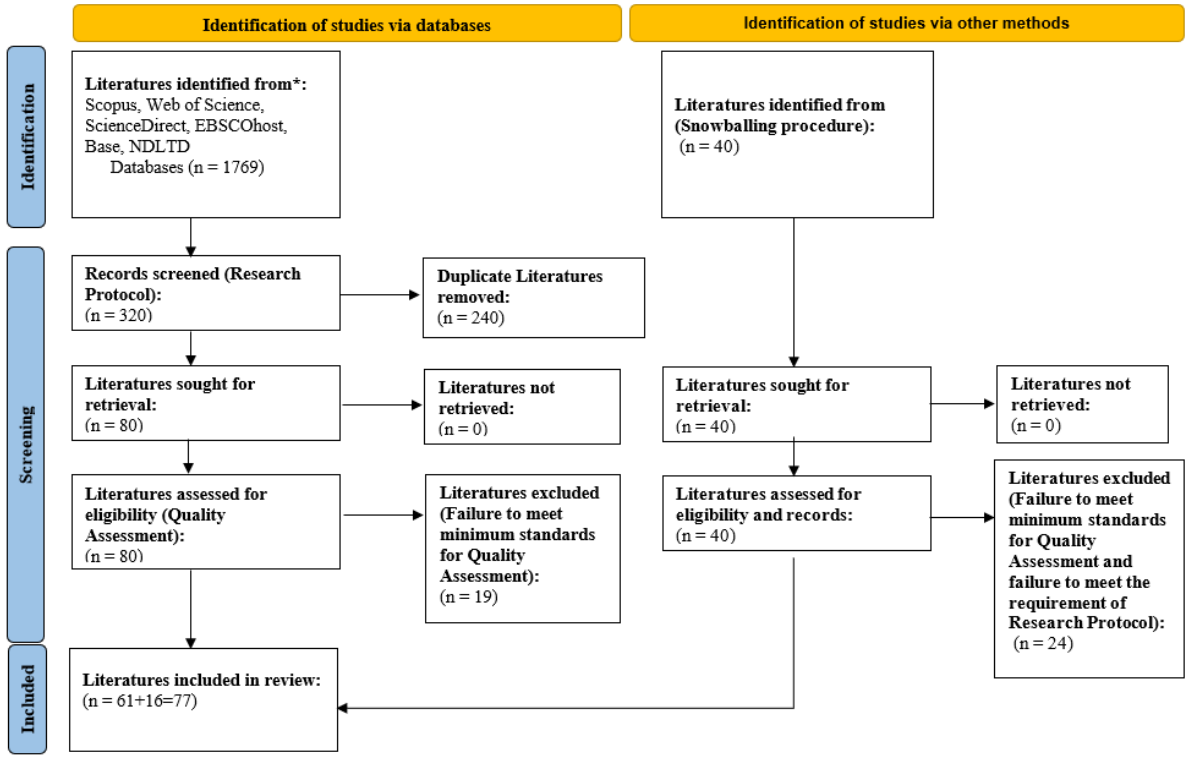
3.1 Evaluating the quality of the literature.

The authors recognise that producing high-quality research and subsequent publications takes time and the purpose of this study was to examine the immediate literature that captures what was happening at the time of the pandemic. Therefore, availability was a key consideration, however, it is important that quality of the evidence is considered, so the papers were assessed for quality whilst accepting the reality that this is a subjective assessment of a limited number of papers. In the post-pandemic period, more robust and rigorous studies maybe performed that would question this assessment.

Quality assessment (QA) systematically examines the selected data to assess its validity and relevance (Heyvaert et al., 2016). This step further assesses the quality of the data and classifies it by the rating method. The step narrows the data scope and ensures that the selected data has the highest relevance to the demand. Further quality assessment of the selected literature was based on different criteria for rating: Contents, Structure, Credibility and Value. The design of the criteria in this study was informed by the Quality Assessment Tool proposed by Health Evidence (2016) and the Methodology checklist introduced by Healthcare Improvement Scotland SIGN membership using these criteria: “Contents” is to ensure that the topic is highly relevant to the research objectives, “Structure” aims to check the integrity of the study, “Preciseness” ensures the rigorous of the study, “Credibility” means

to eliminate those studies with low trustworthiness, and "Value" ensures that the selected study has practical significance (Healthcare Improvement Scotland SIGN).

After completing quality testing, the data for the final study is determined. A PRISMA Flow Diagram (Figure 3) is then used to document the entire data collection process. PRISMA (2021) records the flow of information at different stages of data collection and filtering, including the criteria for retrieval, the source of the data, and the screening process.



Take in Figure 3. PRISMA Flow Diagram for the Study

3.2 Interpreting the findings

The entire search process is divided into four rounds. In the first round, keywords and search strings are identified to determine the associated literature range. In determining keywords and strings, synonyms and conjunctions are continuously tried and updated to increase the number of articles. Every time the number of articles is updated, it returns to the first round to redefine keywords and strings until no new articles appear. A title and abstract review are performed in the second round to narrow the scope according to the developed research protocol (Table II). In the third round, the results of the second round are refined in the form of full-text readings according to the developed Quality assessment to determine a start set of articles. In the fourth round, a Snowballing procedure is initiated to supplement the data further. The search results are presented through PRISMA Flow Diagram (Figure 3). Next, the data is extracted and coded using NVivo.

The initial keyword search (R1) returned 1479 results from five auxiliary search engines and 290 results from the Scopus database for 1769 pieces of literature.

In Round 2 (R2), the titles, abstracts, and keywords of the articles were read to identify further 320 relevant articles which matched the set Research Protocol. After that, duplicates were removed from the five auxiliary search systems, and their identical results with Scopus were also excluded. A total of 80 articles were retained in the screening process of R2.

In the process of R3, 80 studies were reviewed by QA. After full reading and quality grading, 61 studies were retained.

In the final fourth round (R4), a Snowballing Procedure was applied to the results of the R3 and identified a further 16 papers that met both QA and Research Protocol. The results of the third and fourth rounds were summed to the final number of data to be analysed, which was 77 studies.

4. Analysis and Results

4.1. Narrative Analysis

The literature analysis identified impacts at each stage of the FSC through the restrictions on transport and movement, particularly the import and export of goods, and the infection control measures of social distancing, lockdowns, and isolation, as well as the catastrophic loss of life.

4.1a) Issues in the Agricultural, Primary Production and Fresh FSC

Transport restrictions during Covid-19 hampered access to agricultural inputs, such as fertilisers (Omer and Hassen 2020; Agyemang and Kwofie 2021; Priyadarshini and Abhilash 2021; Pu and Zhong 2020; Sharma et al. 2020a; Zhang et al. 2020a; Zhang et al. 2020b). During Covid-19, farmers' incomes were significantly affected by restrictions on transportation. These restrictions prevented the sale of agricultural products in the market (Pan et al., 2020), and even in regions where transportation is not restricted, farmers' incomes were reduced. Mainly because releasing large stocks to meet the high downstream demand lowered farm gate prices, affecting farmers' incomes (Priyadarshini and Abhilash 2021; Coopmans et al. 2021).

Several studies mentioned the existence of debt, financing difficulties, and cash flow shortages among farmers (Jackson-Smith and Veisi 2021; Kumar and Kumar 2021; Kumar et al. 2021b; Omer and Hassen 2020; Priyadarshini and Abhilash 2021; Sharma et al. 2020b; Yu and Rehman Khan 2021). The consequence of the debt is the long-term loss of farmers. Pu and Zhong (2020) mentioned that most farmers changed jobs for a living during the blockade, and only 60% returned to their jobs at the beginning of 2020.

4.1b) Issues in the Manufacturing and Food Processing Supply Chain

Worker shortages were the most significant problem in producing and operating food products during a pandemic. The shortage is referred to in 35 of the 77 reviewed papers. The main reasons for this include lockdowns, social distancing, cross-border mobility restrictions, and worker infections (Singh et al. 2021b; Sharma et al. 2020a; Priyadarshini and Abhilash 2021; Marusak et al. 2021). The lack of employees triggered a chain reaction. The first was rising production costs (Jackson-Smith and Veisi 2021; Pu and Zhong 2020). Rising costs are considered the most detrimental to the FSC (Abu Hatab et al., 2021). Secondly, the lack of a workforce leads to a decrease in output. Some researchers indicate that the decrease in yield was due to the reduction in the number of workers and efficiency issues caused by the need to maintain physical distance (Barman et al. 2021; Burgos and Ivanov 2021; Mishra et al. 2021; Weersink et al. 2021). In addition to staff shortage, Zhang et al. (2020a) found a significant relationship between the number of infected people and agricultural productivity through model analysis. Warehouse management was also put under pressure during Covid-19. Three studies expressed concern about this. (Kaur et al. 2020; Mishra et al. 2021; Priyadarshini and Abhilash 2021).

To adapt to the changes in the market, food companies adjusted their production lines. Producers serving restaurants before the outbreak were forced to adjust their logistics, packaging, labelling, and product sizes to gain market access to supermarkets and other retailers (Weersink et al. 2021; McClements et al. 2021; Hobbs 2020).

Ten articles addressed the seriousness of restricting exports. Countries decided to restrict exports to ensure local food supplies (Aday and Aday 2020; Coluccia et al. 2021; Kumar and Kumar 2021; Zhang et al. 2020a; Zhang et al. 2020b). Those producers who relied on exports lost their distribution channels, yet few were able to divert them. Relocating local sales channels adds time and costs and requires re-designing the logistics operations, adding extra monetary costs.

In downstream logistics, the most recognised issue for food retailers is the change in consumer demand. Due to the closure of restaurants, consumers needed to purchase raw materials to cook their meals at home (Aday and Aday 2020; Barman et al. 2021). More troubling for retailers was the tendency of consumers to buy food with a long shelf life rather than perishables (Derossi et al. 2021; Barman et al. 2021; Coluccia et al. 2021). Panic buying directly reduced retailers' efficiency (Jamil and Soares 2021). Changes in demand required food retailers to be highly resilient. However, most food retailers needed help managing supply shortages and demand shocks.

The just-in-time production system and upstream supply chain disruption are described as the leading cause of the inventory shortage (Hobbs 2020; Kumar and Kumar 2021; Pu and Zhong 2020; Yadav et al. 2021). Only Mui et al. (2021) conducted an empirical study on food shortages in production and operations. They surveyed 2011 respondents in the US in an online tool and analysed the data using cross-sectional and chi-square tests. The results found that the food shortage was one of the main factors influencing the difficulty in obtaining food. Several retailers have implemented measures to reduce costs from empty shelves due to a short food supply. Coopmans et al. (2021) discovered that some food retailers reconsidered market relationships and introduced alternative products to reduce empty shelves in response to supply shortages. However, managing these alternative products became a problem after the shortage was relieved.

Another notable change in consumer behaviour was the increase in online business. Consumers increasingly opted for online delivery (Kumar and Kumar 2021; Pappalardo et al. 2020). This change forced food enterprises to launch online businesses, and those traditional food retailers suffered if they did not transform (Jamil and Soares 2021). Meanwhile, Jamil and Soares (2021) expressed their concern about the well-being of workers. They indicated the simultaneous development of online and offline businesses exponentially increasing the workers' workload, causing them to lose motivation to work.

Amongst all the issues, logistics was of the most concern to scholars. Twenty-six reviewed papers considered that transportation significantly impacted the food supply chain. The disruption of logistics is seen as the root of many of the issues.

Ten studies addressed this phenomenon in their articles. However, only Nordhagen et al. (2021) conducted an empirical study on downstream firms' earnings to explore the impact of Covid-19 on SMEs. The authors surveyed 367 companies in 17 countries in Asia and Africa. They found that declining sales/revenue and financial problems were the most prevalent issues.

A factor of most concern in the FSC is food waste. Waste is mentioned in 15 papers. Most researchers state that food waste occurs due to interrupted distribution and transportation channels (Adhikari et al. 2021; Barman et al. 2021; Do et al. 2021; Jackson-Smith and Veisi 2021). During the pandemic, consumers preferred non-perishable products leading to the waste of perishable products (Agyemang and Kwofie 2021; Pappalardo et al. 2020). In addition, the pressure on storage facilities and the limited processing capacity also contributed to the food waste in the upstream supply chain (Kumar and Kumar 2021; McClements et al. 2021; Omer and Hassen 2020; Weersink et al. 2021). Restriction on travel led to the rise of the delivery business, which indirectly increased the use of packaging materials. However, matching the corresponding recycling and processing capacity in turbulent and uncertain times is complex, and this could cause damage to the environment (McClements et al., 2021; Sharma et al., 2020a). Table III summarises the impacts and Issues at each stage of the process.

Take in Table III

Table III – Impacts and Issues at Each Stage of Process

5. Discussion of Food Supply Chain Findings

The review exposed 3 major issues, the restrictions on movements of goods within the supply chain, the labour shortages in the workplace and the changing demand. The issues identified were compared with the SCR Assessment Model described by Pettit et al. (2013). In the assessment model, the authors identified 7 Vulnerability Factors (Table IV) and 13 Capability Factors (Table V) and mapped the capabilities required to alleviate the impacts of the vulnerabilities (Figure 4).

Take in Table IV

Table IV – Vulnerability Factors (adapted from (Petit et al., 2013)

Take in Table V

Table V – Resilience Capability Factors (adapted from Petit et al., 2013

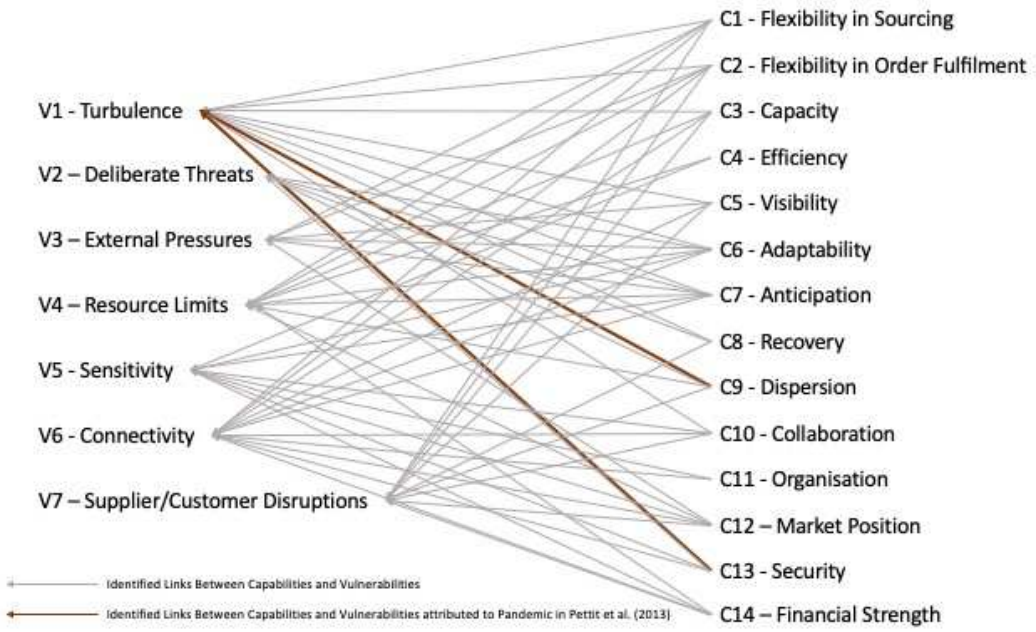


Figure 4 – Mapping of Capabilities Required to Alleviate Vulnerabilities in Supply Chain Resilience (based on Pettit et al., 2013)

Take in Figure 4 - – Mapping of Capabilities Required to Alleviate Vulnerabilities in Supply Chain Resilience

The results of this review of the impacts of Covid-19 on FSCs considered that this categorisation is too simple. A major global pandemic, like Covid-19 cannot simply be categorised as a simple turbulent vulnerability. Once a major pandemic occurs there is a ripple effect in response to external pressures, such as the political and legislative measures of travel restrictions and lockdowns of whole countries. The social distancing and other infection controls, including the self-isolation and death of infected people, imposed resource limits and transport restrictions inhibited the export and import of goods. The closures of hospitality, non-food shops and manufacturing disrupted the supplier and customer channels and created a supply and demand price sensitivity in the market. This is shown in Figure 5.

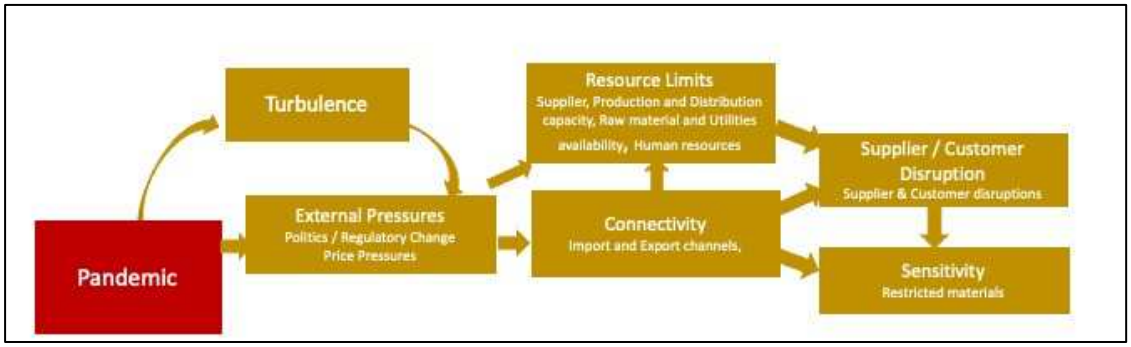


Figure 5 – Chain of Events during a Major Global Pandemic

Take in Figure 5 – Chain of Events during a Major Global Pandemic

This chain of events created gaps in the Pettit et al. (2013) model illustrated in Figure 4. These impacts were not identified as the model considered pandemics only as Turbulence, as a result we have remapped the pandemic vulnerabilities to capabilities to address efficiency, organisation and financial strength and proposed some recommendations for policy makers and food producers to build resilience for potential future pandemics.

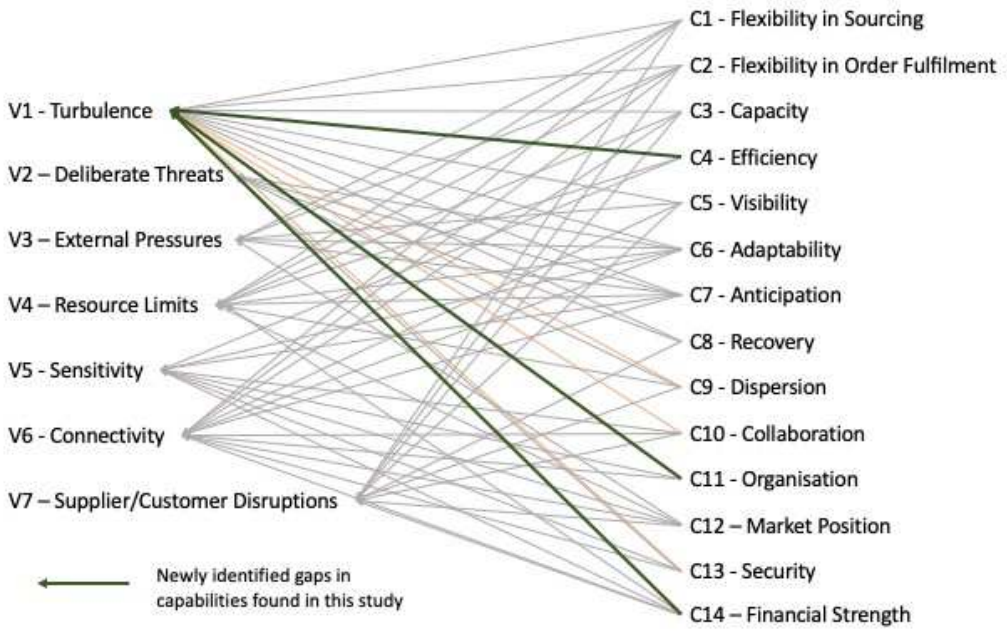


Figure 6 – Remapping of the Linkage between Capabilities Required to Alleviate Vulnerabilities in Food Supply Chain Resilience

As a result, this review identified recommendations for policy makers and food processors to build resilience against potential future pandemics (Table VI)

Take in Table VI

Table VI - Recommendations for Policy Makers and Food Processors

5.1 Recommendations for Policy Makers

Based on Table VI most researchers believe that governments should first solve the financial problem of participants in the FSC to maintain normal activities. In addition, it is suggested that governments should develop export and e-commerce policies to expand food distribution channels. Food reserves should be strengthened in the public sector regarding food shortages, and more regional public distribution centres should be established. Some researchers also refer to different forms of food production, such as home gardening. They believe that promoting home gardening can relieve local and community-based food shortages and help enhance household livelihoods.

5.2 Recommendations for Food Producers

Following Table VI most researchers consider those food companies should apply modern technology (i.e., Blockchain, IoT, Robots), implement short-term policies, and shorten their supply chains to increase their resilience to cope with changing demand. 3D printing technology is proposed to solve the shortage problem in terms of food shortage. The

protection of the health and safety of the workers also contributes to the sustainable production of food. Also, setting some shopping restrictions on consumers can ease the pressure on retailers. Leading suggestions for food transportation are to improve the efficiency of logistics, such as the establishment of regional DCs and the application of Information Communcation Technology (ICT) (Ekren et al. 2021). Another area that has attracted the attention of scholars is the application of e-commerce. Eight studies concluded that food companies should develop or cooperate with third-party e-commerce providers to expand market channels. The recommendation in terms of sustainability is to evaluate the effectiveness of post-processing of food waste by applying LCA to determine its effectiveness. It is also recommended that sharing Distribution Centre resources is beneficial to reduce storage costs and transportation costs.

5.3 Future Research Scope

Current research focuses on providing usual guidance and recommendations while lacking practical solutions. It is most striking that academics generally provide suggestions for improving the resilience of FSCs and eliminating food shortages. However, there is a lack of feasible solutions to these two topics. The current research direction of the solutions focuses on improving operational efficiency and capturing downstream demand such as production, customer needs, logistics, and market channel, for example. It is suggested that future research should tend to provide specific solutions for supply chain resilience and food shortage. Furthermore, the quantification of resilience strategies is overlooked by many authors in their studies (Singh et al. 2021a). We all have seen how Covid-19 pandemic started in China initially and how then it affected other Western countries and in the end, whole supply chain collapsed. Thus, analysing the impact of disruption propagation (ripple effect) is a very important topic in today's world (Burgos and Ivanov 2021).

Another theme is employee motivation. Employees have been under tremendous physical and mental stress during the pandemic. Therefore, solutions to this problem should be on the agenda. For example, exploring how to re-measure KPIs in a crisis and re-organise work shifts will be the field of future research. Firms had to run the facilities with a limited workforce therefore, more studies are needed by considering the employees' restrictions (Nagurney 2021). Very few studies proposed mathematical models for designing a robust and resilient supply chain network in the context of Covid-19. Further, simulating the various scenarios of global disruption considering real-life data is lacking in the academic literature. Scholars can look into this topic and develop good studies based on simulation.

Appendix B and Appendix C demonstrate the class distribution of issues, recommendations, and suggestions, respectively. After comparing them, it is observed that both recommendations and solutions proposed by scholars for upstream FSC are lacking in the following directions:

1. Safety issues related to the external packaging of food
2. Survival of exporters in export-restricted scenarios
3. Warehouse management issues in times of uncertain supply and demand (how to optimise inventory for resilience)
4. Food packaging recycling and disposal issues (how to effectively carry out recycling and disposal to reduce damage to the environment)

In the downstream FSC, most of the issues have been covered by recommendations and solutions. However, one thing that needs exploring is the survival of distributors and retailers downstream of the FSC. An apparent difficulty during Covid-19 is the decrease in sales and income. Future research is suggested to simulate different marketing and operational strategies in the context of a significant disruption, such as a global pandemic, to determine which strategies these enterprises should adopt to survive the difficult period smoothly. The topics that need to be addressed to fill the research gaps are sustainability, food safety, labour shortage, employee motivation, finance, agriculture inputs, resilience, and food shortage.

6. Conclusion

This paper provides a systematic review of 77 studies related to the food supply chain in a major global pandemic in terms of business and management aspects. The study results present the problems encountered in the FSC (upstream, downstream, and overall) during Covid-19. Issues focus on agriculture, production and operation, supply chain, finance, and sustainability. SCR strategies like flexibility, agility, visibility, collaboration, and redundancy are discussed and how they can be effective to manage major disruptions The upstream issues in the food supply chain, including packaging, distribution channels, warehousing, and the environment have received less attention from researchers and practitioners. Unexpectedly, a comparison of the number of solution- and recommendation-oriented articles shows that there are fewer solution-oriented, mathematical and simulation-focused articles than discussion-based articles, both in terms of number and direction of interest. This trend reveals that most of the studies are based on the views and discussions of the researchers, rather than quantitative studies. It must be acknowledged that these studies have made a guiding contribution to understanding the nature and development of things. However, the root of the problem is difficult to be solved simply through discussions and recommendations. Hence, there is an urgent need for future research that focuses on empirical, mathematical, and simulation-based studies to propose practical and implementable solutions to alleviate the pressure on the food supply chain during the outbreak. Hypothetical case studies are common in extant literature which shows the huge potential to develop studies by collating real data and problem characteristics.

Moreover, solution-based research focuses mainly on improving operational efficiency and demand management in the research direction. The lack of broad-based solutions is the biggest problem facing us today. Finally, several critical studies are selected for in-depth discussion, and the corresponding expandable research directions are proposed.

Natural disasters are often complex and unforeseen and not preventable. Checklists of similar events can help policy and decision-makers find typical risks, but that may only help a little for such unprecedented events as global pandemics.

Many people have been trying to understand the nature of hard-to-detect risks or uncertainties. After "unknown unknowns" were mentioned (Rumsfeld, 2002), people started using quadrants of knowledge to understand and explain the nature of risk. However, for many reasons, it is impossible to identify all risks in advance, and unidentified risks remain "unknown unknown" once they are identified (Kim 2012).

This paper is the first study that provides a detailed classification of the challenges to the food supply chain during major disasters. For researchers, this clearly shows the difficulties currently faced at each node of the food supply chain, which provides them with the research topic for future studies. Resilience strategies for each node added value to this study.

Furthermore, matching the current research findings (solutions and recommendations) with the existing problems reflects the research gaps to the greatest extent. It gives guidance to the researchers to focus on the unsolved issues. More valuable is that researchers can directly explore critical studies in greater depth by referencing the extendable directions proposed.

Based on findings from the literature and studies of Covid-19, a matrix model, such as that presented by Kim (2012), may help identify the unknown unknowns in advance to help the planning for potential future global pandemic risks.

The limitations of this study are apparent. Firstly, the selection of databases is not comprehensive. Due to time limitations, authoritative publishers such as Springer, Emerald, Wiley, and Taylor & Francis were not selected. Secondly, a single author completed the literature quality testing and text analysis, possibly reducing the credibility of the results due to subjective bias. Thirdly, the selected literature are the studies published during the immediate event of Covid-19 and before January 2022, other research studies may have been completed but are still in the state of auditing at this time. In this case, the data integrity is affected. Future research can minimise these defects and further explore this area to continue discovering the research gaps in the food supply chain. However, this review was designed as a study of the immediate effects and responses of Covid-19 and future research conducted in the post-Covid period will determine the reality of major global pandemics.

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