Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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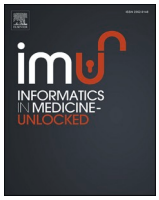

Identifying resilience strategies for disruption management in the healthcare supply chain during COVID-19 by digital innovations: A systematic literature review

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ABSTRACT

The worldwide spread of the COVID-19 disease has had a catastrophic effect on healthcare supply chains. The current manuscript systematically analyzes existing studies mitigating strategies for disruption management in the healthcare supply chain during COVID-19. Using a systematic approach, we recognized 35 related papers. Artificial intelligence (AI), block chain, big data analytics, and simulation are the most important technologies employed in supply chain management in healthcare. The findings reveal that the published research has concentrated mainly on generating resilience plans for the management of COVID-19 impacts. Furthermore, the vulnerability of healthcare supply chains and the necessity of establishing better resilience methods are emphasized in most of the research. However, the practical application of these emerging tools for managing disturbance and warranting resilience in the supply chain has been examined only rarely. This article provides directions for additional research, which can guide researchers to develop and conduct impressive studies related to the healthcare supply chain for different disasters.

1. Introduction

The term "supply chain" (SC) refers to the sum of organizations and procedures in different enterprises like suppliers, manufacturers, and distributors that work together with the whole value chain to obtain different materials, transform them into final products, and distribute them to consumers [1]. The supply chain determines how operations can be run effectively to get the suitable supplies to the suitable place at the appropriate time [2]. Supply chain management (SCM) integrates and coordinates product and financial flows between companies to convert and rationally utilize resources throughout the value chain and to convey raw materials to pertinent consumers. SCM is responsible for stabilizing supply and demand throughout the value chain, which is considered one of the key elements of all organizations [1,3]. In other words, the SC includes whole components that are related together to meet customer needs [4]. Healthcare supply chain management (HSCM) is defined as a subset of SCM; however, healthcare SC is unlike the regular supply chain because of its high volume of complications, the exclusive substances, and their relevance to the lives of people [5,6].

In the literature, a disaster is defined as "*a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction, and human suffering*" [7,8]. The World Health Organization (WHO) defines a pandemic as the spread of infection worldwide. New classifications distinguish disasters as natural or technological. Technological crises include industrial and transport events, and natural crises are classified as hydro-meteorological and biological crises, of which the COVID-19 pandemic is one. "*Pandemic is characterized by the contagion that spreads from human to human, can be fatal, and is capable of rapid worldwide proliferation. The contagion is likely to be, although does not have to exclusively be, novel influenza, and it will be a disease to which humans have no immunity. It generates panic amongst the population and there is no vaccine available and possibly no effective anti-viral medication either*" [7,9].

Crisis management encompasses the realization of some efforts during the occurrence of a crisis to diminish its disastrous outcomes [10]. COVID-19 is a catastrophe that hit the world in the second half of 2019, and it has affected all countries. Through October 1, 2022, this

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disease had infected over 623,300,000 people and taken the lives of about 6,550,410 patients [11].

Pandemics and other disasters interrupt the whole supply chain for an undetermined period [12]. The COVID-19 pandemic has necessitated lockdowns and social distancing instructions that negatively influence the worldwide economy. Additionally, this crisis has caused the postponement of most essential world activities [13]. Because of the increasing number of patients, the available medical supplies may not support the population volume, and the healthcare supply distribution is disrupted [14,15]. The failure of the global supply chain during this pandemic has created severe scarcity in key frontline medical supplies and personal protective equipment, generating distress among caregivers and disturbance regarding the sustainability of the healthcare industry. This situation requires further coordination, integration, and management of the healthcare SC to reduce the devastating impacts of the pandemic [16]. Despite the importance of health management systems, SCM and inventory management receive little attention. Taking these issues into account can have a significant impact on cost as well as the quality of healthcare [2,17,18]. For supply chain management and control, numerous tools have been developed and used in the logistical revolution that fits logistical processes with the requirements of the new manufacturing process. The technologies used in the supply chain can be defined as "*tools and technologies that can be implemented for integrated management of the supply chain within and beyond organizational boundaries*" [19].

1.1. Knowledge gap

Research on supply chain management in healthcare has highlighted the potential positive and significant effects of innovative tools in SC visibility and healthcare sector performance [20–22], the influence of digital technologies on the implementation of novel solutions [23], the impact of technology on business model innovations in the supply chain [24–26], and the overview of barriers and challenges in adopting digital technology [27–29].

Based on the literature, innovative technologies can impact considerably; nonetheless, the literature demonstrates that the utilization of these tools is still in a growing stage [30]. Thus, supply chain management studies face challenges related to novel technology usage. One dominant obstacle identified in the literature is the absence of a resilience strategy informing policymakers about the application of innovative technology in the healthcare sector [31–33].

During the COVID-19 pandemic, there has been debate about whether the implementation of digital technology enhances efficiency and supply chain performance [16,34,35]. Given the current knowledge gap and because a healthcare sector's prosperity is essentially related to the performance of its supply chains, there is a need for policymakers to formulate an appropriate response. Therefore, disaster management activities with innovative tools are necessary for evaluating needs, forecasting demands, and managing inventory. Moreover, most currently available papers have concentrated on various technological disasters [20], while the pandemic issue has been neglected by researchers.

1.2. Research question

The literature has looked into a variety of supply chain disturbance reduction techniques, most of which focus on demand management, supply management, process enhancement, SC integration, and capital adequacy methods [36]. Although different research has been conducted on SCM in healthcare, the literature recommends that a comprehensive study be conducted to identify technology-driven resilience strategies in the healthcare supply chain [37].

Currently, contributions by different studies have concentrated mostly on investigating resilience strategies and have tried to classify their nature [38–40], but detailed information regarding particular activities for dealing with emergencies, like Covid-19, is lacking. This research aims to bridge the knowledge gap in the healthcare SCM literature concerning the use of innovative technologies for risk management, which leads to the following research questions:

- What are the main technologies for supply chain management in healthcare?
- What are the main application domains of the supply chain in healthcare?

1.3. Research implication

The knowledge gap addressed in this research is essential, as SCM studies and professionals have acknowledged the expanding application and influence of innovative tools to make business value and represent this value by obtaining a competitive advantage in the healthcare industry [41]. The importance of adopting these emerging technologies such as block chain [42,43], artificial intelligence [44], cloud computing [45], big data [46], and robotics [47], is emphasized in the SCM literature [40]. This research attempts to propose some resilience policies with novel technologies for SCM in healthcare by considering lessons learned from the COVID-19 pandemic. The proposed insights could help healthcare policymakers broaden their horizons to resilience and efficiently make suitable decisions in case of possible future crises.

The rest of the paper is organized as follows: Section 2 is dedicated to the research methodology, the result of SLR is presented in Section 3, the discussion of the paper will be in Section 4, Section 5 is dedicated to research opportunities, and Section 6 is related to research contribution; the conclusion is presented in Section 7.

2. Methods

2.1. The research steps

The literature review approach was conducted in multidisciplinary sectors to determine supply chain management and identify resilience strategies for disruption management in healthcare pandemics. Here, we take the approach used in Ref. [48]. The main research goal was to identify key strategies for mitigating supply chain disturbance for different healthcare supplies during pandemics. In the current SLR, an eligibility evaluation was conducted after the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process. PRISMA has the advantage of defining a clear research question, identifying inclusion and exclusion elements, and covering a large database of scientific literature. As a result, this methodology can assist researchers in locating relevant studies on mitigating resilience strategies for disruption management in the healthcare SC during pandemics by digital technologies. Furthermore, the standards assist researchers by providing guidelines and references for locating high-quality reports in the studied research area. As shown in Fig. 1, this SLR was conducted in 3 phases. Each phase is demonstrated in the next parts.

Step 1 **Planning the SLR**: In this phase, the researcher defined the purpose of this SLR and performed the next activities that are subsequently explained in detail.

1.1. **Determining the need for SLR**: Based on the vast number of papers on technological innovation in the supply chain, it is clear that the utilization of these tools in the healthcare context has been a crucial issue. Ascertaining the critical application domain of technological innovation in healthcare SC is essential for upcoming investigations.

1.2. **Defining research question(s)**: To develop an extensive view of the aforementioned issue, the main aim was divided into these research questions:

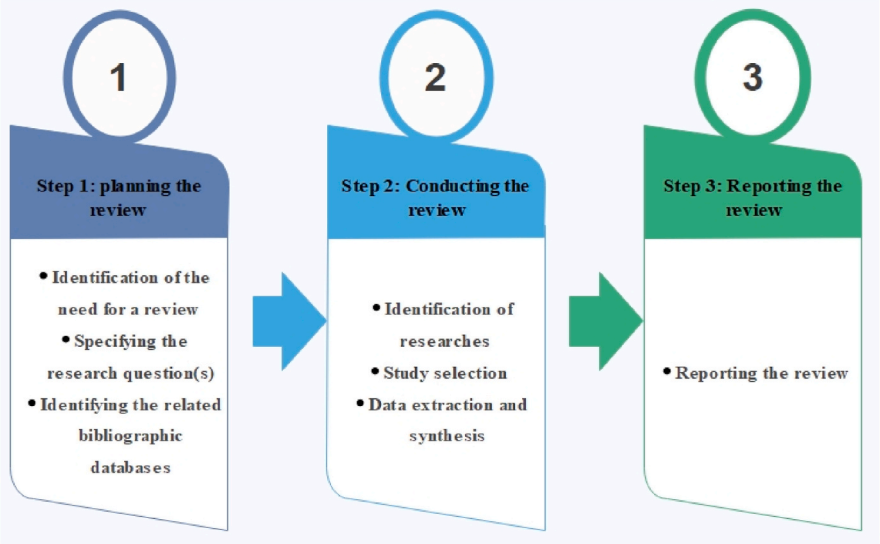

Fig. 1. Systematic literature review steps and details.

- What are the main technologies for supply chain management in healthcare?
- What are the main application domains of the supply chain in healthcare?

1.3. Identifying the relevant bibliographic databases

Scopus and Web of Science, considered in this study, are two reliable databases forming a large source of research in the healthcare, business, and management disciplines. From the papers identified in a search, it was determined that Scopus encompasses all the papers from Web of Science. Scopus was searched using article title, abstract, and keywords. The initial search, conducted on June 20, 2022, yielded 1040 papers in the English language within the subject areas of engineering, business management, science technology, operations research, operations management, transportation, computer science, healthcare, and medicine. The first two authors of this study reviewed the data obtained from scanning the titles, abstracts, and keywords and eliminated 866 articles by analyzing the dataset for the exclusion criteria listed in the following section.

Step 2: Conducting the review

To determine the search string, keywords matching the research questions were extracted, and synonyms pertinent to the major terms were selected. The whole set of search string was drafted as follows:

The keywords in this study included: ("Supply Chain") AND (COVID-19) AND ("Resilient*" OR "Robust*" OR "Disruption*" OR "sustainability") AND ("innovative technologies" OR "Predictive analytics" OR "Big Data" OR "Industry 4.0" OR "Big Data Analytics" OR "block chain" OR "internet of things" OR "IoT" OR "Additive Manufacturing" OR "3D Printing" OR "RFID" OR "Cloud computing" OR "cyber-physical system*" OR "Sensors" OR "smart factory" OR "advanced robotics" OR "artificial intelligence" OR "Supply chain analytics" OR "digital technologies*" OR "digitalization") AND ("Health care" OR "Hospital" OR "Medicine" OR "Vaccine" OR "Drug" OR "Personal protective equipment" OR "Blood").

2.2. Study selection

The authors reviewed the abstract, introduction, and conclusion of the articles and selected those written in English and meeting at least one of the following criteria:

- Any article pertinent to any research methods such as empirical, case study, modeling, or analytical.
- The idea of supply chain disruptions, resilience, or robustness by technology-driven strategies in healthcare, must have been covered in the article.
- Studies introducing novel technological tools in healthcare supply chain resilience, whether evaluated or not.

The exclusion criteria comprised:

- Any article not categorized as a peer review article (editorial or industry report) or review article.
- Any papers written in a language other than English.
- Any papers not pertinent to the convergence of innovative tools and healthcare supply chain resilience and disruptions.
- Any papers without the full text.

2.3. Data extraction and synthesis

To extract the pertinent data from all suitable papers, a data extraction approach was applied to get the answer to the research question. To answer the research questions, various approaches were applied. In general, a narrative combining method to answer different research questions was used. Moreover, different visualization methods like tables and charts were applied based on the research question.

RQ1: To answer this research question, the most prominent technological innovations in the healthcare supply chain were identified.
RQ2. To answer this question, the most important domains of the supply chain in healthcare were identified.

3. Results

3.1. Distribution of publications per year

The search of the two databases identified 1040 candidate records as depicted in Fig. 2. After that, inclusion and exclusion criteria were implemented, which resulted in 540 papers being selected. After reviewing the title, abstract, and keywords, only articles that met merely one of the inclusion criteria were accepted, leaving 164 articles. Eventually, 35 articles were utilized to get an answer to the research questions (See Appendix 1). These studies described supply chain management in healthcare crises. Fig. 3 demonstrates the rising demand

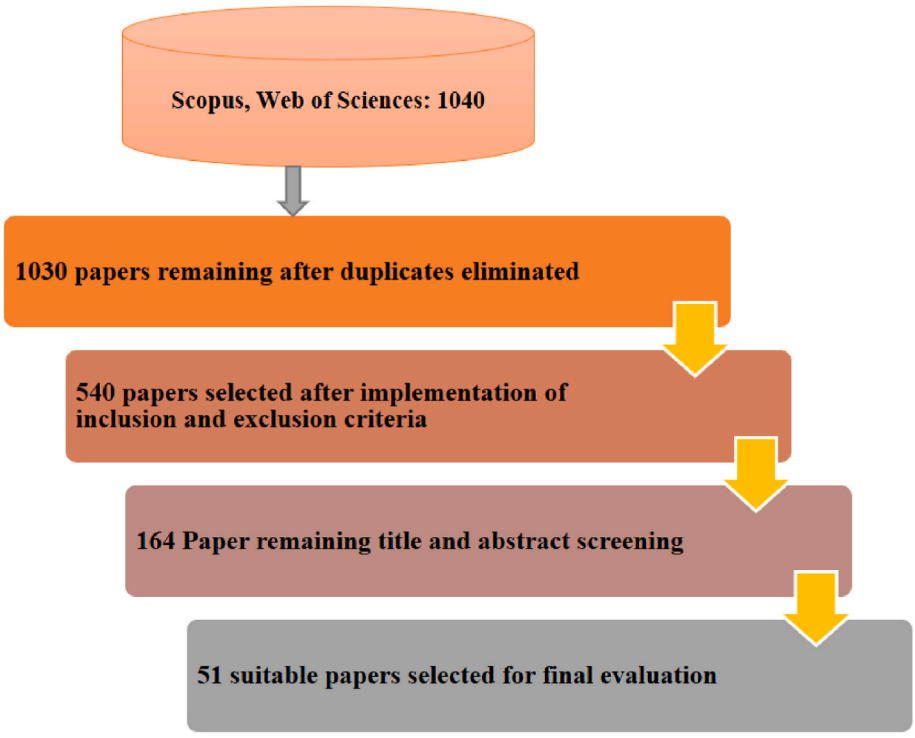

Fig. 2. Flow diagram pertinent to the current SLR and inclusion and exclusion criteria.

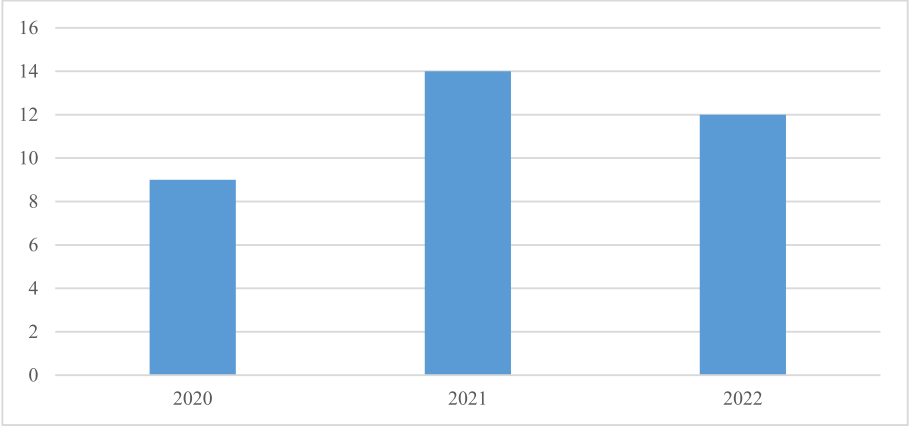

Fig. 3. Distribution of research papers per year.

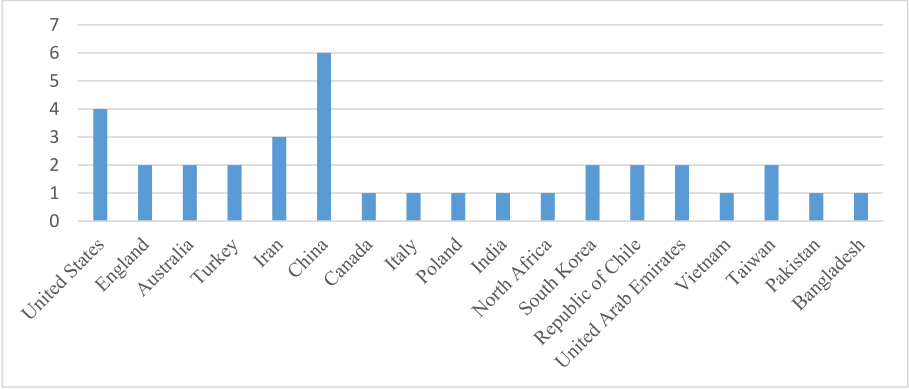

Fig. 4. Distribution of publications per country.

and popularity of healthcare SCM in COVID-19, although the number of relevant articles decreased in 2022. Even though not as many research and case studies have been conducted in healthcare industries compared with other industries, a clear trend seems to have arisen in the implementation of technology-driven approaches for SCM in healthcare during pandemics.

3.2. Distribution of articles per country

Fig. 4 demonstrates the distribution of articles by country. According to this figure, the United States and China published most of the papers about the technology-driven approaches in SCM in healthcare.

3.3. Technology-driven strategies for supply chain management in healthcare

Artificial intelligence (AI), block chain, big data analytics, and simulation were the most important technologies used in SCM in healthcare. Artificial intelligence is defined as the potential of machines to imitate the capabilities of humans [49]. To perform the analysis, we first identified all scientific articles that proposed an extensive and full list of AI methods in practice and the literature. Studies by Ref. [50] offer a set of AI methods and their functions. Moreover [51], represents a comprehensive classification of AI methods as a reference work applicable to various objectives. For example, Araz et al. [52] proposed a plan for decision-making for extensive vaccine distribution activities. The proposed method supports the decision-making process for large-scale vaccine distribution, and also supports the organization of pandemic response plans through the study of interventions and policies. Accordingly, Kannan Govindan [34] proposed a decision support system based on a fuzzy inference system to manage demands in healthcare SC. This approach can classify the population and manage the demand in healthcare SC during outbreaks. The deep learning method was also determined to be a suitable solution for demand forecasting in pandemics [53]. Furthermore, machine learning methods were used for vehicle routing and scheduling models to ensure minimal response time in COVID-19 [54]. Therefore, AI and machine learning methods were seen as prominent techniques for reducing supply chain disruptions in healthcare; these tools can help the quick recovery and anticipation of future pandemics.

Block chain technology was also vastly employed in the reviewed papers. This technology is an immutable, tamper-proof distributed ledger technology (DLT) activated in a mutual and contemporary setting where all transactions are authorized by end-users and are identifiable. It creates a dispersed setting where all the users of a network can collaborate securely without the obligation of a trusted authority. Hence, it decreases the need for a central authority employing a distributed consensus to validate and store all transactions [55]. Previous studies have also shown that block chain technology offers immutability, audibility, and integrity in the SC process in the healthcare industry [42,43,56,57]. Zoughalian, for example, points out the promising properties of block chain technology in distribution networks, especially in the pharma industry, at which transparency, integrity, and data validity are crucial for monitoring agencies and combating the circulation of fake therapies to provide a sustainable health service [58]. Accordingly, based on Yuriy Kamenivskyy et al. [59], block chain technology reduces the transmission of fake vaccines and vaccination records, improves communication between chain participants, enhances supply chain security, and accelerates the inventorying and handling of vaccination procedures. Further studies have emphasized the value of block chain technology in ensuring data integrity and nonrepudiation in the distribution of vaccines [60].

Block chain technology can assist the healthcare sector in establishing a secure information-sharing model to decrease the concerns of hospitals sharing health data and acquiring up-to-date information to adapt their production, guarantee their medicine delivery capacity, and upgrade their collaboration capacity to withstand disruptions created by global crises. This information also can be used to demand management, justify the assignment of medical resources, and enhance the flexibility of the supply chain.

Prior research also highlighted that big data analytics has been applied in different sectors to make the supply chain more resilient. Big data analytics is the process of applying sophisticated statistics to any type of electronically stored data, such as but not limited to "*messages and updates, posted on social networks, readings from sensors, and GPS signals from cell phones*" [61]. In peer-reviewed studies, Yi git Kazançoglu et al. [62] illustrated the challenges to circular economy (CE) in the healthcare industry using big data tools and providing solutions to barriers. The results support managerial, policy, and theoretical applications that will promote initiatives for sustainable development in the healthcare industry.

A simulation is defined as "the imitation of the operation of one system or process through the operation of another." It is a simulation of an actual system [63]. In the reviewed papers, Shirazi et al. [64] provided a four-echelon SC finding for blood collection centers and determining the allocation of temporary or permanent facilities to hospitals. Fernando Rojas also analyzed how the skewness and kurtosis of the distribution of demand data, obtained through sensors, affect the modeling of stocks of hospital pharmacies' COVID-19 treatment-related products [65]. Due to their inherent resilience, short-term disruptions have little impact on SC operations and performance but long-term disruptions can be highly devastating to supply chain efficiency, service levels, and customer satisfaction.

Based on the aforementioned innovations, the literature also discussed the significance of the technologies such as 3D printing, Internet of Things (IoT), and computerized physician order entry (CPOE). One revolutionary and innovative technology in the digital industry is 3D printing. Direct digital manufacturing, fast manufacturing, and additive manufacturing are terms used to describe 3D printing. It is a cutting-edge piece of technology that uses a digital design file that can be printed out in three dimensions [66]. Some of the reviewed articles discussed the effect of 3D printing on healthcare SC. Regarding the capabilities of 3DP in the pandemic and future post-pandemic age, this research emphasized the sector that can assist in managing emergencies like pandemics and determines gaps where more research is needed [67]. This article also emphasized the utilization of additive manufacturing to boost hospital flexibility and the use of the Internet to disseminate the benefits more quickly than would typically be possible with traditional supply chain procedures [68].

A concept known as IoT makes use of sensor networks. The ubiquitous presence of devices like radio-frequency identification (RFID) tags, actuators, mobile phones, and sensors is the core idea behind IoT. Wearable technology is a crucial part of IoT [69]. Furthermore, in government, enterprise, and at the user level, the reviewed papers developed a viable application system for intelligent medicine [70,71]. IoT technologies can be used to anticipate and adapt to peaks in demand and respond promptly to market changes. In this way, the application of novel IoT-based tools will provide the possibility of anticipation of disruption in healthcare, limit the disruptive impact, and ensure uninterrupted supplies.

Using CPOE is a satisfactory solution that is recommended in Ref. [72]. In this method, uninterrupted personnel scheduling, SC integrity, continued provision of clinical services, adaptive use of IT tools, and determining educational programs are provided.

3.4. Distribution of publications per application of supply chain in healthcare

To determine the application of SC in healthcare using thematic content analysis (Appendix 1), five central themes were identified: vaccine supply chain, personal protective equipment, drug supply chain, blood supply chain, and healthcare delivery strategies.

3.4.1. Vaccine supply chain

The vaccine SC is a set of steps essential to getting vaccines from producers to final users for administration. Strengthening the vaccine SC is vital to making the necessary vaccines accessible for the immunization of a population [73]. Walwyn [74] evaluated South Africa's public-private cooperation for the localization process of vaccine research. In this research for handling vaccine SC, the researchers concentrated on the advantage of public-private cooperation, which encompasses skills development, technology transfer, localization, and preservation of a valid and well-organized supply chain. Moreover, Lamanna et al. [75] provided an M-Health method based on short message Services (SMS) that permit healthcare workers in rural areas to send vaccine stock amounts to an online platform. The results showed that this method can accumulate follow-up data. In addition, Tanvir Alam offered practical tips for stakeholders and government policy-makers internationally to determine the major difficulties of the COVID-19 vaccine SC [76]. Some studies used block chain technology for COVID-19 vaccine allocation. The suggested approach reduces the circulation of fake vaccines and vaccination records, enhances communication among distribution chain partners as well as supply chain security, and streamlines vaccine inventorying and managing procedures [59,60]. The other research proposed a fuzzy technique for order preference by similarity to ideal solution (FTOPSIS)-fuzzy weighted intersection (FWI) method; in the COVID-19 pandemic, this method was used to determine possible alternative suppliers [77].

3.4.2. Personal protective equipment

Healthcare supply chains should be constantly controlled and the pandemic response challenges clarified [75]. Throughout the COVID-19 pandemic, there has been tremendous scarcity in the materials and pharmaceutical SC, such as personal protective equipment, medicines, testing kits, respirators, gloves, gowns, and other necessities. Based on the literature [75], there are five essential elements for an immune supply chain system, namely flexibility, traceability, persistence, global independence, and equity. Flexibility requires strategic resource planning for every requirement that might arise during disasters. Traceability highlights that supplies should be tracked with valid tools to protect against hoarding. In addition, this data must be efficient in decision-making according to data created using a visibility system. It also should be able to identify opportunities and threats for SC to avoid possible inefficiencies. In addition, global independence is the main element for creating agility in the supply chain. Finally, an equitable system is driven by some ethical concepts that respond to needs and enable the screening and distribution of supplies. Some important considerations for the regulatory framework of certification of personal protective equipment can be seen in Ref. [78]. These reflections can be used in investigating the structure of international regulations and rules about essential PPE and allocating a set of tests that should be deemed essential in a pandemic.

A game-theoretic method to schedule PPE orders in healthcare institutions is proposed in Ref. [79]. In this game, each institution enhances storage utilization to keep personal protective equipment costs at a low level. According to a survey conducted with actual data at the National Health Services (NHS), the problem of securing PPE supply in a crisis like the COVID–19 pandemic can be solved by using an appropriate inventory management process. This game-theoretic-based model can diminish peak demand significantly if adopted to an unsteady personal protective equipment utilization profile. Furthermore, Kwan et al. provided a report that outlined interventions to diminish the total personal protective equipment utilization rate throughout the initial phase of the pandemic. This program demonstrated a successful method for monitoring and controlling the utilization of personal protective equipment in the healthcare setting, and the interventions were confirmed to be efficient [80]. In addition, Sonu Bhaskar et al. [16] offered a method that demonstrates main stockpiles and elevates production effectiveness by advanced analytics and novel technologies such as block chain. These technologies serve as a driving force for improving supply chain efficiencies.

Jennifer Cohen et al. [81] investigated four major factors behind PPE shortages in the US during COVID-19: First, a dysfunctional budgeting approach in healthcare facilities; second, a large demand shock caused by the needs of the healthcare system; and third, the federal government's failure to keep and allocate domestic inventory. Finally, disruptions in the worldwide SC for PPE have considerably affected PPE export to the United States. In addition, the lack of suitable federal measures to keep and distribute domestic supplies and the serious disturbance of the PPE global SC exacerbated the problem.

Providing efficient deployment and inventory design to enhance personal protective equipment availability in a fuzzy environment has been proposed in Ref. [17], and the utility of these methods is examined in this study. The proposed approach provides practical and theoretical insights into institution-wide deployment and storage decisions for a variety of engineering and medical institutions. In addition, Adam L. Gordon [82] explored challenges for nursing homes and residents identified in the response to COVID-19. They made it clear that PPE for home care in a pandemic is not optimal and that better integration of procurement and supply is essential. Also, Terri Rebmann investigated whether the SC for PPE is still broken and if the PPE needs to be reused or disinfected [83].

3.4.3. Drug supply chain

Despite the existence of evidence regarding the advantages of adopting supply SCM for a notable competitive advantage and cost savings, the healthcare industry has taken a long time to adopt these techniques. Research ensures that 46% of the health system operating budget goes to logistics activities [84]. Enormous variability was observed in the design of SC and drug distribution, and the fact that previous actual results were in sharp contrast was controversial. Moreover, the academic research supporting successful design implementations of SCM programs and recommended best practices is limited.

Edward Faiva et al. [85] examined the attempts and challenges of a drug shortage in Nigeria during the COVID-19 pandemic. They recommend that suitable measures be taken to guarantee ethical procedures in the manufacturing, importation, pricing, and distribution of pharmaceuticals to prevent unavoidable events in pandemics. In addition, assessing the crisis in the pharmaceutical market in the era of COVID-19 and determining the short-term and long-term impact of the pandemic on the pharmaceutical sector were surveyed [86]. Based on the results, the short-term effects of COVID-19 infectious disease include changing demand, regulatory changes, and changes in the R&D process, telecommunications, and the shift to telemedicine. In addition, slowing industrial growth, delayed approvals, shifting drug supply chains to self-sufficiency, and changing ethical dilemmas and trends in the consumption of health market products are seen as the long-term effects of the COVID-19 infectious disease on constrained sectors that may occur.

Fahian Huq et al. [36] focused on intrinsic, exogenous, and environmental supply chain disruptors and their relative importance in constructing the global supply chain. Their paper explores strategies that make up various supply chains for Western pharmaceutical companies and provides a framework for assessing the extent of disruptors related to the outsourcing or placement of manufacturing procedures in Western Europe. The authors found that the five main elements of which managers must be aware when constructing the supply chain are quality defects, unexpected random delays in the manufacturing process, difficulty in order processing, timely product processing, and the discrepancy between shipping, market demand, and supplier response. Furthermore, Sabegh et al. [87] introduced a multi-purpose mathematical approach to pharmaceutical SC for natural disaster response, taking into account quality and green concepts. The administrative implications of this study were focused on elevating the effectiveness of healthcare SC, saving time, diminishing costs, reducing environmental effects, and efficient use of resources.

3.4.4. Blood supply chain (BSC)

The BSC coordinates the passage of blood products from donors to patients through five steps: the donor, a mobile collection station, the blood center, demand nodes, and the patient [88]. The waste of these products is unpleasant because of the scarcity of blood products and the costs related to operational processes. Therefore, it is essential to optimize the blood SC operation process. The reviewed papers have presented a generalized Nash equilibrium method of SC network competition between blood service organizations [89]. This method was also used on a set of numerical data to demonstrate the effects of disruptions in donor decreases along with reductions in vital link capacities like testing and processing blood product prices, demands, and total revenue of blood service firms.

The two-step probabilistic programming method for red blood cell supply chain management developed by Hosseini-Motlagh [90] considers two goals for this model. The first goal is to meet all demand while minimizing the overall cost of the SC, including fixed costs, operating costs, inventory holding costs, waste costs, and transportation costs. The second goal function is to diminish the number of substitution units. Saman et al. [91] provided a two-step preventive policy by which the disruption risk is reduced by fuzzy analytics for determining supplementary blood facilities, cooperating in production procedures, and decreasing interruptions. The proposed method is a controlling approach that can be extensively applicable in disasters.

3.4.5. Healthcare delivery strategy

The gap between increasing demand and availability of the finest, low-cost, and timely medical care remains a difficulty all over the world. Trained community healthcare professionals improve access to necessary healthcare services in situations where the healthcare sector lacks the ability to properly provide [92]. Siekman et al. [93] investigated the value of community-based health systems to ensure continued treatment of children's illnesses during the Ebola crisis. They recommended that in crises, providing education on infection prevention and strengthening drug supply chain management are necessary.

A study to determine the impact of maritime disruption transportation to hospital-based acute healthcare supplies and personnel was conducted in Ref. [94]. According to this study, significant drawbacks for hospital-based acute care encompass the shortage of data on existing supply chains, the absence of official planning and agreements, and insufficient local supply repositories and labor force. Resolving the complicated interrelations and competing agendas of disaster response requires multi-sectoral engagement.

The effect of a significant disruption on SC performance was studied by Ref. [1]. The results revealed that in case of a long-term disruption, enabling a backup supply is an effective mitigation method. In the case of a small, short-term disruption, it determines a suitable method to mitigate the impact of disruptions on minor increases in transshipment costs.

The drive-through COVID-19 test site is an efficient method for fast collecting samples in suspicious cases while minimizing risk to healthcare professionals and patients. Nevertheless, the lack of test kits and a limited number of medical staff cause many logistic and operational problems, such as long delays in sample collection. To overcome this challenge, it is crucial to first understand the disease's epidemiology. Araz et al. [52] presented a mathematical method to reduce the waiting time for patients to acquire essential services. The method they proposed not only helps support large-scale sample collection and decision-making on vaccine distribution activities, but also assists in the evaluation of interventions and policies and develops infectious disease response plans. This framework assesses the dynamic development status of public health data and enhances operational decisions. The decision support system introduced in this paper is very useful for practicing and visualizing, gaining insight, and making smart decisions.

Botchie [4] conducted in-depth interviews with people in charge of disaster management practices to investigate key factors in the successful operation of post-disaster operations management in Africa. Employing thematic data analysis techniques, they managed these elements and categorized them into nine topics: management, resources, politics, governance structure, socio-cultural, education, training, infrastructure, and stakeholder participation and cooperation. In addition, Kannan Govindan [95] provided a decision support method based on the fuzzy reasoning method to help demand management in healthcare SC. As a result, this system is applied to classify members of the community, manage demand accordingly, and control the occurrence of an epidemic in the healthcare supply chain.

Moheimani et al. [96] introduced and implemented a new approach for estimating the agility level of disaster management in healthcare. The outcome approved the capabilities of this method in hospital assessment, based on the hospital's agility factor and geographic observation. It also provides some indicators for measures hospitals can take to increase the level of agility in crisis management.

Based on research by O'Sullivan et al. [97], risk and resilience in healthcare are essential requirements for the prevention of COVID-19. The recommended strategies require specific risk assessments and communications that take the local context into account. In addition, pandemic resilience requires skilled primary healthcare groups with adaptable responses to create pandemic healthcare flows. The response comprises adopting novel prevention, screening, and ambulatory methods to protect healthcare providers from exposure while reducing patient screening and continuing healthcare for the vulnerable population.

An emergency drug closed-loop SC study was conducted to examine returning unused factors from the emergency center to the hospital [98]. The researchers' investigation into central decision-making revealed that a central decision-making system is more effective in controlling expiration dates and costs. Furthermore, to prompt reaction to a disturbance in drug distribution, Yuhe Shi proposed an interruption management approach to cope with the disruption of cold chain logistics created by disturbance events and create health supply distribution safety [99].

4. Discussion

4.1. Technology-driven strategies for supply chain management in healthcare

Identifying the key strategies to mitigate supply chain disturbance in pandemics for different healthcare supplies is currently receiving increased attention [100]. Because of the increasing number of available research, some studies have employed rigorous and systematic methods to review studies in this field. To prevent repetition and provide comprehensive reporting of the situation in the research, we have determined and analyzed 35 papers that rigorously reports the findings up to 2022. The major results of the review are summarized as presented below.

It was determined that none of the 35 reviewed papers applied empirical methods for collecting and analyzing data; most of the studies used mathematical methods, researcher opinions, and interview and case study methods. The absence of empirical methods is a problem identified in most of the research on examining key strategies to mitigate supply chain disturbance in healthcare during pandemics [100]. Opinion-based methods using simulated data may create useful data at the onset of pandemics. Nevertheless, researchers should go further, using empirical data to conduct a rigorous study to show how the COVID-19 pandemic has influenced a variety of topics pertinent to the supply chain, and how these effects can be controlled by confirmation from real-world data. Research teams can use both exploratory techniques like focus groups and Delphi and quantitative techniques like investigation-based models.

We acknowledge that the studies considered in this study were conducted in various geographic locations. Some of the papers simply

considered the context as an example and did not gather empirical data. Thus, it is proposed that the scope of national and industrial levels be diversified in upcoming research. It is also recommended that comparative research of developed and developing nations be conducted. This research may bring to light useful data on whether the effects of COVID-19 differ in a variety of organizational and technological contexts. Furthermore, this research provides an idea of how contextual elements affect the results of COVID-19.

Many businesses are evolving from remote controlling to management, upgrading, and advanced autonomous AI-based methods to increase productivity [49]. Supply chain management is widely regarded as one of the probable disciplines to utilize artificial intelligence methods. Despite AI's long history, its capability of resolving difficult issues and searching for information in the SCM domain has not been fully realized. Several leading initiatives have aimed to launch AI solutions in the SCM domain. Fuzzy logic, neural networks, decision trees, and genetic algorithms, in particular, have been widely used to solve supply chain management challenges concerning inventory management, location planning, and scheduling issues [101–104].

It is becoming highly essential for SC stakeholders to benefit from automated supply chain procedures. Along these lines, artificial intelligence has been proposed as a valuable decision-support facility that assists the healthcare industry in connecting its customers and supply chain partners by promoting data interchange by different business parts through the supply chain. Despite the existence of AI over the years and its recent development in the supply chain management domain, its relevant technologies have not been properly utilized to tackle supply chain difficulties, as their implementation is either too costly or impossible to accomplish due to their intrinsic complexity [49,105].

Block chain technology has the possibility and flexibility to be employed in different SCM settings. Block chains can promote SC information transmission, making supply chain management more reliable and secure. As a result, this method is considered a boosting technique for identifying counterfeit pharmaceuticals in worldwide trade [106,56]. The findings of the current review revealed a critical gap in the literature concerning block chain-SCM integration in emerging economies. Block chain–SCM applications are still in their primary phases in the healthcare sector within different countries, and this could be a factor for limited awareness about the relevance, development, implementation, and benefits associated with this trend. Our research further revealed that there is a scarcity of empirical studies reporting on the implementation lessons and the main challenges.

Block chain technologies will positively affect the quality of life and also decrease the cost of the healthcare system [57]. Furthermore, block chains illustrate a cutting-edge tool that promises to transform established business models. From a social-change perspective, block chains are already remodeling relationships between customers and organizations as well as business-to-business relationships without an intermediary to validate the transaction [106].

Big data analytics has altered the healthcare setting through data analysis and management [107]. In other words, healthcare is one of the most promising sectors in which big data analytics can be applied. Big data analytics can diminish healthcare prices, forecast disasters, and help avoid communicable diseases. Demand forecasting using actual data is achievable, further assisting to diminish expenditures by increasing customer satisfaction and elevating the healthcare industry's usefulness.

4.2. Distribution of publications per application of SC in healthcare

Based on the current results, healthcare SCM in pandemics concentrate on the five domains of vaccine distribution, personal protective equipment, drug supply chain, blood supply chain, and healthcare delivery strategy.

Throughout an outbreak, efficient and effective vaccine distribution is essential to prevent an explosive rise in infections [108]. Vaccine supply is important to reducing the potential loss of infectious diseases. One important concern is whether the constrained supply chain can be sustainably expanded in a crisis. Since the outbreak began, numerous studies have extensively investigated the COVID-19 vaccine. According to the results, the inadequate number of vaccine manufacturers, lack of coordination with local agencies, the long distance between vaccine stores and vaccination camps, scarcity of financial support for vaccination costs and vaccination purchases, and difficulty in tracking the population are critical issues in vaccine SC. Failure to master determined issues can have serious consequences [109]. Vaccine supply chain research generally gives us a unique perspective into supply chain management. Vaccine supply chains in developing and developed countries differ significantly, particularly at the distribution stage. As a result, inventory management literature should concentrate on developing countries with unreliable power systems and transportation.

Personal protective equipment (PPE) is equipment or clothing that an individual wears to protect themselves from infection. However, during the COVID-19 crisis, rising demand, low product quality standards, and disruptions in the global SC for PPE have endangered the lives of the public as well as front-line healthcare professionals [77]. The Department of Homeland Security's Supply Chain Registrar's Guide for 2018 and 2020 states, "*The most effective way to send supplies to disaster-affected areas is to rebuild pre-disaster supply chains.*" Creating resilience in SC systems and rapidly providing recovery are two most important issues in responding to different disasters [110]. Based on the articles reviewed, we need access to real-time data, such as database dashboards, that illustrates the current situation of supply chain supplies. A material system that tracks the location, quantity, expiration date, and location of materials in the medical supply chain is essential. Furthermore, the main elements of the immune country's medical SC system are flexibility, traceability, transparency, sustainability, and responsiveness [110].

Other studies have highlighted criteria for emergencies, such as the essential safety requirements of PPE, and norms and provisions that allow rapid intervention in ever-changing situations and can include a variety of peculiarities. Considering low-resource settings is among the main directions of research papers, as low-resource areas are usually characterized by the absence of medical evidence, a shortage of specialized expert personnel, and a lack of medical supplies, pharmaceuticals, and spare parts because of supply chain hazards [78].

Communication and the training of staff in control and management of PPE consumption are necessary for the healthcare industry to cope with PPE shortages in times of crisis [111]. Absence of transparency in inventory SC and vagueness in transaction actions are considered to be some of the other important obstacles to supply chain distribution [16]. During a pandemic, the security and capacity of global SC systems are the main challenges. Thus, tools like block chain and big data analytics can serve as a driving force for building robust supply chain models of the future. Block chain technology has been found to automate the task of connecting suppliers directly to the organization as connectors to stakeholders, automating auditing and reporting of process-related tasks, and removing intermediaries. These technologies can form the main agenda for increasing the effectiveness of supply chains. Increasing government coordination of supply and distribution across hospitals and local and state governments in different countries has also been emphasized by studies [81].

In the pharmaceutical supply chain, different supply chain disturbance mitigation strategies consist of demand management, supply management, product management, process improvement, supply chain integration, and equity ratio strategies and are being reviewed in various studies [36]. In addition, the top four obstacles of which managers need to be aware when constructing a supply chain are quality weakness, unexpected disruptions to manufacturing processes, order processing issues, and inconsistencies between market demand and vendor response to the timely delivery of products. Organizing the pharmaceutical supply chain is critical, but it requires different objectives and

compound constraints to address environmental and operational issues [87,112].

Efficient management of the blood SC is critical and challenging for blood service organizations. Blood is an essentially volatile product that complicates blood supply chain planning. These elements encompass blood product perishability and longevity differentiation, blood product supply, demand uncertainty, and multiple blood types. Furthermore, several environmental factors, like disruptions in the blood SC, have affected the overall network's fulfillment and added to the difficulty of blood SC planning [90].

Healthcare strategies must develop resilience measures, such as strengthening community-level preparedness to reduce the need for hospital-based management of epidemics. Furthermore, current cross-disciplinary emergency planning groups should be formed or employed to evaluate healthcare SC planning for the sophisticated dependencies and competing procedures in responding to an epidemic [94]. The healthcare process has a variety of players, including donor organizations, non-governmental organizations, governments, the military, logistics service providers, and suppliers [94]. The medical environment is associated with many different practices with various missions, interests, abilities, and logistics expertise, and it faces many challenges. These challenges range from human material, internal to external issues, and non-technical issues and consist of operational coordination, warehouse coordination, transportation coordination, management, human resources, politics, finance, education, information, tools, resources, and environmental and cultural issues. Therefore, it is necessary to draw the attention of researchers to identify these issues [4].

Another important success in the field of infectious disease management and administration is the *sharing of information* with various institutions that support crisis management. This study found that effective collaboration and communication with disaster management actors are essential to achieving success in management and administrative practices. Financial resources for disaster management are considered the most important factor. General education for disaster management and training of field workers are required. A sufficient supply of medical facilities, road networks, and telecommunications networks is critical to successful crisis management. During a pandemic, healthcare assets and people should be tracked and traced. Using tracking technology may reduce errors in inpatient care. RFID technology enhances healthcare providers' capability to track the kind and amount of supplies used for each patient [113,114].

In this regard, technical considerations; data management, security, and privacy; organizational and financial problems pertinent to RFID-assisted medical plans in the event of a disaster are important. Supply chain integration promotes the effective and efficient flow of products, finance, and information throughout the supply chain to maximize the profits of the entire network of suppliers, manufacturers, distributors, and customers. RFID technology can contribute to supply chain integration in terms of information flow, facilitating accurate, timely, and secure movement of information between members of the supply chain. Researchers have agreed that technologies like big data analytics, IoT, cloud computing, robots, and block chain will have a great impact on SC processes. These tools allow for improved performance characteristics such as being more efficient, faster, more flexible, more reliable, more transparent, more visible, and more traceable [115].

5. Research opportunities

Article analysis presents many opportunities for future research in healthcare SC management during pandemics. Since the beginning of COVID-19, several systematically and methodologically sound articles have been published, but there is still a lack of research to identify the key strategies to mitigate supply chain disturbance in pandemics for different healthcare supplies.

Following the thematic consolidation of the articles, and taking into account the existing literature on the occurrence and disruption of previous epidemics in the healthcare supply chain, this section proposes several important areas that still need to be investigated. While some researchers investigated the effect of COVID-19 on healthcare supply chain interruptions, none have ever comprehensively investigated all likely short-time, medium-time, and long-time effects of interruptions. Future research will need to consider a variety of products such as blood products, PPE, and medical devices to explore these effects.

The capability to prepare and provide critical functions in times of interruption, recover from that interruption, and adapt to the shape fit by the new present is measured by supply chain resilience [12]. The reviewed papers proposed several resilience strategies including resource allocations, reforming supply chains, and collaboration among different parts. This demonstrates that current methods to help supply chain resilience may be practical in worldwide disasters like COVID-19. Nonetheless, it is obvious that COVID-19 has seriously affected healthcare SC; it has demonstrated the vulnerability of these supply chains, and necessitated the development of better resilience approaches. Therefore, additional research is required to determine how the strategies recommended in past research can assist in handling healthcare supply chain challenges that arise during a pandemic and in better integrating these approaches to manage the consequences of COVID-19.

In past research on COVID-19 diseases, some literature has recommended that tools like block chain, IoT, and 3D printing could be applied to control the effects of the pandemic. The literature declares that these tools may help quickly increase the construction of PPE, ventilators, and other necessary supplies in the medical supply chain [68,116]. Research for the utilization of other state-of-the-art tools will assist in enhancing supply chain elasticity and sustainability. Such studies can help us recognize how these tools can help control the pandemic disruption.

Most studies have investigated the applicability and advantage of utilizing emergency techniques to control the impact of COVID-19 disease; however, recent studies examining the use of new technologies to manage disruptions and ensure resilience are particularly rare. During epidemics, we realize that there is a lack of studies examining how advanced tools can assist in delivering last-mile supply chain-related issues. Therefore, future research should investigate how technology can be used to improve responsiveness and reliability and to control this last-mile delivery through an epidemic.

In the event of a pandemic, information sharing in the healthcare SC is critical; retailers, suppliers, and manufacturers confront this issue in an SC by sharing information on customer demand, inventory levels, and distribution [117]. Furthermore, one of the most serious problems in SCM is the absence of data for decision-making. Information technology has a critical role in enabling decision-making through information sharing in the SC. These technologies include decision Support systems (DSS), CPOE, and Electronic Health Records (EHR). Information sharing promotes cooperation in the SC to manage material flow effectively and diminish inventory costs. In the reviewed papers, there is rare research related to developing information systems to strengthen supply chain management. As factors such as lack of data standards, insufficient visibility, and poor quality of available information are significant information technology system challenges in the SC, it is recommended to conduct research based on implementing cloud-based technology in healthcare to facilitate internet-based supply chain management systems.

In our analysis, we found that none of the researchers applied empirical methods to gather and analyze data; most of the reviewed papers were based on researchers' opinions or employed mathematical models, interviews, and mixed methods. Some papers applied quantitative methods with no empirical data. At the start of different pandemics, the quantities method using simulated data can create proper information for key policymakers. Currently, it is necessary to conduct precise research utilizing empirical data to determine real world situations of how pandemics influence different parts of the healthcare SC

and how to employ the practical evidence used in the real-world supply chain to control such impacts. Using different methodologies, like case studies, focus groups, and Delphi techniques, can be useful.

The current results reveal that researchers were from different geographical locations. In some of the papers, only the context was taken as an example, and no empirical data was gathered. We recommend expanding the domain of different healthcare industries examined in subsequent studies. We also propose that a comparative study of developed and developing countries be conducted. This research could provide worthwhile data on whether the effects of this epidemic vary in different environments where organization and technical configurations differ.

The reviewed papers proposed sustainable SCM in the healthcare supply chain as well as intermodal railroad transportation in which supplies are transported in the same unit by various transportation methods, such as rails and roads. Intermodal railroad transportation is an effective way to diminish the environmental effects of the cold chain. These novel approaches encourage the use of combined transportation tools. High-speed trains, for example, can reduce travel time and increase time efficiency. Furthermore, IoT, with its physical, digital, and operational interconnectivity, demonstrates potential assistance for open international logistics networks. Despite these innovations, it is still difficult and rare in the medical field to implement combined rail transport for time and temperature-sensitive products. The use of combined rail transport into the SC has various difficulties, and cold chains now lack the right logistics infrastructure and technology. Greater integration, coordination, and information sharing with the various sectors in the healthcare supply chain are also needed. Therefore, it is necessary to determine the key factors that enable innovations that facilitate the adoption of combined transportation in the medical sectors with diverse actors in the medical and supply chains.

6. Research contribution

A vast number of papers have been published on studies pertinent to SLR and related to investigating COVID-19 on supply chain management issues such as sustainability and disruption [80,118–120]. This field of study is still emerging and fragmented, and it is difficult to understand from the literature what is actually happening in academic practice.

Innovative digital tools present a crucial element in helping the healthcare industry become more resilient, and these technologies also have an indispensable impact on strategic decisions. The current SLR determined dominant technologies in healthcare supply chain management and investigated practicable resilience strategies debated in studies to strengthen them [121–123]. The results of this study will be applicable to determining the most favorable disruption management strategies that can be utilized by the pertinent supply chain stakeholders to successfully address future pandemics.

7. Conclusion

In the current paper, we systematically recognized and analyzed 35 papers dealing with the healthcare SC in the COVID-19 pandemic. In addition, we examined investigations into the occurrence of different pandemics in the past and disruptions in the field of the SC and provided a unique and influential research opportunity to synthesize the findings. The analysis demonstrates that the major concentration of the literature pertained to the effects of COVID-19 on the healthcare SC and creating flexible strategies to manage these impacts. In addition, most of the reviewed papers were mathematical methods without empirical data. The results will assist researchers and policymakers to get an overview of the current literature on identifying key strategies for mitigating disturbances in the healthcare SC and determining domains that necessitate more investigation in future research.

This manuscript systematically identified and analyzed current studies on identifying key strategies to mitigate disturbances in the healthcare SC. This manuscript contributes to the research in various ways. According to the analysis, healthcare supply chain management in pandemics concentrates on six domains such as vaccine distribution, personal protective equipment, drug supply chain, blood supply chain, healthcare delivery strategy, and medical supply tracking methods.

Although this paper contributes to the healthcare SC, it also has some restrictions. In this paper, we analyzed papers published merely up to June 20, 2022 and only those in the English language; books, conference proceedings, and gray literature were not included in the current research. Furthermore, we searched Scopus and Web of Science for these papers. It is possible that some other papers not included in the mentioned databases have been ignored. Therefore, the results presented in this paper may not demonstrate the whole facts in this field.

This research can be extended by focusing on the key supply chain issues, methodological innovations, and theoretical research based on hypothesis development. Moreover, future research may focus more on the uncertainty modeling approach in healthcare supply chain operations during the COVID-19 pandemic.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

Table 1
Characteristics of the reviewed papers in the current SLR

No.	Author (year)	Country	Object	Subfield	Technology/tool	Conclusion
1	Robert Handfield (2020) [110]	USA	To provide a framework for a constellation of intelligence sources operating in the center that targets global SC risk	Personal Protective Equipment	Blockchain	It is critical to have a coordinated response, that will direct traditional and new suppliers to meet requirements and minimize hoarding.
2	Khaled Abedrabboh (2020) [79]	England	Offering a game-theoretic method to organizing PPE orders	Personal Protective Equipment	Game theory Big data analytics	Providing PPE dedicated storage space may be a sustainable solution to avoid straining PPE supply chains.
3	Ozgur M. Araz (2020) [124]	USA	Recommending a decision-making structure for vaccine distribution operations	Healthcare delivery strategy (Mass testing)	Machine learning Artificial intelligence, Genetic algorithm	The proposed method not only facilitates decision-making for vaccine distribution operations but it o assists in the creation of global epidemic response procedures.
4	Sonu Bhaskar (2020) [16]	Australia	Proposing an approach that employs predictive analysis and Block chain to	Personal Protective Equipment	Block chain	Block chain technology can enhance the efficiency of supply chains.

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Table 1 (*continued*)

No.	Author (year)	Country	Object	Subfield	Technology/tool	Conclusion
			identify essential stockpiles and increase productivity			
5	Elifcan Göçmen (2020) [17]	Turkey	Proposing a suitable distribution method to maximize PPE allocation in a fuzzy environment	Personal Protective Equipment	Machin learning model -Artificial intelligence, fuzzy logic	The suggested model guarantees both practical and theoretical perspectives of storage and distribution decision-making throughout all disciplines.
6	Kannan Govindan (2020) [95]	Iran	Proposing a DSS based on a fuzzy inference system to demand management	Healthcare delivery strategy(Demand management)	Decision support system - Artificial intelligence, fuzzy inference system (FIS)	A DSS was proposed to classify community members and demand management in the healthcare supply chain.
7	Robert A. Moye (2021) [72]	USA	Sharing risk mitigation experiences in the COVID-19 pandemic	Pharmacy Practice	CPOE	The pharmacy's integrated clinical practice framework allowed for continuous personnel scheduling, supply chain integrity, and educational program continuation.
8	Belinda O'Sullivan (2021) [97]	Australia	Investigating rural primary healthcare response during the COVID-19 in risk, resilience, and response	Healthcare delivery strategy(Primary healthcare)	Telehealth	Mainstream pandemic initiatives should identify the dimension of rural environments and recognize funding and support strategies per each stage of rural risk, resilience, and response.
9	Jie Yang (2020) [18]	China	Assessing the causes and effects of SC risk management issues	Healthcare delivery strategy (Health supply chain)	Block chain	The information processing capacities improve supply chain risk management capabilities, which leads to increased supply chain resilience.
10	Shahriar TanvirAlam (2021) [109]	Bangladesh	Combining the decision-making trial and evaluation laboratory approach with fuzzy sets to investigate the key challenges of the COVID-19 vaccine supply chain	Vaccine supply chain	Artificial intelligence, Fuzzy sets theory	The findings provide practical guidelines for stakeholders and policymakers worldwide in developing an improved supply chain for the COVID-19 virus.
11	Kavyan Zoughalian (2022) [58]	UK	Investigating current block chain-based distribution system solution proposals	Drug distribution	Block chain	The study states block chain technology's great potential in distribution networks, particularly in the pharmaceutical industry, for monitoring agencies and combating fake medicine circulation to maintain a sustainable healthcare system.
12	Jie Zhang (2022) [125]	Canada	Describing the significant themes of COVID-19 supply chain response in British Columbia	Personal Protective Equipment	Data dashboard	Effective and trusted leadership, unity of purpose, integrated and robust digital infrastructure and capabilities, resilience building, and environmental sensing are critical for planning for and mitigating the crisis.
13	Mario Tani (2022) [68]	Italy	Identifying the main opportunities and risks that additive manufacturing may pose to healthcare organizations	Personal Protective Equipment	3D Printing	The case demonstrates how AM can be used to elevate hospital flexibility and how, by leveraging the Internet, the benefits can be spread faster than the traditional SC processes.
14	Beata Skowron-Grabowska (2022) [126]	Poland	Determining the variables that affect the reliability of the healthcare SC regarding patient inter-hospital	Healthcare delivery strategy (Air transport of patients)	Electronic medical records	The integrated cooperation of institutions involved in transportation processes is crucial for consistency.
15	Ali Sibevei (2020) [127]	Iran	Establishing a new structural framework for assessing SC risks by a risk assessment approach	Blood Supply Chain	Social Network Analysis - Big data analytics	The analysis indicated that attempting to resolve the blood supply chain's root risks involves management skills.
16	Wei Rong (2020) [128]	China	Simulation of an infection evolving after an epidemic utilizing the system dynamics approach	Healthcare delivery strategy(Epidemic Spreading)	Simulation	The findings are as follows: (1) The number of patients can be managed by increasing the speed of the initial emergency response. (2) A quarantine policy can assist to decrease the spread of infection. (3) It is crucial to create emergency plans for managing epidemic spread.
17	Nikki Rathore (2022) [129]	India	Proposing a new vehicle routing and scheduling model to ensure minimal response time	Healthcare delivery strategy (Vehicle routing)	Machine learning - Artificial intelligence, Random Forest (RF)	The results show that the Random Forest (RF) method outperforms better than other models.
18	Yuriy Kamenivskyy (2022) [59]	USA	Providing a solution for COVID-19 vaccine distribution by block chain technology	Vaccine Distribution	Block chain	The proposed approach assists in preventing the spread of fake vaccines improve communication among stakeholders, secures the supply chain, and simplifies vaccine inventorying processes.
19	Aicha El Filali (2022) [53]	North Africa	Recommending a deep-learning approach for demand forecasting		Machine Learning - Artificial	The comparison of the test results demonstrates that the proposed

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Table 1 (*continued*)

No.	Author (year)	Country	Object	Subfield	Technology/tool	Conclusion
			based on Long-term Memory Multilayer Networks (LSTM)	Healthcare delivery strategy (Demand forecasting)	intelligence, Long-Term Memory Multilayer Networks (LSTM)	approach is the best performance in comparison with other methods.
20	Abir EL Azzaoui (2022) [130]	South Korea	Proposing an information hiding approach for data privacy in medical SC systems	Healthcare delivery strategy (Health care supply chain security)	Block chain	The use of block chain and information-hiding method can make better the security and privacy of data communication.
21	Jingshou Chen (2022) [60]	China	Proposing a traceable block chain-based vaccination record storage and sharing system	Vaccination	Block chain	This system has the capability of providing and ensuring data integrity and confidentiality.
22	Jingsi Zhang (2022) [131]	China	Investigating whether the digital revolution can assist manufacturing firms in improving the organizational resilience	Healthcare delivery strategy (Medical device manufacturing)	Wearable devices	Digitalization boosts organizational resilience, which in turn enhances firm growth.
23	Xingqun xue (2022) [70]	China	Exploring ways to apply information technologies to the healthcare industry	Healthcare delivery strategy(Smart Healthcare)	IoT	This article suggests a three-tiered application system for intelligent medicine: government, enterprise, and user.
24	Hossein Shirazi (2022) [64]	Iran	Designing a four-tier supply chain to identify blood collection facilities and determine how collection centers are assigned to the temporary or permanent plasma-processing site	Blood supply chain	Simulation	The results demonstrate that as the plasma demand elevates the number of system costs and flow time rise, too.
25	Cristian Salazar-Concha (2021) [132]	Republic of Chile	Proposing an approach to prediction of blood donation intent	Blood supply chain	Decision Tree Algorithm - Artificial intelligence	The findings demonstrate that the intention to donate blood again can be predicted with 84.17% accuracy.
26	Fernando Rojas (2021) [65]	Republic of Chile	Evaluating how the distribution of data collected data by sensors influence the modeling of hospital pharmacy product inventories	Drug supply chain	Simulation	Researchers conclude that the demand statistical distribution's asymmetry does not affect hospital pharmacy product inventories.
27	Ilhaam A. Omar (2021) [133]	United Arab Emirates	Proposing a block chain solution by smart contracts to automate the contract process for Group Purchasing Organizations (GPO)	Healthcare delivery strategy (Medical supply chain)	Block chain	The analysis shows that the suggested approach is feasible because the stakeholders pay a small transaction fee.
28	Xuan Hung Nguyen (2021) [134]	Vietnam	Investigating the relationship among SC risk, integration, resilience, and firm performance in the pharmaceutical industry	Pharmaceutical supply chain	Artificial intelligence,	SC integration is critical in the pandemic to ensure performance and SC risk resilience.
29	Aamer Nazir (2021) [67]	Taiwan	Determining the importance of 3D printing in crises and the post-COVID era	Personal Protective Equipment	3D printing	This study outlines the aspects which can help m emergencies and critically discusses the research gaps to fully utilize the possibilities of 3DP.
30	Iram Mushtaq (2021) [135]	Pakistan	Introducing a two-tiered pharmaceutical SC with hospitals, pharmacies as customers and various pharma-distributors as suppliers	Pharmaceutical supply chain	Multi Criteria Decision Analysis - Artificial intelligence, Principal Component Analysis	This investigation takes into account the expertise of experts to determine an aggregate score of priorities to make an informed decision.
31	Chenxi Lian (2021) [136]	China	Developing a theoretical method to expand supply support organizations' shared networks during an epidemic	Health care delivery strategy (Public Health Emergency)	Network analysis - Big data analytics	The research results emphasize the roles of organizations in the development of cooperative networks and in creating theoretical structures for policymakers to use in motivating social cooperation in an emergency.
32	Hee Kyung Kim (2021) [137]	Korea	Investigates the relationship between digitalization and supply chain performance in healthcare manufacturing companies	Healthcare delivery strategy (Healthcare manufacturing)	Artificial intelligence,	Social capital formation in the supply chain can aid in the visualization of the global supply chain and has a positive impact on real-time information sharing among key elements of those chains.
33	Yigit Kazançoglu (2021) [62]	Turkey	Identifying the barriers pertinent to Circular Economy (CE) in the healthcare	Healthcare delivery strategy (Health care sustainability)	Big Data	According to the results, managerial, policy, and theoretical approaches are suggested to assist healthcare sustainable development initiatives.
34	Haya R. Hasan (2021) [138]	United Arab Emirates	Proposing a private block chain-based solution to overcome the healthcare challenges	Healthcare delivery strategy(Telehealth services)	Block chain	To ensure that restrictions are enforced on-chain, registered participants are given access privileges based on their roles.
35	Toly Chen (2021) [77]	Taiwan	Proposing a calibrated fuzzy geometric mean (cFGM)-fuzzy method to order preference	Vaccine supply chain	Machine learning - Artificial intelligence- Fuzzy logic	The proposed method has been used to choose appropriate alternative suppliers for a Taiwanese foundry during the COVID-19 pandemic.

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