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Hospital Supply Chain Management: Cross-Disciplinarity Opportunities in the Post-Pandemic Era and Research Agenda

Erika Tatiana Ruíz Orjuela
Departamento de Ingeniería de Sistemas e Industrial
Universidad Nacional de Colombia, Colombia
Email: erruizo@unal.edu.co (*Corresponding Author*)

Oscar Rincón-Guevara
Departamento de Ingeniería de Sistemas e Industrial
Universidad Nacional de Colombia, Colombia
Email: oarincong@unal.edu.co

Wilson Adarme Jaimes
Departamento de Ingeniería de Sistemas e Industrial.
Universidad Nacional de Colombia, Colombia
Email: wadarmej@unal.edu.co

ABSTRACT

The COVID-19 pandemic has impacted various aspects of society, and research has been published across different sectors beyond healthcare. This article presents the results of a literature review in Hospital Supply Chain management (HSCM) to identify current and future research areas. The literature review identified four main research themes associated with the scope of HSCM, the flow type, and the approaches employed. The results of this study suggest that COVID-19 is a catalyst for short- and long-term changes that require the attention of researchers, strategies to incorporate 4.0 technologies, and integration of different stakeholders to improve the resilience and sustainability of the Supply Chain (SC) in future pandemic scenarios. This paper provides relevant information to the implementation for future research regarding the management of the HSCM for the post-pandemic period.

Keywords: *COVID-19, Hospital Supply Chain, research gaps, systematic review, , trends*

1. INTRODUCTION

A Hospital Supply Chain (HSC) manages the flow of goods and services critical to providing adequate patient service (Dixit *et al.*, 2019). Thus, as COVID-19 impacted several organizations, this created a scenario where they took unprecedented measures to prevent or minimize the dangers posed by disruptions in this chain. To solve these new challenges, healthcare organizations embraced multiple approaches, including real-time decision-making, workforce productivity, business continuity, and security risks (Davis *et al.*, 2022). The transition of society to a post-pandemic phase tests the resilience of organizations seeking to lay the foundation for the future. The COVID-19 pandemic has affected society in terms of health and well-being and commercial environments. These events had an impact that caused significant changes in all sectors, including global SC's. Disruption events were observed, e.g., shortages of Personal Protective Equipment (PPE) and supplies in hospitals, empty supermarket shelves due to food shortages and personal hygiene products, and even electronic products (Scala and Lindsay, 2021). Problems related to SC management, especially those involved with procurement, have caused significant disruption. These problems include a lack of management in adopting sourcing tactics, supplier delivery failures, risk management, and lack of transparency and visibility (Betcheva *et al.*, 2021; Davis *et al.*, 2022). These challenges are further amplified in the context of HSCM and need to be addressed. One of the main approaches found in the literature to cope with disruptions is to embed into the SC the resiliency property.

A resilient SC must respond to disruptions by either returning to how things were before they happened or changing to a more advantageous state. Diverse tactics, including cooperation between HSCM partners, the development of redundant suppliers, capacity slack, creation of demand pools, and balancing internal production and outsourcing have been suggested to promote resilience in SC (Alajmi *et al.*, 2021; Hossain *et al.*, 2022). In addition, researchers highlight the importance of Industry 4.0, Communication Technologies (ICTs) like big data, and the roles of analytics and blockchain in improving resilience (Patel *et al.*, 2022; Rashid *et al.*, 2022; Tani *et al.*, 2022). Since HSCM is receiving more attention, the literature is also growing. According to studies on the effect of technology on the administration of healthcare operations, there is a good correlation *between* the use of digital apps and healthcare performance (Tortorella *et al.*, 2022). Furthermore, research studies have examined the impact of technology on the management of healthcare operations, derived theoretical recommendations for more effective risk management, and provided anecdotal evidence on how specific HSC organizations have handled the COVID-19 pandemic. Also,

research suggests that SC practices are potentially advantageous to resilient performance in hospitals (Best and Williams, 2021; Davis *et al.*, 2022; Govindan *et al.*, 2020; Sawyer and Harrison, 2022). However, due to its novelty, research on HSCM post-pandemic is still in its development.

This paper discusses how HSCM should foster the adoption of new approaches to be more prepared and resilient to sudden disruptions in current and future events. Likewise, this paper helps practitioners and researchers to rethink how HSCM supports the strategical redesign of the involved entities to be better prepared against future disruption threats. This paper reviewed literature from COVID-19 and HSCM articles, with the following guiding questions: How does academic research address HSCM concerns during pandemics? What issues or gaps need to be worked on to strengthen HSCM? This literature review addresses those questions by examining research focused primarily on papers published since the COVID-19 pandemic began; articles are coded according to the variables under analysis. This research also includes a bibliometric analysis, which groups the pandemic HSCM literature by author, journal, and number of publications.

The results show that HSCM during a pandemic should address not only shortages of medical personnel, PPE, medical devices, and medication but also integrate the use of lean methods and technologies 4.0 to develop a sustainable HSCM that enables a timely response to disruptions. Therefore, considering these elements, building a resilient SC for pandemic decision-making is important. This paper contributes to the HSCM state-of-the-art by examining existing research characterizing benefits, challenges, and opportunities to provide insight to the involved actors when managing these potential disruptions as well as potential areas where innovative research could have a more significant impact. Additionally, this paper provides suggestions for possible future directions related to post-pandemic HSCM, which could inform the decision-making processes within organizations. The study also updates the HSCM research framework, summarizes the leading methodologies used in recent research, and proposes future research directions based on chain classification (internal and external), approaches (Macro logistics processes and Techniques), and flows. Additionally, as opposed to the earlier literature reviews, this work thoroughly examined every facet of post-pandemic HSCM instead of concentrating on only one. Further, healthcare industry practitioners interested in HSCM applications can benefit from the knowledge gathered from this study.

This manuscript has the following structure, Section 2 describes the article's research methodology, followed by the significant problems associated with HSCM, and then explains techniques and approaches employed in extra and intra-hospital logistics. After interpreting the evaluation results in Section 3, Section 4 summarizes the findings from the literature review and provides an overview of future research in the field of study. Finally, section 5 provides conclusions and additional insights into the HSCM.

2. METHODOLOGY

To answer the guiding questions introduced in this paper, manuscripts related to supply chain management in the healthcare sector during the COVID-19 pandemic were reviewed. In the first stage, a literature review was conducted based on the guidelines described by Tranfield *et al.* (2003) through the following stages: a) planning the review, b) conducting the review, and c) reporting the results. Bibliometric analysis is a pragmatic approach to examining the evolution of research fields, including topics and authors, according to the disciplines' social, intellectual, and conceptual structures (Van Eck and Waltman, 2010). The search was conducted to identify related articles from databases such as Scopus, Pub Med, and Web of Science. The protocol consists of the search equation, the inclusion, and the exclusion criteria.

Search equation: ("covid 19" OR "coronav*" OR "sars-cov-2") and ("health supply chain" or "Hospital Supply Chain" or "healthcare supply chain")

Inclusion Criteria:

- The documents registered in the main collection in the Scopus, Pub Med and Web of Science databases were included.
- Titles, abstracts, and keywords were established as search criteria.
- Documents from January 1, 2020, to January 15, 2023, were included.
- The types of documents cataloged as articles and reviews were included.
- Languages included: English.

Exclusion Criteria:

- Documents not directly related to COVID-19 and for which the source does not guarantee the reliability of the information were excluded.
- Duplicate documents were excluded, i.e., those indexed in multiple databases.
- Documents related to clinical studies, the development of medical devices, psychological support, and public health decrees or norms were excluded.

To further ensure the unbiased selection of articles, a multistage process was utilized that involved two researchers (Cumpston *et al.*, 2019) who documented the reasons for inclusion/exclusion at every step according to the following criteria:

- The objectives were clearly stated (along with a rationale for why the study was conducted).
- The methods used have been adequately described.
- The study’s findings were succinctly expressed, reliable, and the authors supported their conclusions.

These criteria ensure that a particular study's findings could be an important addition to the review. A dichotomous ('yes' or 'no') scale was used to assign grades to each criterion. In addition to incorporating chance selection, Cohen's Kappa index was used because it is appropriate for nominal coding. It is frequently employed when two coders support the agreement assessment between raters (Tang *et al.*, 2015). The Kappa coefficient was then calculated as suggested by (Cohen, 1960).

With the results obtained in the previous stage, an exploration was made regarding the issues primarily related to the impact on the HSCM during the COVID-19 pandemic, as well as the techniques, methods, or models employed. To identify new themes, a keyword analysis was performed using VOSviewer. Co-word analysis applies text mining

techniques to article titles, abstracts, and keywords. The relationship between keywords was determined based on the number of articles in which the keywords appear together (van Eck and Waltman, 2010). To perform the analysis, datasets extracted from Scopus, PubMed, and WoS databases were combined. Coding errors in sources, links, and cited references were corrected for further analysis. VOSviewer was used, which collected all keywords in the dataset and created a co-word network. These themes would aid in identifying transformational elements to rethink and potentially enable effective change in HSCM.

3. RESULT

3.1 Literature Review and Bibliometric Analysis

The results consisted of three stages; in the first stage, 111 journal articles were found, and 29 duplicate articles were excluded. In the second stage, the authors collectively read the title, abstract, and conclusions of every study that had emerged from the first stage to assess its applicability to the systematic review (82 articles). Studies categorically unrelated to HSCM during COVID-19 were rejected at this level and excluded 11 articles. Finally, at the third stage, both authors individually evaluated each of the 71 articles that were still present after stage 2 using the four criteria. The number of observed agreements for the 71 articles assessed was 64 (91%). The Kappa coefficient of agreement, which accounts for chance agreement, was also calculated. According to (Landis and Koch, 1977), the evaluations' Kappa coefficient was 0.72, which they describe as strong agreement. Before proceeding to the next stage, all differences were solved in a conversation that involved all researchers. This conversation led to removing an additional six articles, having 65 articles in the final set. In the last stage, the main findings from these articles were analyzed. This study presents a critical analysis of the relevant and existing literature on HSCM during this period of disruption to find insights to address post-pandemic risks. **Figure 1** details the review process.

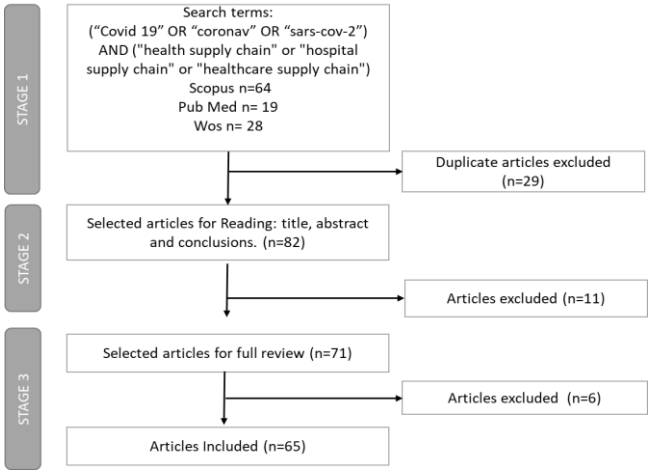

Figure 1 Stages of the Study Selection Process

According to Error! Reference source not found., the number of articles related to the management of HSCM during the pandemic has increased over time, with the USA, UK, Canada, India, and China being the leaders in the number of articles produced about this subject. In general, the geographical distribution of this research indicates that HSCM has received increased interest from higher education institutions and research centers worldwide.

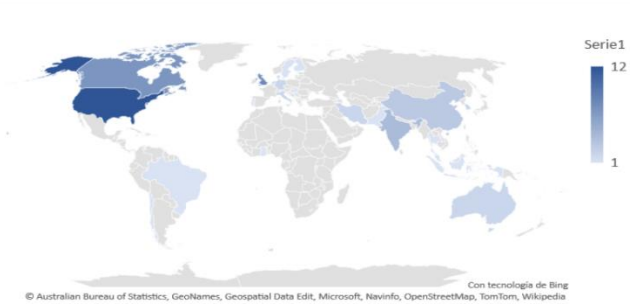

Figure 2 World Map Showing the Number of Studies About HSCM

A total of 168 authors were identified, of which 5 had at least two publications. The University of Windsor's Snowdon, Saunders, and Wright team has the most publications. Professor Snowdon is a member of the Health Supply Chain Advancement Network (SCAN Health). They are employed by SCAN, a global knowledge translation platform that collaborates with SC specialists and leaders from the healthcare industry to advance the adoption and scaling of best practices in the SC healthcare industry. In addition, they formulate tools for decision-making by improving responsiveness (Snowdon and Saunders, 2022a), integrating information technologies (Snowdon and Wright, 2022), and employing empirical approaches (Snowdon and Saunders, 2022a; Snowdon and Wright, 2022). The author's affiliations of the publications are considered to determine the main institutions contributing research results in this field **Table 1.**

Table 1 Institutions Focused on HSCM by Location

Organization/Institution	Location	Articles
University of Windsor	Canada	6
Mississippi State University	USA	2
University of toronto	Canada	2
Syddansk Universitet	Denmark	2
Macquarie University	Australia	2
University of Tehran	Iran	2
Cardiff University	UK	2
Arkansas State University	USA	2
School of Social Sciences	UK	2
Odette School of Business	Canada	2

The journal, International Healthcare Management Forum, leads the number of publications. Moreover, the top five journals have published 16 articles or approximately 33% of the published papers. Furthermore, the Journal Citation Report (JCR) database ranks these journals as Q1, Q2, and Q3 (see **Table 2**).

Table 2 JCR Raking of Main Journals Related to HSCM

Journal	Count	JCR
Healthcare Management Forum	6	Q3
Healthcare Quarterly	3	Q2
Journal of Humanitarian Logistics and Supply Chain Management	3	Q2
Annals of Operations Research	2	Q1
Computers and Industrial Engineering	2	Q1

The following network helps to understand research interests and relationships between keywords. Two themes emerged from this analysis (**Figure 3**).

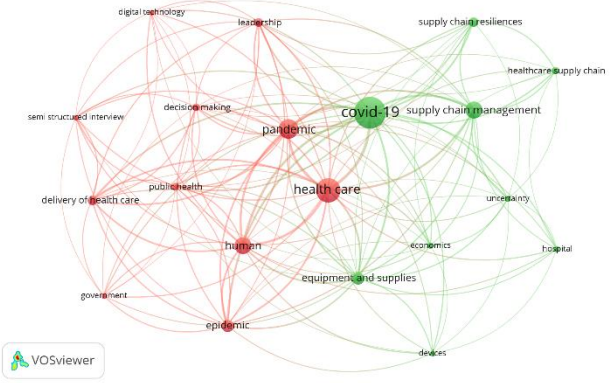

Figure 3 Keyword Co-Ocurrence Network

In general, two clusters are identified and intercommunicated by the words in the center of the map: "COVID-19" and "healthcare" which indicates a high interrelation of the keywords with the other groups: 1) external SC, 2) internal SC. Cluster 1: External SC: includes research that addresses collaboration among actors, norms, and rules associated with public health, governance, decision-making, and technology. Cluster 2: Internal SC: includes research on case studies related to hospital delivery of devices, equipment, and supplies and aspects of SC resilience. This result aligns with previous studies where the chain is classified into internal and external: the former covers the flow of patients, resources, and information within the health institution, and the latter is the study of the relationships between actors in the same hospital network (Dixit *et al.*, 2019).

3.1 HSCM Issues in a Pandemic

The COVID-19 pandemic has caused severe challenges worldwide and, in many SC's, especially in the HSCM. In low and middle-income countries, the pandemic may lead to increased poverty and restricted access to health care (Evans and Bufka, 2020). Indeed, the health sector will undergo significant changes at the economic level. In addition, major concerns have been raised related to the cost this pandemic adds to the public health system, which may increase from 4% to 40% (Popescu *et al.*, 2022). Specifically, in SC's, there are two types of risk: operational and disruptive; the incidence of this pandemic in SC's belongs to the second group, which is considered low frequency and high impact (Ivanov *et al.*, 2017). Under normal conditions, the HSCM has problems associated with the variability of patient needs, high demand for care, and different stakeholders involved in health services (Volland *et al.*, 2017; Vries and Huijsman, 2011) that the pandemic may exacerbate. Therefore, the HSCM must be flexible to adapt quickly to external changes and mitigate risk (Dixit *et al.*, 2019). In addition, significant disruptions in upstream SCs, as well as downstream hoarding and panic buying, have occurred under pandemic conditions.

The supply-demand balance is further affected by travel and commercial restrictions imposed by different countries (Betcheva *et al.*, 2021). Due to these disruptions, short-term, real-time forecasting of pandemics and their impact on the SC requires a strategic approach. Recent work has indicated that this crisis has led to the rapid deterioration of economic indicators, including productivity and global GDP (Lal *et al.*, 2022). Similarly, COVID-19 generated unprecedented challenges in hospitals as demand exceeded the current capacity of the healthcare system (Murray, 2020). The impact of HSMC in the face of the current COVID-19 outbreak has led to severe shortages of medical devices and PEE (Davis *et al.*, 2022; Sharma *et al.*, 2020). To mitigate risks and manage resource uncertainty, greater coordination, integration, and management of the global SC will be required (Grida *et al.*, 2020; Leite *et al.*, 2021).

COVID-19 increased the influx of patients to hospitals, and healthcare organizations faced unprecedented operational constraints in addressing growing demand and capacity pressures (Leite *et al.*, 2021). As the COVID-19 pandemic progresses, it exposes gaps in the SC and logistics, affecting active pharmaceutical ingredients, medications, medical devices, and vaccines (Sharma *et al.*, 2020). In addition, the World Health Organization reported severe and increased damage to the global supply of PPE, N95, disinfectants, and test kits was triggered by increased competition, panic buying, hoarding, and abuse (Nartey *et al.*, 2022). Other failures in HSCM systems have been attributed to dependence on foreign production and insufficient strategic reserves (Kumar and Pundir, 2020). The COVID-19 pandemic has tested healthcare systems worldwide and revealed several failures, demonstrating the importance of HSCM and, consequently, the well-being of individuals, families, and communities.

3.2 Approaches Employed in the HSCM During the Pandemic

During this stage, data were retrieved using a specified extraction form from each of the 65 main studies that were a part of this systematic review (see Appendix A). The main results identified in each of the categories defined for the content analysis are presented in **Table 3**.

Table 3 Approaches to HSCM, Identified From Final Set of Research Articles

Chain classification	Intra-hospital logistics: Programming of hospital resources (capacities, facilities, personnel).
	Extra-hospital logistics: Integration with suppliers, communication with stakeholders.
Approaches	Macro logistics processes: procurement, warehousing, distribution, and manufacturing.
	Techniques: Integration, lean, resiliency, decision making, logistics 4.0.
Flow type	Physical: medicines, PPE, vaccines, waste, patients.
	Information.

3.3.1 Chain Classification

the articles introduced different tools and models established to support the COVID-19 response in the context of HSCM. Fifteen percent (15%) of the articles dealt with internal logistics and eighty-five 85% with external chain

logistics. According to the research analysis, most articles address aspects related to the integration of the health SC (28%) since coordinating its internal and external links is challenging. Among these papers, the following topics can be identified: coordination mechanisms (Handfield *et al.*, 2022; Zhang *et al.*, 2022), collaboration strategies (Francis, 2020; Friday *et al.*, 2021), group purchasing (Snowdon and Saunders, 2021, 2022b, 2022a; Snowdon and Wright, 2022; Snowdon and Wright, 2022), integrating factors influencing chain performance (Betcheva *et al.*, 2021; Lal *et al.*, 2022; Nartey *et al.*, 2022; Snowdon *et al.*, 2021), application of game theory (Bian *et al.*, 2021), risk management across the different links (Dai *et al.*, 2021), and activities such as government regulation, government support, and tax cuts (Lau *et al.*, 2022).

3.3.2 Approaches

Another focus of the studies analyzed corresponds to macro logistical processes: 8% correspond to procurement, where studies on PPE forecasting (Best and Williams, 2021; Gonzatto *et al.*, 2022), supplier selection (Pamucar *et al.*, 2022), and analysis on public procurement during the pandemic (Harland *et al.*, 2021). About 3% of the studies are related to storage, location of inventory (Rastegar *et al.*, 2021), and PPE inventory tracking and control (Means *et al.*, 2020), 12% are related to distribution, formulating scheduling models to optimize transportation of PPE, vaccines, and wastes (Ash *et al.*, 2022; Bala *et al.*, 2021; Göçmen, 2022; Goentzel *et al.*, 2022; Gonzatto *et al.*, 2022; Kargar *et al.*, 2020; Tirkolaee *et al.*, 2021); use of drones to deliver drugs (Banik *et al.*, 2022; Koshta *et al.*, 2021) and a study (2%) related to internal production logistics focusing on the implementation of process modularity at HSCM (Saïah *et al.*, 2022).

Around 22% of the papers are related to logistics 4.0, such as blockchain applications (Bhaskar *et al.*, 2020; el Azzaoui *et al.*, 2022; Fusco *et al.*, 2020; Hawashin *et al.*, 2022; Vishwakarma *et al.*, 2022). Online platform design, healthcare product deliveries, and the Internet of Things (IoT) (Bag *et al.*, 2021; Boutas *et al.*, 2020a; Radanliev *et al.*, 2021; Yu *et al.*, 2021). Digital SC design uses a flexible online platform to share real-time information, improve communication with stakeholders and shorten product procurement lead times while eliminating critical gaps and failures (Boutas *et al.*, 2020; Radanliev *et al.*, 2021; Rashid *et al.*, 2022). Identify constructs that assess the relationship between big data and HSCM performance (Bag *et al.*, 2021). Identifying critical success factors for AI adoption in HSC (Kumar *et al.*, 2023). IoT equipment for distribution and storage (Sabri *et al.*, 2022). Also, there is research related to the application of smart contracts to the consumer-supplier relationship in the HSC (González and Trujillo, 2022; Musamih *et al.*, 2022).

Furthermore, 15% of the articles analyze and evaluate availability and adaptability strategies to improve SC resilience and avoid HSCM disruptions (Hossain *et al.*, 2022; Mazingi *et al.*, 2020; Opfermann *et al.*, 2021; Scala and Lindsay, 2021; Spieske *et al.*, 2022) Among the strategies proposed by the studies, public-sector networks are regarded as enablers of collaboration, which is regarded as a fundamental mechanism for resilience (Friday *et al.*, 2021). All countries and sectors affected by the disruptions must coordinate their efforts (Falagara *et al.*, 2022). For example, hospital groups established central pandemic supply warehouses to improve distribution and visibility by providing supplier procurement support or leveraging long-term buyer-supplier relationships (Spieske *et al.*, 2022). Snowdon has done the majority of the work on this approach, exposing the weaknesses of the HSCM through case studies in various Canadian provinces, primarily due to a lack of participation of healthcare personnel in decision-making, resulting in shortages of vital supplies and waste of supplies (Snowdon *et al.*, 2021, 2022; Snowdon and Forest, 2021; Snowdon and Saunders, 2021, 2022b, 2022a; Snowdon and Wright, 2022). Other studies concentrated on developing models to assess the long-term viability and resilience of HSCM in the face of the COVID-19 pandemic outbreak (Azadi *et al.*, 2022; Mazingi *et al.*, 2020; Opfermann *et al.*, 2021; Scala and Lindsay, 2021). About 9% of studies are related to the application of techniques or systems design for decision-making (Alizadeh *et al.*, 2022; Govindan *et al.*, 2020; Grida *et al.*, 2020; Sequeiros *et al.*, 2023; Suri *et al.*, 2022; Zamiela *et al.*, 2022) and finally, 2% of the articles evaluate the role of lean practices in HSCM management (Alemsan *et al.*, 2022). **Figure 4** shows the number and percentage of participation according to the focus of each of the studies reviewed.

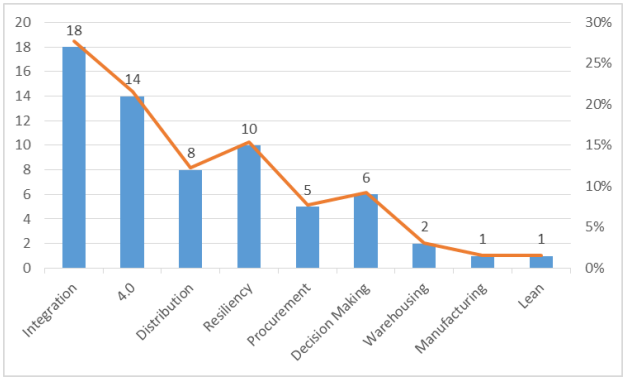

Figure 4 Study characteristics. Overall topics of the research papers.
Number of papers (n= 65) (left axis), and percentage (right axis)

3.3.2 Flow Type

Considering the definition of the HCSM that includes physical and information flows necessary to deliver a good service to patients at the lowest cost (Dixit *et al.*, 2019; Nikolopoulos *et al.*, 2021), almost 80% of reviewed articles are focused on vaccines, medication, and PPE, the remaining is distributed among waste, patients, and information. **Figure 5** corresponds to the main flows considered vital in the HSCM during the pandemic.

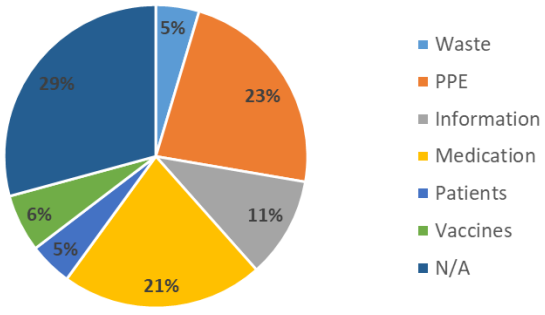

Figure 5 HSCM' Flows (n=65)

4. DISCUSSION

Considering the COVID-19 outbreak, many pressing HSCM decision-making issues have arisen, with uncertain information and different actors' involvement in solving these problems. The interaction of these elements provides several learning experiences for a post-pandemic transition that decision-makers should consider for rethinking the development of the HSCM. Currently, the world is struggling with COVID-19 variants, affecting almost every sector and causing disruptions in the healthcare sector regarding uncertainty in demand for PPE kits, vaccines, medical devices, and pharmaceuticals. As a result, several HSCM approaches have been used: supply and demand management, alliances between public and private partners, partnerships among primary and secondary health care, and patient- and staff-oriented reallocation of resources. Moreover, it is necessary to propose an agenda of research topics based on the previously defined categories (**Table 3**) to support decisions and policymakers in the HSCM-related fields.

4.1 Chain Classification

The internal HSC serves Doctors, nurses, and clinical support staff. The most common methods for distributing supplies range from requisition-based systems that rely on clinical staff participation to methods in which the hospital's central stores manage inventory and replenishment (Gonzatto *et al.*, 2022; Leite *et al.*, 2021). Par level systems, automated cabinets, and Kanban replenishment methods are popular storage and distribution methods. RFID technology has improved on this leading practice by introducing the possibility of proactively managing supplies by triggering replenishment rounds based on a variety of criteria (Arıöz *et al.*, 2022; Chtioui *et al.*, 2020; Duarte *et al.*, 2021; Göçmen, 2022; Peppa and Moschuris, 2013). The external SC includes raw material suppliers, manufacturers or production units, distributors, and intermediaries. Consider logistics when designing packaging in this chain and use economies of scale to save money on procurement (Dai and Tang, 2022; Sazvar *et al.*, 2022). Significant cost savings can be realized by managing inventory and distribution in the external chain effectively, and demand can be managed by using forecasting techniques and standardizing supplies (Azadi *et al.*, 2022; Sriyanto *et al.*, 2022; Tan and Parcia, 2022). Purchase consolidation should result in efficient order management practices (Spieske *et al.*, 2022). Preliminary resource allocation and emergency distribution planning research opportunities relate not only to optimization models but also to the need to implement more sophisticated simulation techniques (Currie *et al.*, 2020), which also consider aspects of equity (Bertsimas *et al.*, 2012). In addition, queuing theory, scheduling, and forecasting approaches should be explored in pandemic contexts for resource allocation in internal and external logistics.

There is a progression tomore advanced methods that increase the value of the internal and external chain. When there are consistent goals, processes, structures, and information sharing between departments and organizations, the HSC integration process is created (Chtioui *et al.*, 2020). Manufacturers can control inventory levels and eliminate waste through effective stock management; on-site storage of products allows manufacturers tooffer vendor-managed inventory (Shang *et al.*, 2022); and by tracking consumption at the product/location/patient level, manufacturers can identify trends as they occur and forecast more effectively (Dai and Tang, 2022; Falagara *et al.*, 2022). Collaborative SC schemes must be implemented tomeet the needs of healthcare organizations. Manufacturers reorganized their product, process, and SC offerings to manufacturing items essential to healthcare operations, such as PPE, hand sanitizer, and ventilators (Davis *et al.*, 2022).

4.2 Approaches

Risk management is important to cope with shortages of the medical workforce, PPE, equipment, active ingredients and to prepare a solid contingency plan while implementing Lean methods and Industry 4.0 technologies for a sustainable healthcare system. Therefore, building a resilient SC is critical for decision-making during pandemics (Momaya, 2020; Singh and Parida, 2022). Compared to other risks, the COVID-19 pandemic has displayed distinct characteristics such as unprecedented demand surges and supply shortages, increased volatility, and an unusually long duration (Ash *et al.*, 2022; Friday *et al.*, 2021; Zamiela *et al.*, 2022). In the context of a pandemic, resilience-related studies and investigations suggest that the primary goal is to provide uninterrupted treatment and care to patients in the event of a disruption (Sawyerr and Harrison, 2022; Spieske *et al.*, 2022). Spieske *et al.*, (2022) identify that the most important enabling properties in the SC are flexibility, redundancy, collaboration, and visibility. Standardization of products and procedures can increase the sourcing flexibility of HSCM actors and protect them from supplier failures. Healthcare Centers can increase redundancy by bringing on multiple suppliers to cover delivery gaps. Collaboration between healthcare centers and their suppliers, such as increased information sharing and co-creation, can help to mitigate risks even further. Implementing vendor-managed inventory systems can improve the visibility of an HSC product flow (Hossain *et al.*, 2022; Scala and Lindsay, 2021; Snowdon *et al.*, 2022; Spieske *et al.*, 2022).

HSCM actors have embraced new ICTs from Industry 4.0, such as big data, cloud computing, and IoT, to support and streamline medical and administrative procedures. With a technology-driven strategy that enables real-time customization of healthcare and eases the shift to a patient-centered environment, such ICTs support digitization, social media and interconnectivity of processes, products, services, and people (Hawashin *et al.*, 2022; Seddigh *et al.*, 2022; tortorella *et al.*, 2022). Infrastructure for healthcare 4.0 will establish a framework that enables healthcare systems to increase their capabilities rapidly.

There had been extensive research on using Lean in healthcare settings before COVID-19, but many studies and articles have emerged supporting the benefits. Lean can improve patient and public safety while enabling operational excellence in healthcare services, lowering risk, and improving service (Duarte *et al.*, 2021). The following lean techniques were found: standardizing of products and services across departments within the hospital reduces risk. Supply and demand may be balanced by purchasing departments, preventing shortages, exorbitant expedited freight fees, and expensive product expiration. This is made possible by timely and accurate visibility into available

inventory and production data like expiration date (Alemsan *et al.*, 2022; Chakraborty and Gonzalez, 2018; Duarte *et al.*, 2021; Khorasani *et al.*, 2020). The essential lean tools for constructing organizational resilience in the prospective areas of business operations and patient safety are value stream mapping (VSM), data analytics, and failure modes and effects analysis (FMEA) (Duarte *et al.*, 2021).

Medical supply availability during disruptions is essential; therefore, the discussion of improving SC resilience in healthcare has taken on new significance. The availability of medical supplies can be increased by distribution and procurement-related initiatives, which can also increase supply security during a pandemic (Best and Williams, 2021). Opportunities to reinvent HSCM should also consider expanding the adoption of information technologies. Overall, many opportunities are related to the digitization of industries and business models. This period has seen a prominent role of robotics, including autonomous vehicles and drones to facilitate unmanned systems applications, and has also considered a variety of technologies such as IoT, artificial intelligence (AI) 5G networks (Bala *et al.*, 2021; Francis, 2020; Ben-Daya *et al.*, 2022; Snowdon and Saunders, 2021; Zamiela *et al.*, 2022). in addition, hospitals and their staff should receive improved training and be given lean tools during a global health pandemic like COVID-19 to provide the best care to patients.

4.3 Flows

Unique bullwhip and ripple effects caused by the COVID-19 epidemic affected HSCM's upstream and downstream flows. Understanding pandemic preparedness using the SC immunity metaphor includes capacity building, clinical standards organization, materials, and information management monitoring systems (Handfield *et al.*, 2022). The most significant flow of HSCM was the accessibility of vital medications in pharmaceuticals, vaccinations, and Personal Protective Equipment (PPE). The pandemic has worsened the already strained PPE SC's and greatly boosted demand for protective goggles, medical masks, protective gowns, and gloves, resulting in shortages of several PPE (Falagara Sigala *et al.*, 2022; Opfermann *et al.*, 2021; Zhang *et al.*, 2022). Due to the complexity of the product, distribution, geography, responsiveness, and prioritization of supplies, the SC's for medicines and vaccines are difficult to manage. This knowledge guides decision-making when developing treatments and vaccines, planning immunization campaigns, and allocating resources (Adhitya *et al.*, 2022; Dai and Tang, 2022; Goentzel *et al.*, 2022; Lusiantoro *et al.*, 2022; Rastegar *et al.*, 2021). Recognizing the flows within the chain and each of its supply sources will formulate strategies to make them less vulnerable to disruptions, i.e., determining how much stock to maintain, in what form, and in what part of the chain. To eliminate dependencies on a single source and establish a flexible and adaptable SC, organizations are expected to ensure that they can obtain these supplies from their region (Dai and Tang, 2022).

4.4 Opportunities and future challenges

This study has selected several research issues that can serve as the foundation for additional research by analyzing and examining the current and previous research contributions. These research questions also point to future research agenda gaps that contributions from present studies can fill. This study has selected a set of open issues that can serve as the foundation for further research by analyzing current and previous research contributions. These issues can be thematically organized as ideas that lead to additional questions in the HSCM community. These ideas provide a research agenda the HSCM community can explore, and these are as follows:

- Cases of collaborative innovation have emerged in these sectors throughout the pandemic response; how can these practices be adapted to improve the coordination of the HSC's internal and external chains? Future studies can employ these practices and experiences to address post-pandemic health system challenges and formulate new coordination and collaboration mechanisms across actors, disciplines, and regions.
- How can traditional SC management techniques be integrated with new approaches to improve HSC efficiency? Future studies can evaluate the application of industry 4.0 and digitization technologies to improve HSC management practices.
- How can disruptions to all flows within the HSC be managed? to create resilient HSC, future work can investigate strategies that serve to establish a flexible and adaptable SC, reducing the flow disruption risk not only of materials but also of information, patients, and knowledge.
- Previous studies focused mainly on countries such as the USA and Canada, which, based on the Global Health Security Index, an index that measures the capacities of 195 countries to prepare for epidemics and pandemics, are ranked 1 and 4, respectively. What are the technical, social, and institutional factors that affect the performance of these operations in different contexts? Future studies can be conducted in countries with other performance levels, such as those in Latin America. In addition, studies can also consider human and social capital, power relations, organizational climate, and negotiation skills. Similarly, the effect of technologies to manage asymmetries between nodes can be included.
- In addition, how can the results of these studies be integrated into the countries' public policy? These circumstances provide a broad scope for researchers to work on applying of research to policy, and a concerted effort is needed between academia and the public sector to create the structures, mechanisms, and standards for effective evidence-based policymaking.
- Previous studies have focused mainly on the evaluation of economic outcomes; can the evaluation of social or environmental outcomes be considered in HSCM performance? Future studies can incorporate other performance dimensions, such as environmental and social, to measure the overall effect of HSCM practices.
- Finally, previous studies mostly applied qualitative data and research strategies, such as case studies, while rarely using quantitative techniques. What data are required for the use of quantitative research strategies? This would enable other techniques, such as simulation and optimization, to be applied in future studies.

5. CONCLUSIONS

HSCM is an approach to optimize flows (medicine, PPE, patient, and information) in SC's and can potential be very beneficial (Chtioui *et al.*, 2020). However, it also identifies some difficulties in putting HSCM into practice and areas for further study on how hospital systems might better use it. Finally, this article offers perceptions on potential HSCM future directions that may assist organizations in making better decisions. The current study aims to investigate the aspects of HSCM during the COVID-19 pandemic and offer new perspectives in the academic domains. To highlight the characteristics of the current research, a descriptive analysis using 65 papers was carried out using three search engines (Scopus, PubMed, and Web of Science) that were part of a literature review. After thorough content analysis, topics related to the external SC were identified. These topics include research on actor collaboration, norms, and standards related to public health, governance, decision-making, and technology. Internal SC: this area of research covers case studies involving the delivery of supplies, equipment, and gadgets to hospitals as well as issues of SC resilience. Furthermore, the research is divided into three main topics: 1) Macro logistics processes such as procurement, warehousing, distribution, and manufacturing. 2) Techniques: integration, lean, resiliency, decision-making, and logistics 4.0. Finally, the last topic was assessed according to 3) flow: medications, personal protective equipment, vaccines, waste, patients, and information. One of the most important conclusions drawn from the analysis was that it showed the most recent research breakthroughs with the specific processes among all participants in HSCM practices. Finally, when combined, these new findings support the update of the HSCM research framework, which included the conceptual foundation and application fields. We also summarized the main methodologies used in HSCM research today, compared our findings to earlier reviews and offered suggestions for the future.

COVID-19 highlighted the importance of SC management more than any other event in decades. The results indicate that the field is still developing and at an early stage, as there has yet to be a dominant author. In addition, researchers from different places have contributed to the field. Even with current initiatives, more coordination, integration, and management of the global SC are needed to mitigate the effects of a pandemic caused by a virus and its variants (Betcheva *et al.*, 2021; Dai and Tang, 2022; Scala and Lindsay, 2021). the focus of SC researchers during COVID-19 has been on investigating the negative effects and proposals being implemented around the world to mitigate the effects of this crisis. During the pandemic, the main problems were related to low hospital bed capacity, lack of medical resources, vaccines, PPE kits, and equipment, shortage of active ingredients, shortage of healthcare workers, and a mismatch between supply and demand (Chtioui *et al.*, 2020). The main approaches to address HSCM issues are classified according to their scope of intervention into an internal chain consisting of healthcare centers, operating rooms, pharmacies, intensive care units, and other patient care units, and the external chain consisting of healthcare service providers and the medical industry. The work also depends on the type of flow analyzed within the chain, mainly personal protection items, vaccines, and medication. Finally, the use of new technologies and logistics 4.0 equipment, as well as strategies to improve the integration of the different stakeholders and strengthen the SC's resilience and sustainability, is important for future pandemic scenarios. The complexity of HSC management provides opportunities for new research approaches. It also presents a new perspective on practices and possible research directions for the SC management community. The study results help healthcare practitioners and managers use the various models to facilitate resources along the SC and thus plan for a resilient and sustainable HSC in the future.

These discoveries advance our knowledge of HSCM in two ways. First, from the standpoint of theoretical contributions, this paper synthesized three research dimensions in the HSCM domain: chain classification, approaches, and flow type. It also summarized recent contributions from the selected papers, updated the HSCM research framework, listed the most common methodologies used in recent research, and outlined seven research directions. In contrast to previous studies, our investigation thoroughly examined every component of HSCM rather than concentrating solely on a single administrative department or nation, particularly during COVID-19. Second, from the standpoint of practical contributions, healthcare professionals might pay more attention to the HSC research's application component. Therefore, by using the updated HSC research framework and the content analysis, they can use the current research as a reference to learn about the advantages of HSCM adoption, the enhanced SC performance under various HSC instruments, the present difficulties, and the prospects of HSC among others. This study looked at peer-reviewed, high-quality papers published in Scopus, PubMed, and Web of Science. However, with the addition of other databases like Google Scholar, EBSCO, and at the Latin American level, Scielo could have been more accurate in the data's representation. Additionally, conference proceedings and book chapters were not included in this analysis, which solely included journal articles. These databases and papers can be used in future studies to provide thorough analysis findings and prevent biases and developed practical work to confirm the suggestions made.

Disclaimer: The findings and conclusions in this paper are those of the authors and do not represent an institutional position of any other organizations.

APPENDIX A

No.	Ref	Chain classification		Approach	Flow	Objective
		I	E			
1	(Gonzatto *et al.*, 2022)	X		Procurement	PPE	Predicting the demand for Personal Protective Equipment in hospitals during the COVID-19 pandemic.
2	(Ash *et al.*, 2022)	X		Distribution	PPE	Design a multi-period distribution optimization model to improve supply chain resilience.

No.	Ref	Chain classification		Approach	Flow	Objective
		I	E			
3	(Zamiela *et al.*, 2022)		X	Decision making	Information	Use multi-criteria decision-making techniques.
4	(Zhang *et al.*, 2022)		X	Integration	PPE	Identify response mechanisms to potential crises along the health care supply chain.
5-8	(Snowdon and Saunders, 2021, 2022b, 2022a; Snowdon and Wright, 2022)		X	Integration	NA	Implement sourcing strategies in seven case studies conducted in Alberta, Ontario, Terranova, Newfoundland, and Scotia.
9	(Metge and Islam, 2022)		X	Integration	PPE	Formulate a proposal for the centralization of purchases for PPE.
10	(Nartey *et al.*, 2022)		X	Integration	NA	Formulate a structural equation model of supply chain performance during the pandemic.
11	(Lal *et al.*, 2022)		X	Integration	NA	Assess the key areas of impact of the PAHO Strategic Fund related to procurement.
12	(el Azzaoui *et al.*, 2022)		X	4.0	Information	Implementing Block chain to improve communication security and privacy in the Hospital Supply Chain.
13	(Goentzel *et al.*, 2022)		X	Distribution	Vaccines	Design an optimization model to maximize immunization coverage.
14	(Hossain *et al.*, 2022)		X	Resiliency	NA	Identify drivers of resilient healthcare supply chain preparation.
15	(Handfield *et al.*, 2022)		X	Integration	NA	Propose Hospital Supply Chain immunity as a new chain capability.
16	(Banik *et al.*, 2022)		X	Distribution	Medicines	Design a support model to select an optimal drone for two specific scenarios related to the delivery of medical supplies.
17	(Saïah *et al.*, 2022)		X	Manufacturing	NA	Analyze the implementation of process modularity in the Hospital Supply Chain during the pandemic, in the case of Médecins Sans Frontières.
18	(Spieske *et al.*, 2022)		X	Resiliency	Medicines	Formulate procurement-related strategies to improve the availability of medical supplies.
19	(Pamucar *et al.*, 2022)		X	Procurement	PPE	Selecting suppliers using attractiveness measurement through a category-based evaluation technique.
20	(Best and Williams, 2021)		X	Procurement	PPE	Literature review on the management of PPE supply chains during a pandemic.
21	(Bala *et al.*, 2021)		X	Distribution	PPE	Design a linear programming-based transportation model to deliver donated PPE to health care centers.
22	(Betcheva *et al.*, 2021)		X	Integration	NA	Analyze the concepts and strategies in supply chain management to apply and adapt to health care.
23	(Bian *et al.*, 2021)		X	Integration	Medicines	Construct a game theory model to evaluate the optimal strategy of participants in a healthcare supply chain consisting of a manufacturer, a 3PL provider, and a retailer.
24	(Radanliev *et al.*, 2021)		X	4.0	Vaccines	Assess ethical issues in shared digital supply chain environments.
25	(Koshta *et al.*, 2021)		X	Distribution	Medicines	Propose the use of drones in the Hospital Supply Chain.
26	(Snowdon *et al.*, 2021)		X	Integration	NA	Identify the main characteristics of an agile healthcare supply chain.
27	(Opfermann *et al.*, 2021)		X	Resiliency	PPE	Formulate a multidisciplinary Integration approach to mitigate the effects of the pandemic on the provision of PPE.
28	(Leite *et al.*, 2021)	X		Lean	Medicines	Evaluate the role of lean practices in demand and capacity management and quality improvement in healthcare operations and the supply chain.
29	(Yu *et al.*, 2021)		X	4.0	Information	Design a model based on organizational information processing theory (OIPT).
30	(Harland *et al.*, 2021)		X	Procurement	Medicines	Analyze public procurement for the supply of medicines during the pandemic.
31	(Bag *et al.*, 2021)		X	4.0	Medicines	Formulate a structural equation model to assess the impact of using big data on Hospital Supply Chain innovation.
32	(Scala and Lindsay, 2021)		X	Resiliency	PPE	Analyzing resilience in the Hospital Supply Chain.
33	(Friday *et al.*, 2021)		X	Integration	NA	Systematic review of collaborative planning, forecasting, and resupply practices during a pandemic.
34	(Nikolopoulos *et al.*, 2021)		X	Procurement	Patients	Perform forecasting of COVID-19 growth rates with epidemiological statistical models.
35	(Tirkolaee *et al.*, 2021b)		X	Distribution	Waste	Design a mixed integer linear programming model to solve the routing problem for medical waste management in the COVID-19 pandemic.
36	(Rastegar *et al.*, 2021b)		X	Procurement	Vaccines	Design a linear programming model for inventory allocation for equitable distribution of influenza vaccines in developing countries during the pandemic.
37	(Kargar *et al.*, 2020)		X	Distribution	Waste	Design a multi-objective linear programming model for waste transportation.
38	(Bhaskar *et al.*, 2020b)		X	4.0	Information	Formulate a supply chain integration framework using block chain.

No.	Ref	Chain classification		Approach	Flow	Objective
		I	E			
39	(Grida *et al.*, 2020)		X	Decision making	Information	Solve a multicriteria decision making problem using the Best-Worst Method (BWM) and the Technique of Order of Preference by Similarity to the Ideal Solution (TOPSIS).
40	(Fusco *et al.*, 2020)	X		4.0	Information	Design a blockchain based predictive model in healthcare and SARS-CoV-2 infection to highlight the opportunities and limits of its adoption.
41	(Means *et al.*, 2020b)	X		Warehousing	PPE	Perform emergency preparedness, using the example of warehousing and PPE supply management.
42	(Francis, 2020)		X	Integration	NA	Assess the implications for supply chain management during the pandemic.
43	(Mazingi *et al.*, 2020b)	X		Resiliency	Medicines	Analyze vulnerabilities in surgical systems using examples from the current pandemic and making recommendations for future health emergencies.
44	(Boutas *et al.*, 2020b)		X	4.0	Medicines	Design a flexible online platform based on a combination of REST API and messaging technologies.
45	(Sharma *et al.*, 2020)		X	Integration	NA	Design a management framework to strengthen the medical supply chain.
46	(Govindan *et al.*, 2020)	X		Decision making	Medicines	Develop a practical decision support system based on physician knowledge and fuzzy inference system (FIS) to assist with demand management in the healthcare supply chain.
47	(Göçmen, 2022)	X		Distribution	PPE	Design a model for more efficient inventory planning and distribution to optimize PPE availability.
48	(Dai *et al.*, 2021)		X	Integration	PPE	Formulate strategies for the supply chain to operate in a resilient and seamless manner that aligns interests, shares risks, and rewards, and promotes data transparency.
49	(Kumar *et al.*, 2023)	X		4.0	Information	This study focuses on identifying critical success factors for AI adoption in HSC in the context of a developing economy. the most essential comp According to the findings, the most essential components environmental, human, and organizational features.
50	(Sequeiros *et al.*, 2023)	X		Decision making	Patients	They analyze the demand for patients before and after the pandemic using various predicting methodologies.
51	(Sabri *et al.*, 2022)		X	4.0	Medicines	Proposal to use IoT-enabled vehicles for cold medicine transport.
52	(Rashid *et al.*, 2022)		X	4.0	Medicines	A generic healthcare supply chain framework is presented, complete with algorithms that combine blockchain technology and distributed warehousing to increase transparency, improve stakeholder communication, and shorten product procurement timelines while eliminating critical disparities and failures.
53	(Lau *et al.*, 2022)		X	Integration	Medicines	Identify the primary difficulties and provide some ideas for current healthcare supply chain management methods in COVID-19 contexts in Hong Kong and the United States.
54	(Sazvar *et al.*, 2022)		X	Integration	Medicines	A multi-objective mixed-integer linear programming model is created to build a closed-loop pharmaceutical supply chain.
55	(Snowdon and Wright, 2022)		X	Resiliency	NA	The findings point to five emerging trends: supply inventory redundancy, geographic supplier diversification, and digital infrastructure maturity to provide transparency, proactivity, and distribution equity to protect everyone's lives.
56	(Sriyanto *et al.*, 2022)		X	Resiliency	NA	Evaluate the role of health care supply chain management during the COVID-19 pandemic in 42 selected Sub-Saharan African (SSA) countries. in order to contain coronavirus cases, SSA countries required to quadruple their supply chain for health-care logistics, according to the findings.
57	(González and Trujillo, 2022)		X	4.0	NA	The key discoveries are how to describe and improve supply chain performance, how to speed information flow, how to apply smart contracts to the consumer-supplier relationship in the healthcare supply chain, and the benefits that this delivers. Because of the nature of the transactions and operations required to satisfy industry needs, this sector is delivered in a timely manner.
58	(Musamih *et al.*, 2022)		X	4.0	Medicines	They offer a token-based, non-fungible approach for healthcare product management. Product ownership is maintained through digital verification, and smart contracts simplify healthcare product purchases and deliveries, reducing conflicts. Arbitrators can settle it while all relevant information is retained on-chain for audit purposes.
59	(Azadi *et al.*, 2022)		X	Resiliency	NA	A unique Network Range Directional Measure (RDM) approach was developed to examine the sustainability and resilience of healthcare SCs in response to the COVID-19 pandemic outbreak. the proposed method proposes methods for improving the efficiency of healthcare SC.

No.	Ref	Chain classification		Approach	Flow	Objective
		I	E			
60	(Alizadeh *et al.*, 2022)		X	Decision making	Patients	Use a multilevel probabilistic technique to construct a viable architecture for pandemic health networks in this study. Medical centers computed tomography scan centers, hospitals, and clinics are all included. His three objectives are as follows: Increase the likelihood of patient recovery, reduce expenditures for all network centers, and reduce coronavirus lethality.
61	(Vishwakarma *et al.*, 2022)		X	4.0	NA	This study focuses on the application of blockchain technology to enable sustainable healthcare supply chains in order to improve the performance of healthcare supply chains.
62	(Hawashin *et al.*, 2022)		X	4.0	Waste	They offer a blockchain-based system that ensures all participants' commitment and accountability, preventing them from generating unnecessary waste in registration, commitment, production, delivery, and consumption.
63	(Falagara Sigala *et al.*, 2022)		X	Resiliency	EPP	This paper examines the many interruptions that occurred in the supply chain of Personal Protective Equipment (PPE) during the COVID-19 pandemic and offers effective mitigation techniques for the pandemic's worldwide and multifaceted interdependence.
64	(Sawyerr and Harrison, 2022)		X	Resiliency	PPE	The purpose of this exploratory study is to assess the resilience of the UK healthcare supply chain from a customer standpoint prior to the coronavirus pandemic. As a core perception of supply chain resilience, use availability, resilience, resilience, and adaptability.
65	(Suri *et al.*, 2022)		X	Decision making	Vaccines	To investigate and model the obstacles encountered in the immunization supply chain during important moments such as COVID-19 in order to determine the high-priority issues affecting vaccination strains of the public.

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Erika Tatiana Ruíz Orjuela. Industrial Engineer and Magister in Engineering from Universidad Industrial de Santander, Colombia. Currently, she is a Ph.D student in Engineering - Industry and Organizations at Universidad Nacional de Colombia and also an associate researcher of the Society, Economy, and Productivity (SEPRO) research group. Her research interests include optimizing hospital logistics using metaheuristics, implementing lean healthcare, and conducting partial least squares (PLS) analysis.

Oscar Rincón Guevara. Industrial Engineer from Universidad Nacional de Colombia, Colombia. He completed his Ph.D. in Industrial Engineering at Purdue University, USA. Currently, he is an associate researcher of the Society, Economy, and Productivity (SEPRO) research group at Universidad Nacional de Colombia and a Postdoctoral research fellow at the Centers for Disease Control and Prevention, USA. His research interests include supply chain, systems engineering, healthcare delivery systems, manufacturing systems, and data science.

Wilson Adarme Jaimes. Industrial Engineer - Universidad Industrial de Santander, Specialist in Production Management and Continuous Improvement - Universidad Pedagógica y Tecnológica de Colombia, Master in Engineering - Universidad del Valle, Doctor in Engineering, Industry and Organizations - Universidad Nacional de Colombia. Professor at the Universidad Nacional de Colombia, Bogotá. Member of the of the Society, Economy, and Productivity (SEPRO) research group. He has worked in projects related to Supply Chain Management, Transportation, Inventory Management, Industrial and Health Logistics.

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