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The Drivers of Complexity in Inventory Management Within the Healthcare Industry:
A Systematic Review

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ABSTRACT

The purpose of this study is to investigate the complexities of inventory management in the healthcare industry for improving efficiency and resilience in healthcare supply chains. A Systematic Literature review using Scopus database and PRISMA approach was performed. Driven by innovation and technology, new developments are changing the face of inventory management. Predictive analytics and stock optimization are made possible by the increasing deployment of AI and machine learning. Autonomous Mobile Robots and RFID technology are being used more for quick identification and data collection, while Internet-of-Things devices are used for real-time tracking. Blockchain technology to guarantee supply chain traceability and transparency is also being investigated. Another is automation through robots, which lowers human error and increases warehouse operation efficiency. Finally, the incorporation of cloud-based systems such as SMART logistics and E-logistics platforms enables distant access to inventory information, encouraging adaptability and cooperation across various sites.

KEYWORDS

Economic Order Quantity Model, Healthcare, Inventory Management, Just-In-Time Methodology, Lean Supply Chain, Reorder Point Method, Supply Chain Management, Technology

Inventory management in healthcare plays a crucial role in maintaining patient safety and satisfaction. By carefully monitoring and controlling the flow of medical supplies, equipment, and pharmaceuticals, healthcare organizations can ensure timely access to essential resources for patient care. Additionally, effective inventory management helps prevent waste (Mahyadin et al., 2015) and expiration of perishable items, thereby reducing unnecessary costs and optimizing resource allocation. Furthermore, by leveraging technology such as inventory tracking systems and automated replenishment processes,

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healthcare facilities can streamline operations, improve accuracy, and enhance overall efficiency in delivering quality healthcare services (Moons et al., 2019).

IMPORTANCE OF INVENTORY MANAGEMENT IN HEALTHCARE

Unlike other industries, in healthcare management, each item is viewed as critical, and there is a perceived necessity to provide exceptionally high levels of service (Beier & Hoboken, 1995). Moreover, hospitals and other healthcare industry organizations need to prioritize precision over the competition, as errors in this sector can have life-altering consequences. The stakes are high, and the cost of a mistake could potentially be someone's life (Turhan, 2009). Successful inventory management provides healthcare organizations a balance between maintaining adequate stock to meet patient demand and avoiding excess inventory that can lead to waste or expiration. While managing demand and supply uncertainties can reduce inventory costs and risks to some extent, focusing on internal controls can offer a significant opportunity to minimize inventory costs and environmental impacts (Rubigha, 2020) Inventory management in healthcare is important for securing medical supplies, optimizing operational efficiency, and ultimately enhancing patient care (Lomnitz, 2023).

Components and Challenges Within the Healthcare Inventory Management System

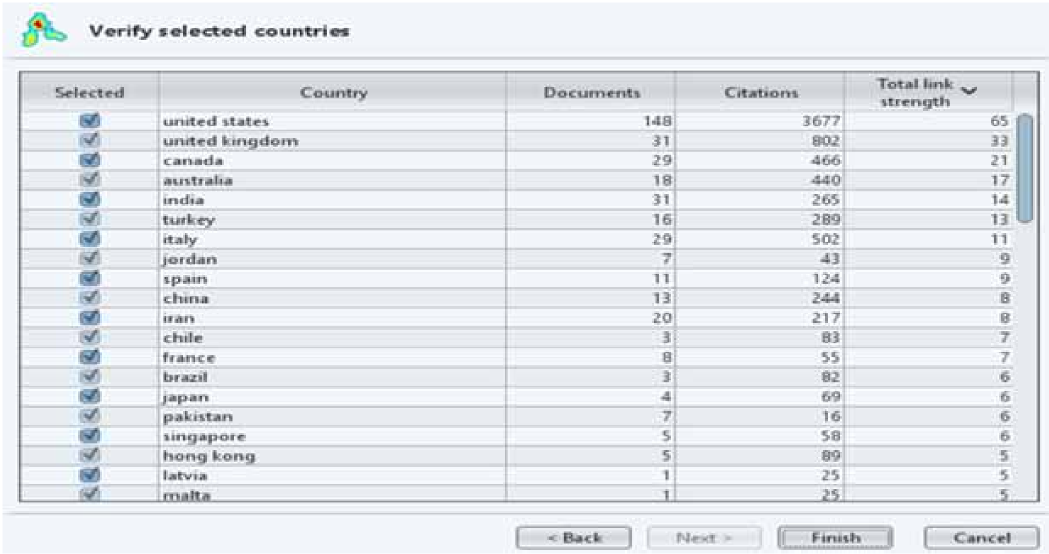
A healthcare inventory management system is marked by stages that contribute to the effectiveness and efficiency of the system. The first stage is the procurement of medical supplies. Next is the storage stage, where inventory integrity and shelf life are maintained. Next, in the usage tracking stage, consumption patterns are monitored. Last are the ordering/reordering, technology integration, and risk management stages (Lomnitz, 2023). Current models assume demand as a random variable, but factors like changing patient conditions and treatment responses impact medication demand. Limited shelf life, high costs, and the need to minimize waste complicate inventory management (Priyan & Uthayakumar, 2014). Healthcare institutions depend on multiple vendors, making maintaining connections and ensuring timely deliveries challenging, especially with limited storage space. Errors in inventory can have life-threatening consequences, emphasizing the need for accurate tracking. Decision-making challenges persist within healthcare systems, hindering resource optimization and introducing errors in the item master. Handling epidemiological challenges, supplier inconsistencies, SKU management complexities, and addressing environmental concerns in healthcare inventory management further add to the complexity. Strategies involve investing in early detection, developing flexible healthcare systems, prioritizing research, implementing dynamic supply chains, and fostering an agile healthcare system. Overcoming these challenges requires a multidisciplinary approach and collaborative efforts to standardize metrics and incentivize sustainable practices (Balkhi et al., 2022).

RESEARCH AIMS AND OBJECTIVES

This research paper addresses six key objectives outlined as follows:

Objective 1: Explain traditional healthcare inventory management and associated challenges/ limitations.
Objective 2: Identify technology management models in healthcare inventory management and their associated limitations.
Objective 3: Perform a comparison of three-echelon distribution networks and determine the impact of their efficiencies.
Objective 4: Outline the role of decision-making in healthcare inventory management.
Objective 5: Demonstrate case studies of innovative inventory management in healthcare.
Objective 6: Determine the aspects of lean and efficient inventory management in healthcare.

Figure 1. Countries with Greatest Number of Publications with Research Subject "Healthcare Inventory Management Models"



Verify selected countries

Selected	Country	Documents	Citations	Total link strength
✓	united states	148	3677	65
✓	united kingdom	31	802	33
✓	canada	29	466	21
✓	australia	18	440	17
✓	india	31	265	14
✓	turkey	16	289	13
✓	italy	29	502	11
✓	jordan	7	43	9
✓	spain	11	124	9
✓	china	13	244	8
✓	iran	20	217	8
✓	chile	3	83	7
✓	france	8	55	7
✓	brazil	3	82	6
✓	japan	4	69	6
✓	pakistan	7	16	6
✓	singapore	5	58	6
✓	hong kong	5	89	5
✓	latvia	1	25	5
✓	malta	1	25	5

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The aim of this research paper is to determine:

R1: What are the drivers of complexity in inventory management within the healthcare industry?

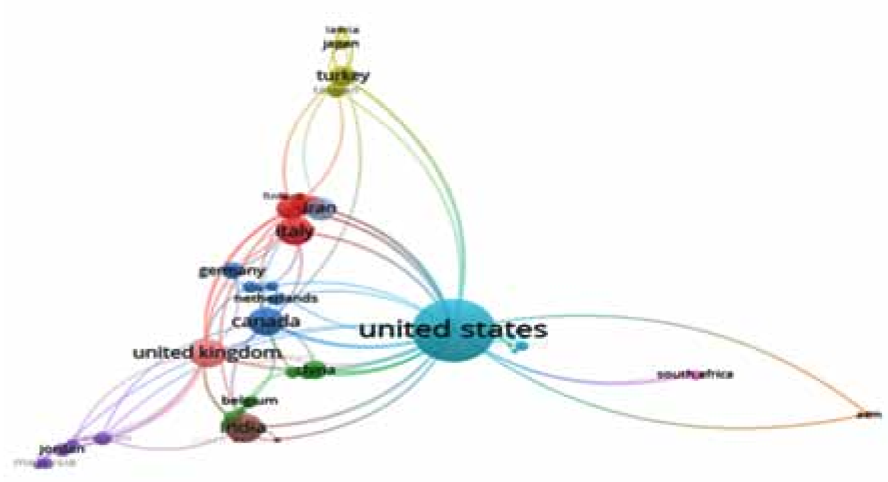
RESEARCH METHODOLOGY

We conducted a systematic analysis and critical evaluation of the literature on healthcare inventory management and its drivers of complexity for the years 1990-2023. We looked through the scholarly literature that was published in English between 1990 and 2023 and was found in ProQuest Central, Scopus, and IEEE Xplore database(s). We also looked into grey literature, which included reputable news items, trade journals for expert insights, and websites run by well-known and respected organizations. Additionally, we followed (PRISMA) guidelines (Page et al., 2021) for conducting our systematic literature reviews (SLRs) and summarizing and reporting the findings.

Following a bibliographic study, the keyword search strategy "healthcare inventory management models" was selected, and the initial search was limited to the previously designated time period. VOSviewer software was used to produce bibliometric networks based on the outputs of the Scopus database, which have been used in this study to build the different bibliometric maps. Upon exporting the advanced 401-based search results to the VOSviewer software, a network visualization was produced, as shown in Figure 1, to illustrate which country has the most the most publications in this field. Based on the verification of the 401 search results, the top 5 countries were the United States, the United Kingdom, Canada, Australia and India. The common denominators of these countries are their industrial landscapes, investments in the healthcare sector, and their lead in the technological sector.

The weight of these countries' representation in the network visualization shown in Figure 2 indicates how frequently healthcare sectors in these countries publish articles regarding healthcare inventory management models, making the USA the country most interested in researching this topic. Additionally, the connections between the circles show how linked the journals are to one another in terms of co-citation relationships, further demonstrating how the relationships influenced the articles in other nations' journals. Next, a VOSviewer mapping was completed with the phrase "healthcare inventory management models." This prompted the authors to expand the radius of SLR

Figure 2. Network Visualization



and extend the combinations of keywords used in various databases other than Scopus, as illustrated in the following sections.

Throughout this study, the existing literature was critically approached, and findings were qualitatively synthesized to provide an exhaustive summary of existing evidence related to the research question/problem. The secondary research data was collected and analyzed in relation to the objectives of this paper. It includes a thorough search to find all pertinent articles, enables a methodical integration of the data, and critiques the evidence in light of the specific research question in the databases shown in Table 1 using a combination of complementary keywords used to avoid overlooking relevant papers. We used forward and backward citations for studies. Publications that are issued between 1990 and 2023 are considered part of the literature review.

To collect data for this review, we searched 1) ProQuest Central, 2) Scopus, 3) IEEE Explore, and 4) Wiley Online Library databases using the following specified keywords in titles and abstracts, leading to the identification of 1591 relevant papers with the desired healthcare inventory management content. However, as a result of the data collection, only 48 papers were included in this research, as those were the only ones relevant to the research aim and objectives.

Additionally, conference proceedings were searched on the ResearchGate database by sorting the papers using the following keywords and limiting the inclusion criteria to full-text conference proceedings published from 1990-2023 as demonstrated in Table 2.

Data Selection

Data gathered from the 1591 references was organized into a soft copy folder in both Excel and Word formats based on the import features of the databases used. Studies whose research objectives were not entirely linked with the aim of this review and papers that did not incorporate empirical research or literature revision were removed. The subjects and substance of the articles and the inclusion and exclusion criteria were used. The criteria are the qualities that a data source must possess in order to be included in this work, whereas the exclusion criteria are those qualities that prevent a data source from being included in the article and help identify 49 pertinent journals that have been published in 1990 and 2023. Twenty conference proceeding sources were identified in three main databases: 1) Research Gate, 2) Atlantis Press, and 3) Authorea.

Given the significance of the topic, the search radius needed to be expanded to reliable industry sources and official newspapers that capture the insights of subject matter experts, and this yielded six

Table 1. Terms Used in Academic Journal Databases

Database Name	Terms			
	Terms used	Query Outcomes	Used in Paper	Reference(s)
Scopus	healthcare AND supply AND chain AND inventory AND management	268	5	(Peter Kelle, 2012), (Turhan, 2009), (Priyan & Uthayakumar, 2014), (Lee, et al., 2012), (Kafa, 2023)
Scopus	pharmaceutical AND inventory AND management AND optimization	4	2	(Uthayakumar, 2013), (Engin, 2011)
Scopus	inventory AND management AND healthcare	33	3	(Balkhi et al., 2022), (Frazier & McComb, 2015), (Ray, 2019)
Scopus	model AND supply AND chain AND medicine	8	7	(Tat et al., 2020), (Opolon, 2010), (Azevedo & Carvalho, 2012), (Heydari et al., 2016), (Friday et al., 2021), (Alghamdi et al., 2023), (Panwar et al., 2015)
Scopus	lean AND healthcare AND supply AND chain AND industry	45	2	(Habidin, 2014), (Moons et al., 2019)
Scopus	sustainability AND healthcare AND medicine AND laboratory	26	1	(Molero et al., 2021)
Scopus	machine AND learning AND inventory AND management	11	2	(Shirisha et al., 2022), (Almarzoqi & Albakjaji, 2022)
ProQuest Central	management AND supply AND chain AND Inventory AND pharmacies	38	1	(Beier & Hoboken, 1995)
ProQuest Central	healthcare AND inventory AND management	255	2	(Rubigha, 2020), (Frazier & McComb, 2015)
ProQuest Central	research AND systematic AND reviews AND literature AND agenda	62	3	(Dhaliwal & Arora, 2021), (Kinnunen et al., 2018), (Allègre et al., 2014)
ProQuest Central	systematic AND reviews AND guidelines AND data	3	1	(Taylor et al., 2021)
ProQuest Central	Inventory AND management AND perishable	61	1	(Duong, 2020)
ProQuest Central	commercial AND health AND challenges	17	1	(American Hospital Association, 2022)
ProQuest Central	Health AND supply and chains AND demand	30	1	(Subramanian, 2021)
ProQuest Central	future AND healthcare AND challenges	94	1	(Cuschieri, 2022)
ProQuest Central	future AND challenges AND health AND business	9	1	(Buttigieg et al., 2016)
ProQuest Central	impact AND Lead time AND supply AND chain	7	1	(Li et al., 2019)
ProQuest Central	internet AND of AND things AND inventory AND management	7	1	(Mashayekhy et al., 2022)
ProQuest Central	Lean AND inventory AND management	3	3	(Moori et al., 2017), (Agarwal, 2020), (Lalou et al., 2020)
ProQuest Central	inventory AND management AND demand AND hospital	3	2	(Duclos, 1993), (Jaradat et al., 2016)
ProQuest Central	lean AND healthcare AND management	68	2	(Bharsakade et al., 2021), (Pizoń et al., 2024)
ProQuest Central	impact AND lean AND inventories	10	2	(Burakhanova et al., 2023)
IEEE Xplore	Limitations AND internet AND of AND things AND healthcare	220	1	(Raza et al., 2021)
IEEE Xplore	5G AND healthcare AND future	123	1	(Cuschieri, 2022)
	Total	1591	49 sources	

Table 2. Terms Used for Conference Proceedings, e-books, Literature Reviews

Database Name	Terms used	Query Outcomes	Reference(s)
Research Gate	Content analysis or thematic analysis	Conference Paper	(Joffe, 2004)
Research Gate	Content analysis or thematic analysis	Books	(Humble & Mozelius, 2022)
Research Gate	Lean inventory management and stock	Conference Paper	(Atanasov et al., 2013)
Research Gate	Healthcare management models covid-19	Lit review	(Mishraa, 2021)
Research Gate	Perishable Inventory Management Healthcare	Articles	(Perlman, 2014)
Research Gate	EOQ model demand healthcare	Articles	(Karuppasamy, 2019)
Research Gate	Just-in-Time inventory management	Conference paper	(Mankazana & Mukwakungu, 2018), (Mukwakungu et al., 2019)
Research Gate	Inventory Management Practices performance hospitals	Articles	(Mahyadin et al. 2015)
Research Gate	Automated vehicles autonomous mobile robots	Articles	(Zhang et al., 2023)
Research Gate	Lean healthcare Replenishment System	Articles	(Landry & Beaulieu, 2010), (Agarwal, 2020)
Research Gate	Risk assessment model inventory management AHP	Articles	(Sales et al., 2020)
Research Gate	Inventory Risk Analysis	Conference paper	(Alfatin & Leo, 2019)
Research Gate	E-Logistics	Articles	(Sankar et al., 2014)
Research Gate	Smart Inventory System	Articles	(Mondol, 2021)
Research Gate	Lean Healthcare Warehouse Operations	Articles	(Venkateswaran, 2011)
Atlantis Press	Inventory Control	Proceedings	(Abdullah et al., 2020)
Authorea	Inventory Model	Articles	(Perez & Torres, 2020), (Alzoubi et al., 2022)
		TOTAL	20 sources

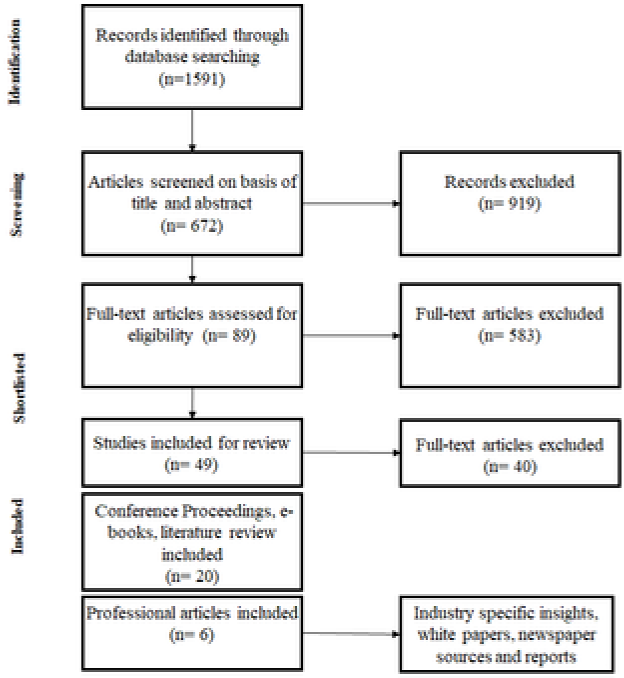
(6) supplementary sources that were included in this research: 1) UNDP, 2) IBM, 3) IdentiMedical, 4) Rishabh Software, 5) StartUS-insights, and 6) LinkedIn.

Figure 3 shows the different steps of the academic journal selection process, giving information about the 75 selected sources (academic, professional and website) that were analyzed to provide an end-to-end view of the identified healthcare inventory management content.

Data Thematic Analysis

In a systematic review, data extraction occurs after pertinent studies have been chosen and before data analysis. In addition to gathering the information needed for qualitative synthesis and meta-

Figure 3. The Systematic Article Selection Process for this Review



analysis, the primary goal of data extraction is to learn more about the selected studies, including their demographics and characteristics. We followed the proper procedures to gather data as effectively and accurately as possible. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting standards for systematic reviews and associated procedures served as our study's compass (Taylor et al., 2021). The Systematic Research (SR) phase involves extracting and analyzing pertinent data from the chosen publications via the application of content and topic analysis techniques. Content analysis is the standard approach used to analyze texts. Most content analysis produces a numerical breakdown of the attributes of a text or collection of images. Although theme analysis and content analysis are similar, the former emphasizes the qualitative aspects of the material under study (Joffe, 2004).

As shown in the results section, we first classified the chosen articles according to their published characteristics in terms of journal name, years, nations, and research techniques. First, we mapped the literature, then we examined the results and categorized them according to the respective category and paper title.

For data analysis, thematic analysis was used to detect patterns in the meaning of the qualitative data that were extracted from the literature in order to discover themes. To interpret the examined data, an active reflexivity method based on subjective experience was used. In addition, we employed content analysis as a research instrument to ascertain the existence of these themes and establish connections among the data derived from the literature study (Humble & Mozelius, 2022).

LITERATURE REVIEW

Traditional Inventory Management Models

Traditional techniques for healthcare inventory management usually involve manual procedures. Although many healthcare organizations are shifting to more modern, technologically-based solutions, some traditional methods are still in use. Traditional techniques include manual record keeping, visual inspection, manual recording, supplier-managed inventory (SMI), first-in-first-out (FIFO), barcode scanning, and the use of Excel spreadsheets. While these traditional methods have been used in healthcare inventory management for years, they are gradually being replaced by more advanced inventory management systems and technology solutions. These modern systems use barcoding, radio-frequency identification (RFID), vendor-managed inventory (VMI) and healthcare-specific software to automate inventory tracking, optimize stock levels, reduce waste, and improve efficiency. These systems offer real-time visibility into inventory data, which can lead to better cost control, reduced errors, and improved patient care (Özden Engin, 2011). It is worth noting that traditional methods rely on financial measures. Using financial measures such as cost minimization or profit maximization in inventory management may not always lead to the best replenishment policies because the exact values of these financial factors can be challenging to define. Additionally, focusing solely on financial measures may result in suboptimal decisions, such as excessive inventory levels (Duong, 2020).

Traditional inventory management methods typically use forecasting. In healthcare, while many problems are predictable, the risk remains that new and difficult-to-manage diseases may emerge. A recent example is the pandemic of Covid-19, in which healthcare resources such as diagnostic kits, drugs, and basic healthcare infrastructure were in short supply, in addition to the negative socio-economic impacts (Mishraa, 2021). Another limitation to traditional inventory management methods is excessive carrying costs. Pharmacies usually have more inventory than they need, which ties up the capital that could be used for other purposes; this is particularly problematic since healthcare products usually expire quickly, leading to costly waste. According to (Perlaman, 2014) "it is necessary to track the ages of units in stock and to plan and control the inventory accordingly," and this study includes models representing a multi-echelon, multi-supplier inventory system and unites aspects of perishability and outsourcing under deterministic demand for medical products. The study includes both perishable and deteriorating goods to determine the optimal number of products to be purchased from regular and outsource suppliers to meet the required demand at the minimum operating cost. However, because demand varies, underestimating demand can lead to stockouts, where critical supplies are not available when needed. This can result in delays in patient care, increased stress on healthcare staff, and potential harm to patients. Moreover, the use of manual processes can exacerbate problems, as they are time-consuming, prone to errors, lack visibility into inventory levels, and lack data-driven insights.

Different Cost-Based Inventory Models

Medical supplies, pharmaceuticals, and other healthcare-related items are optimally managed using cost-based inventory management models while considering a variety of expenses related to ordering, holding, and possible shortages. The economic order quantity (EOQ) model minimizes total inventory costs and is suitable for healthcare items with stable demand and consistent lead times, but may not account for demand variability or sudden changes in patient needs. A study by Karuppasamy (2019) provides a comparison among three types of time varying demand (exponential demand, stock-dependent demand, and linear demand) and concluded that linear demand gives the minimum total cost of healthcare industries Another cost-based model is the periodic automatic replenishment (PAR) model, which maintains a predetermined inventory level by ordering at fixed intervals and ensures items are consistently available, reducing the risk of stockouts. However, it leads to inefficient inventory levels for items with variable demand and may cause excessive carrying costs. The two-bin system model is also used in healthcare management, and it maintains two bins of inventory for each item – one in use and one in reserve. However, it is only suitable for healthcare items with variable consumption rates and may result in higher holding costs due to the need for buffer inventory. The reorder point (ROP) model with safety stock sets a reorder point and safety stock level to accommodate demand and lead time variability; it minimizes the risk of stockouts while accounting for fluctuations in demand and lead times and is also effective for items with variable demand and uncertain lead times. Still, it may increase holding costs due to safety stock (Alzoubi et al. 2022). Finally, the ABC analysis in healthcare classifies healthcare items into categories (A, B, C) based on their importance and manages them differently. It allows for prioritized management of high-value and critical items and ensures that vital medical supplies are given extra attention and resources (Frazier & McComb, 2015). Nevertheless, sometimes, it does not provide detailed inventory optimization for all items.

Technology-Based Inventory Management Techniques

An organization can determine when to place an order by using the reorder point (ROP) method. Quantitative strategies that need proper stock administration can be used to achieve this. Reordering at the right level is essential for maximum efficiency as well as for good retail network execution and customer loyalty. When the stock reaches a certain level, the organization will make a request using the ROP system, and it will be fulfilled immediately. ROP typically lowers stock levels, is more accommodating to desired modifications, works well with various stock types within a single company, and automatically ages recharging requests as needed. As a result, the equation [ROP is equal to Demand per day × New Order Lead Time] can be applied (Mankazana & Mukwakungu, 2018).

Just-in-time (JIT) has an impact on both the overall operation of the business and the inventory management system, and it encourages employee collaboration with management. A business can enhance its system for managing inventories. It is thus strongly advised that businesses incorporate JIT techniques into their inventory control systems. Because JIT is heavily dependent on the success of suppliers, this strategy necessitates that enterprises maintain positive relationships with their customers. Implementing the strategy is made considerably simpler and more effective by having close and trustworthy suppliers. Employers are advised to train staff prior to the complete implementation process because the JIT method will force them to reposition materials closer to the workstation and only around that work stage, changing their movements by eliminating non-value-adding steps and unnecessary movements. Workers must appreciate the importance of this strategy and how it will impact their work processes. If they do, they will be more likely to easily accept it (Mankazana & Mukwakungu, 2018).

The economic order quantity (EOQ) strategy is one that works very well for controlling the inventory of raw materials. One of the approaches most frequently used to determine the ideal level of raw material inventories required by a business to sustain steady production at an economical cost is the EOQ technique. The EOQ method is popular due to its ease of implementation and ability to offer businesses the best solutions. This is demonstrated by the method's calculation of the most appropriate time to make a repurchase (reorder point) and the costs associated with the business incurring its raw material inventory, which is determined by total inventory cost (Abdullah et al., 2020).

Limitations of Technology-Based Inventory Management Models

Notwithstanding the many advantages of the JIT methodology, it is not without its drawbacks. First, JIT may be implemented unsuccessfully due to an organizational culture that makes it challenging to adapt to change. Additionally, the majority of organizations continue to handle materials using traditional procedures, and these companies accumulate inventory to fulfill demand when it is high. These organizations typically have issues utilizing JIT; modifications to problem-solving techniques will take effect if employees are unwilling to adapt, accept, and value JIT processes and concepts. Furthermore, to utilize JIT, employees must possess a variety of abilities, including flexibility (Mukwakungu et al., 2019). The use of on-demand forecasting in computations, the forecast's imprecision, the time-consuming nature of the calculations, and the inability to verify the dependability of the outcome are the drawbacks of traditional EOQ (Yıldız & Yaman, 2018). Fixed ordering point systems have limits and difficulties despite their benefits. Among the difficulties is that EOQ doesn't consider seasonality or demand variations, which can result in either overstocking or understocking. For instance, the reorder point may be too high or too low if the demand changes abruptly, leading to extra inventory or missed sales. The inability of EOQ to maximize order quantity or inventory turnover, which can have an impact on the business's profitability and cash flow, is another disadvantage. Moreover, it would necessitate ordering and handling more often, raising the possibility of human mistake and operating expenses (Gartner, 2023). In summary, both conventional and technology-based inventory management techniques and models have their benefits and drawbacks that need to be taken into consideration prior to adoption.

Distribution Network Strategies

Distribution networks, including providers, facilities, and information systems, play an important role in ensuring the effective delivery of care to patients. For example, health insurance plans often have networks of healthcare providers that are contracted to provide services to plan members. However, health insurance sometimes affects the treatment plan. The type of insurance plan can determine which doctors and hospitals are in-network. Not all treatments and procedures may be covered by every health insurance plan. Health insurance plans often have networks of preferred providers and require pre-authorization for certain treatments. Strategies for healthcare distribution networks should be customized to the unique requirements and difficulties faced by the organization, the area it covers, and the kinds of goods and services it distributes. The distribution network must be continuously assessed and improved upon in order to maintain its status as effective, economical, and able to adapt to the ever-changing needs of the healthcare industry (American Hospital Association, 2022).

Comparison of a Three-Echelon Distribution Network and an Outsourced Two-Echelon Distribution Network

For the three-echelon distribution, the first includes the pharmaceutical or medical device manufacturer, the second includes regional distribution centers or wholesalers, and the third includes healthcare facilities (hospitals, clinics, pharmacies) or patients. Because each echelon has its inventory, medical institutions can always obtain the required supplies immediately. Although this strategy gives more control over stock levels and product integrity, it may result in higher total inventory expenses. The complete distribution process is frequently under direct control of healthcare organizations or manufacturers, enabling customization, quality assurance, and regulatory compliance. A three-echelon network can have longer lead times because of numerous distribution points and inventory management, which may impact the availability of essential medical supplies. However, it also provides for more direct supervision of compliance. For the outsourced two-echelon distribution network, the first is the central distribution center, and the second is the medical products to the end customers, which can be healthcare facilities. The company may own and run the central distribution center, but it contracts with a third-party logistics (3PL) company that specializes in healthcare logistics to handle last-mile distribution.

Better control over inventory costs and levels can result from centralized inventory management. In healthcare institutions, the local inventory may be managed by the 3PL. Because the 3PL frequently has established local distribution networks and knowledge, it may contribute to reduced lead times for local distribution and the company may take advantage of the 3PL's experience to avoid having to invest in a large local distribution infrastructure. The choice between a three-echelon and an outsourced two-echelon distribution network in healthcare depends on the healthcare organization's size, resources, legal framework, and objectives. Achieving a balance between control, compliance, and cost efficiency is critical in the healthcare business due to the distinct regulatory requirements and patient-care requirements. When making this choice, healthcare organizations must carefully assess their unique demands as well as the qualifications and experience of possible 3PL partners (Tat et al., 2020).

Impact of Distribution Network Choices on Healthcare Supply Chain Efficiency

Effective delivery of high-quality patient care depends on purchasing, storing, and delivering medical supplies, pharmaceuticals, and equipment to healthcare institutions within the supply chain. An optimally designed network can minimize the requirement for excess safety stock by guaranteeing supplies are readily available at the correct places and times. As a result, there is less possibility of stockouts and carrying expenses, especially for pharmaceuticals that represent a large portion of the cost in the healthcare industry due to the significance of these products and their storage and control requirements (Kelle, 2012). Regardless, the distribution network should be capable of responding to the variation of demand patterns. Medicine shortages and improper use of pharmaceuticals can not only lead to financial losses but also have a significant impact on patients. Many health systems and hospitals experience difficulties in achieving these goals as they have not addressed how medicines are managed, supplied, and used to save lives and improve health (Uthayakumar, 2013).

Lean supply chain management (LSCM) is adopted to improve business processes, reduce waste, reduce defects, reduce cycle times, provide fast delivery at minimal cost, and accelerate the process in identifying the best solution practices for ensuring excellence in operational and service management (Habidin, 2014). Relationships with suppliers have an impact on the distribution network's efficiency as well. Effective cooperation with suppliers may result in improved lead times, quality control, and supply chain cost efficiency. A well-designed and well-managed distribution network can improve the overall efficiency of the healthcare supply chain, ensuring that essential medical supplies and equipment reach healthcare facilities in a timely and cost-effective manner (IBM, 2023).

Decision-Making in Healthcare Inventory

Healthcare inventory decision-making involves a multidimensional approach that considers demand forecasting, criticality of items, supply chain management, technology integration, cost management, regulatory compliance, data analytics, collaboration, risk management, and continuous improvement. Balancing these factors is essential for ensuring the availability of necessary medical supplies while optimizing operational efficiency and cost-effectiveness (Subramanian, 2021).

Role of Decision-making at Operational, Tactical, and Strategic Levels in Healthcare

Healthcare organizations make decisions at three different levels: operational, tactical, and strategic. Each level has an impact on the performance and general running of the organization. Operational decisions are routine decisions related to the healthcare organization's immediate needs. It includes staff scheduling, supply chain management, and quality control. Operational decisions directly affect efficiency ensuring the smooth functioning of healthcare services. Strategic decision making refers to long-term decisions. Strategic decisions include market expansion, technology adoption, and partnerships. Strategic decisions shape the future direction of the healthcare organization, influencing its competitive position, growth, and overall success. Finally, tactical decision-making fills the gap between operational and strategic decision making. It includes research allocation, budget planning, training programs, and implementing strategies to enhance overall service quality. Healthcare decision-making is a multi-tiered process in which tactical decisions are made in alignment with medium-term goals, operational decisions are made to handle short terms, and strategic decisions are made to determine the organization's long-term vision and direction. The performance and sustainability of healthcare organizations are influenced by the efficient coordination and integration of choices made at all levels (Buttigieg et al., 2016).

Application of Operations Research Techniques to Optimize Healthcare Inventory Decisions

Operations research (OR) refers to mathematical and analytical methods that may be used to make better decisions. To determine the optimal levels of inventory in healthcare, EOQ or stochastic inventory models can be used. They help in minimizing holding costs while maintaining enough supply to meet patients' needs. Demand forecasting based on historical data and patient admission rates, for example, helps in obtaining optimal inventory levels. In addition, vendor selection, resource allocation, and risk analysis play an important role in optimizing inventory levels. Operations research techniques are versatile and can be applied across various industries and domains, including logistics, finance, healthcare, manufacturing, and transportation. The overarching goal is to use quantitative methods to inform decision-making and improve the efficiency and effectiveness of systems and processes (Perez & Torres, 2020).

Inventory Challenges in Healthcare

Current pharmaceutical inventory models in the healthcare industry assume that demand is a random variable that is independent of external circumstances. However, the demand for medications may be significantly impacted by a variety of randomly varying factors, such as changing patient conditions, an undetermined patient response to treatment, an uncertain length of stay, and a transfer from one type of hospital care unit to another at different stages of treatment (Ray, 2019). Pharmaceuticals, medical supplies, and equipment often have a limited shelf life and can be expensive. Managing inventory to minimize waste and ensure items are available when needed is a constant challenge. Much research has considered this issue, but unlike other industries, healthcare management has been slow in implementing effective business logistics concepts (Kafa, 2023). For supplies, healthcare institutions frequently depend on a variety of vendors. It might be difficult to maintain these connections, negotiate contracts, and make sure that deliveries are made on time. Moreover, there isn't much storage space in healthcare institutions, particularly hospitals. Ensuring quick access to essentials while optimizing storage is an ongoing challenge. Of course, errors in inventory management can have life-threatening consequences. Ensuring accurate tracking and labeling of items is essential.

Identification and Discussion of Inventory Problems not Covered by Traditional Analysis

In healthcare systems, the persistent challenge of indecision hampers progress, impeding critical choices that impact patient care and operational efficiency. The lack of decisive actions contributes to a stagnant environment, hindering the optimization of existing system resources. Vital assets like time, manpower, and technology can remain underutilized, diminishing the overall effectiveness of healthcare delivery. Moreover, discrepancies in the item master, which is the centralized database that contains the consumables and supplies' detailed information, further compound these issues, introducing errors and inefficiencies that compromise patient safety and financial integrity. Addressing these interconnected problems requires a proactive approach to decision-making, resource allocation, and meticulous management of item master data to foster a resilient and optimized healthcare ecosystem. Furthermore, various epidemiological features such as elevated attack rates, extensive geographical presence, swift disease transmission, minimal population immunity, genetic lineage, heightened contagion, distinctive qualities, and a significant mortality rate are observed. Conventional healthcare systems are not equipped to handle these kinds of epidemics. Therefore, they have trouble performing while under pressure. Healthcare systems weaken further when a pathogen such as Covid-19 emerges. Molecular biologists developed standardized techniques for identifying pathogens such as PCR, qPCR, and m-PCR. However, developing the techniques takes time, during which many people are impacted by the disease (Raza et al., 2021). Moreover, inconsistencies in supplier lead times and delivery performance may result in surplus inventories or stockouts, but traditional models frequently make the erroneous assumption that lead times are fixed. In addition, sometimes traditional models don't address the complexities of stock keeping unit (SKU) management. Managing many product variants or SKUs is not easy. In addition to SKU proliferation, demand forecasting errors and cross-channel inventory management might be challenging (Li et al., 2019).

Strategies and Approaches to Address Inventory Challenges

To overcome such epidemiological challenges, hospitals may invest in early detection systems and surveillance mechanisms to identify potential outbreaks as early as possible and develop flexible and scalable healthcare systems that can quickly adapt to surges in demand. In addition, they may prioritize research and development of vaccines to build immunity and implement public health education campaigns to promote preventive measures. With regard to inventory management, hospitals should implement dynamic supply chain models that can adapt to changing demand and supply conditions and utilize data analytics and machine learning for real-time demand forecasting. For example, 5G technology played a key role in COVID-19 applications by enabling efficient data exchange in Fangcang shelter hospitals and facilitating real-time contact tracing (Shen et al., 2021).

The low latency of 5G enables real-time communication and data transfer, which is crucial for applications like robot-assisted tele-ultrasound and telemonitoring during ophthalmic surgery. This advancement enhances the accuracy and efficiency of remote medical procedures by minimizing delays in transmitting critical information between the surgeon and the equipment. In relation to demand forecasting, the increased reliability and effectiveness of such remote medical technologies due to 5G's low latency can lead to a higher demand for these services as healthcare providers recognize the benefits of leveraging advanced telecommunications capabilities for remote surgical procedures. Therefore, demand forecasting models may need to account for the potential surge in demand for telemedicine and remote surgery services facilitated by 5G technology (Cuschieri, 2022).

Building strong relationships with suppliers to ensure timely delivery, establish backup suppliers, and diversify the supply chain would be a good solution for such problems. Additionally, education and training are major components that equip employees to effectively sustain inventory management systems and reproduce them across other residences on their campus (Frazier & McComb, 2015). Finally, a major step would be to develop agile healthcare systems that can scale up or down based on demand and establish protocols for efficient resource allocation during emergencies. A multidisciplinary strategy combining public health, research, technology, and international cooperation is needed to solve these intricate problems. Collaboration between communities, organizations, and governments is necessary to create resilient systems that can handle both current and future threats (Khemka & Reddy, 2023).

Consideration of Environmental Concerns in Healthcare Inventory Management

Implementing environmentally conscious practices in healthcare inventory management faces challenges, such as the absence of standardized metrics for assessing the eco-friendliness of products. The conflict between cost considerations and sustainability poses another hurdle, as greener alternatives may be more expensive. The intricate supply chains in healthcare make it challenging to trace and manage the environmental impact at each stage. Resistance to change within traditional healthcare systems and familiarity with existing procedures further hinder the adoption of sustainable practices. Overcoming these challenges requires collaborative efforts to standardize metrics, incentivize sustainable product use, and cultivate a culture of environmental responsibility within the healthcare industry (Molero et al., 2021).

The analysis of healthcare inventory routing problems (HIRP) is crucial for optimizing supply chain efficiency and ensuring timely delivery of medical goods. HIRP involves the dynamic coordination of inventory management and transportation in healthcare settings. One key aspect is the unpredictable demand for medical supplies, necessitating flexible routing strategies. Analyzing HIRP involves assessing factors such as demand variability, perishability of medical goods, and the need for specialized transportation conditions. Optimizing routes to minimize delivery time and costs while maximizing resource utilization is a complex task, often complicated by factors like regulatory compliance and patient-specific requirements. Advanced analytics and optimization algorithms significantly address HIRP by offering real-time insights, allowing for adaptive routing and enhancing overall supply chain resilience. Additionally, considering sustainability aspects in routing decisions can contribute to reducing the environmental impact of healthcare logistics. Continuous analysis and refinement of HIRP solutions are essential to meet the evolving demands of healthcare delivery while ensuring cost-effectiveness and sustainability (Lee et al., 2012).

Innovative Inventory Management Practices

By aligning inventory management strategies with competitive advantages in today's highly competitive marketplace, effective inventory management offers a potential mechanism to boost performance. Supply chain operations, inventory management procedures, and logistics networks are viewed as essential to an organization's survival and competitive edge. Improving coordination is a major difficulty when it comes to inventory management throughout the supply chain. Inventory control is critical as it determines the success or failure of a firm in the face of fierce, ever-increasing competition. Researchers have recommended adopting practices to enhance the traditional inventory management, such as process automation, maintaining precise documentation, enhanced "three-way-matching" of purchase orders, more efficient marketing procedures, better supply and demand management, invoice and packing notes, production planning and control, management of small items, reliability monitoring of improved supplier supply chain integration, automatic restriction of approved supplier, and efficient material plans.

Additionally, improved visibility into inactive inventory, decreased product expenses, minimized wastage, punctual delivery, preparation for urgent orders, improved supply chain efficiency, and stronger supplier agreements are key factors driving management's endorsement of registration. Other recommended strategies encompass maintaining current inventory levels, refining production processes, involving employees from various managerial levels, mitigating master data errors through unified registration, investing in information technology, implementing cycle counting, improving visibility into inventory turnover, fostering vendor growth, implementing real-time inventory management, and advancing budgetary controls (Mahyadin et al., 2015). The next sections address the innovations that may be adopted to enhance some of the aforementioned practices.

Innovative Inventory Management Practices in Healthcare

Automated guided vehicles (AGVs) have been employed in the warehousing and logistics sector, first replacing tractor-trailers and drivers in the transportation of products. AGVs often need operator monitoring and are dependent on rails or predetermined courses. AGVs have evolved into autonomous mobile robots (AMRs) – robots with the capacity to comprehend and navigate their surroundings. With the use of optical sensors, color bars, and track-guided magnetic systems as navigation technologies, AMRs have been included into warehouse and logistics operations (Zhang et al., 2023).

The development of Industry 4.0 technology has impacted all facets of supply chains. Businesses have recently attempted to use these new technologies to generate additional value for their operations. One of the most important parts of a supply chain that Industry 4.0 technologies have influenced is the warehouse. It is advantageous to upgrade a supply chain to an integrated supply chain 4.0. Considering how fourth-generation technology differs from other generations, it appears that traditional inventory replenishment methods are not adapting to new technologies quickly enough or handling Internet of Things (IoT) systems effectively (Mashayekhy et al., 2022).

An integral part of IoT-based inventory management systems are sensors and RFID tags. RFID is a technology that uses radio waves to identify, track, and manage objects, people, or animals remotely. It consists of three main components:

1) RFID tags: small electronic devices that consist of a microchip attached to an antenna. The microchip stores and processes information, while the antenna enables communication with an RFID reader via radio waves. RFID tags come in various forms, including passive, active, and semi-passive, depending on how they are powered and whether they can initiate communication themselves.
2) RFID readers: devices that are responsible for sending radio signals to RFID tags and receiving data back from them. Readers can be fixed in a specific location, such as a doorway or a checkout counter, or they can be handheld or integrated into mobile devices.

3) Middleware and software: an interface between the RFID system and other information systems, such as inventory management or supply chain software. They manage the data collected from RFID readers, process it, and integrate it into existing databases or applications (Dhaliwal & Arora, 2021). RFID technology offers several advantages over traditional barcode systems, including non-line-of-sight communication. Unlike barcodes, which require a direct line of sight between the scanner and the barcode, RFID tags can be read remotely, even if they are not visible to the reader. Additionally, RFID readers can simultaneously read multiple tags within their range, making them suitable for applications where many items need to be identified quickly. Furthermore, RFID tags can be more durable than traditional barcode labels, as they are often encased in protective materials such as plastic or epoxy. Common uses of RFID technology include inventory management (Kinnunen et al., 2018), asset tracking (Allègre et al., 2014), access control, supply chain management, and contactless payment systems.

A company that uses this method attaches an RFID tag to every inventory item. The tag includes pertinent digital data together with a unique identification number. To scan these tags, extract information, and transfer the data to the cloud-based linked system for processing, an RFID reader is needed. The RFID reader shares its information with the cloud-based system. It evaluates the information, adds a time stamp, and combines it with the reader's location information. The cloud-based solution uses this integrated data to provide real-time updates on inventory movements and pinpoint the precise position of every inventory item. Using PCs, laptops, or mobile apps, this technology enables organizations to remotely monitor and control inventories, improving inventory visibility. RFID tags, RFID antennas, and RFID readers are the three primary components of RFID technology. RFID technology and Industrial Internet of Things (IIoT) are combined in IoT-based inventory management systems. IIoT provides producers with total insight into their industrial processes through the deployment of smart sensors. Its function in inventory management is to transform the RFID-collected data into insightful knowledge.

IIoT can use inventory movement to predict the amount of raw materials needed for an upcoming manufacturing cycle. For example, a business uses two locations for its production process: Factory 2 puts the pieces together to create the finished product after Factory 1 makes them. RFID tags with unique IDs are attached to raw materials when they enter Factory 1. As they move on with manufacturing, their movements are watched and logged. Every step involves taking separate RFID readings, and the data is kept in a cloud-based system that may serve as the business's data warehouse. The cloud-based system analyzes every step of the data, which also notifies users if any objects are lost or stolen. New generation sensors are more cost-effective and offer improved performance as IoT technology develops every day. Businesses may effectively manage their supply chain by gaining real-time visibility into their inventories and operations. The major impacts of using IoT-based inventory management systems include:

1) superior interconnectivity
2) real-time analysis and monitoring of inventory
3) finding patterns
4) achieving best possible warehouse management
5) simplified processes
6) automation of reporting and tracking inventory
7) increased processing speed and performance with predictive maintenance
8) fulfillment of regulatory compliance
9) diminished losses (Rishabh Software, 2023)

Machine learning predictive analytics may assist businesses in streamlining current procedures like manually entering accounts, better comprehending consumer behavior, and seeing unanticipated possibilities. A predictive model that uses demand forecasting algorithms for inventories and data warehouses may be created to estimate the demand for items based on historical consumer purchases or seasonal needs. By projecting future demand for a product, the suggested solution will assist in preventing out-of-stock and overstocking situations, guaranteeing to optimize sales potential and profit (Shirisha et al., 2022).

Organizations must continuously adjust to changing consumer demands, vendor compliance measures, and multi-channel difficulties if they hope to outperform the growing competition. A coordinated warehousing procedure can optimize the company's space while enhancing worker productivity and facilities administration. The real-time coordination of commodities and operations within a warehouse is made possible by warehouse management technologies. The process of strategically overseeing the acquisition, transportation, and storage of components, materials, completed inventory, and associated data is known as logistics management. E-logistics facilitates the management of customer relationships. Logistics planning offers consolidation, multiple order items sourced from multiple suppliers, and seamless supply chain integration e-logistics to boost production capacity – enabling a web-based system that provides in-transit visibility, exception notification, warehouse, storage, and distribution services. It also aids in order scheduling, tracking, inventory fulfillment, and invoicing. Pick, pack, and ship operations for order fulfillment are improved by inventory management. Logistics planning can also indicate whether a motorist is ahead or behind schedule by automatically seeing updated route schedules (Sankar et al., 2014).

The smart inventory system is now possible thanks to blockchain technology. Blockchain technology is a key component of business industries' operational processes. Blockchain technology will be used extensively in various industries, including healthcare and financial areas, in the upcoming years. Blockchain is a database-functioning application that runs concurrently on several sets of computers. Data recording and its block methods are continuous processes. Every block has a unique data programming within it, and it connects to other blocks to form a chain of blocks. The program's database manages more than just one group; it is linked to all departments and networks, and each department has the ability to link to the database as a whole. All previous blocks are securely saved, and new blocks are added to the database for data. The blockchain facilitates the creation of files and documents devoid of transaction and information fraud (Mondol, 2021).

Hospital Inventory Management for Emergency Demand

Many types of enterprises are placing more and more focus on inventory management. Inventory is one crucial area where sudden demand scenarios might arise. For example, a hospital's materials manager has to set up effective inventory system guidelines for regular business hours while simultaneously guaranteeing the hospital's capacity to handle high demand during emergencies. To ascertain the relative importance of certain typical inventory system variants on a hospital's capacity to function effectively under both regular and emergency demand scenarios, a simulation model of a hospital inventory system needs to be built. The simulation's results typically show that, in shock demand scenarios, review frequency is critical to the operation's performance. Additionally, the simulation indicates that extrapolating an inventory system's normal-condition performance to anticipated results under (Duclos, 1993).

Lean Inventory Management

Maintaining a supply in designated corridors, scheduling replenishment at the appropriate moment, and consistently cutting working capital are all part of lean inventory management. The lean manufacturing concept views stock as a waste product whose cost needs to be continuously decreased. Good inventory management is now synonymous with inventory management that adheres to the lean mindset (Atanasov, 2013). Industrial cost reductions have been made possible in large part by lean inventory management. Lean inventory management is impacted by company strategy, supply and demand, information technology, delivery speed, affordability, and quality (Moori et al., 2017).

Lean Practices in Healthcare Inventory to Eliminate Inventory Waste

Prioritizing the development of a lean stock management model is necessary to balance resources, demand, and supply. Incorporating new aspects into the measuring model through ongoing research and gradual advancements can facilitate the management of more complex scenarios. The structural equation modeling provides opportunities to improve the model and make it a useful tool for gaining a competitive edge (Moori et al., 2017). When assessing the leanness of healthcare systems, four wastes (waiting, transportation, motion, and defects) play a significant role. Almost 80% of the system's leanness is attributed to these four wastes, and waiting is the most common. In the healthcare system, prompt diagnosis is crucial for several reasons. First and foremost, it allows for timely treatment initiation, which can significantly impact patient outcomes. Additionally, an accurate diagnosis provides clarity for both patients and healthcare providers, guiding appropriate medical interventions and management plans. Furthermore, swift diagnosis can help alleviate patient anxiety and uncertainty, fostering trust in the healthcare system. Moreover, in cases where early detection is key, such as in certain cancers or infectious diseases, minimizing the waiting time for diagnosis can be life-saving. Overall, reducing the waiting time for diagnosis in the healthcare system is essential for optimizing patient care and improving overall health outcomes. When evaluating leanness, the remaining wastes (overprocessing, inventory, and overproduction) are given the least weight. This suggests that those working in healthcare are more aware of the importance of healthcare quality. The evaluation of leanness depends heavily on a few of the sub-criteria, such as test duplication and the unavailability of emergency medications. The total ranking gives these wastes from the overprocessing and inventory category a high priority, which is more significant from a quality standpoint when providing patient-centric healthcare (Bharsakade et al., 2021).

Inventory waste refers to any supply that is either overstocked or unavailable when needed. A hospital needs a variety of material supplies, consumables, equipment, and medications to carry out its intended task. When these resources are stored in excess, it creates additional inventory, and excessive inventory frequently results in financial shortages. Additionally, supplies and medications may expire. One further way to describe inventory waste in the healthcare industry is the holding of patients longer than necessary, which prevents the hospital from accepting new patients. Healthcare inventory management is essential for monitoring system performance and system quality. The lean mindset maintains the lowest possible inventory levels while primarily focusing on the requirements of the patient. Hospitals should consider keeping an adequate supply of emergency medications on hand. Keeping an excessive amount of inventory may be a good use of extra money but running out of supply might result in expensive moves, inefficient processes, or even patient injury.

Hospitals that use better inventory management can also cut down on other kinds of waste. Patient data storage gone too far is one way that inventory waste manifests itself. Extra information waste in the current era of information technology can have a number of negative effects, such as decreased efficiency, treatment delays, or increased complexity in the healthcare system. While inadequate data adds complexity to the healthcare process, excessive data waste makes it harder to gather, store, find, and handle it. In order to access pertinent data when needed, investigations must yield relevant facts in a timely manner (Bharsakade et al., 2021).

Lean Tools in Healthcare Inventory Management

Inventory waste is the result of keeping materials or supplies for a while; this covers both warehouse stock and supplies used during production. It is advised to apply the lean tool Kaizen, integrate the concepts of the complete production system, and create a one-piece flow for inventory management. The key is a five-day Kaizen event where cross-functional groups worked to immediately decrease inventory and improve lead times while also addressing quality and flow concerns. During a Kaizen event, participants from various departments collaborate intensely over five days to analyze workflows, pinpoint inefficiencies, and devise solutions. This teamwork harnesses diverse perspectives and expertise, leading to more effective problem-solving. Immediate changes are implemented, bypassing lengthy planning cycles, generating quick wins, and boosting morale for continuous improvement. Cross-functional collaboration ensures holistic improvements, breaking down organizational silos and fostering teamwork. Overall, the Kaizen event drives significant enhancements in inventory management, lead times, quality, and workflow efficiency, merging lean management principles with structured collaboration for rapid, sustainable results. A product's inventory shouldn't be greater than what is required, and when a product is used, the supply should be replenished. Any business must also ascertain the precise quantity of stock it has on hand and refill the appropriate amount when it hits its reorder threshold. Lean implementation will lower defects, work-in-progress inventory, scrap, and rework costs in an organization since more inventory would result in higher inventory carrying costs. Numerous instruments and methods have developed over time, demonstrating the necessity and significance of inventory management. One method for classifying supplies that makes it possible to distinguish between the most and least vital supplies is the ABC classification (Agarwal, 2020), a hybrid 5S approach that combines inventory management strategies with process improvement tools to create four stages for Kaizen events (Venkateswaran, 2011).

Recently, lean healthcare has gained popularity as a means of using creative solutions to enhance procedures. One of the instruments of lean healthcare is the two-bin Kanban system, which has been implemented in several hospitals across numerous nations. A two-bin system can improve hospital productivity and cut down on a variety of wastes, including extra inventory, expired goods, and needless staff turnover. The two-bin system functions better thanks to RFID technology, making it possible to determine the stock status as soon as labels are removed. This makes it possible to manage inventory proactively, improves replenishment cycles, and notifies the material management department of any possible ward stockouts (Landry & Beaulieu, 2010).

Impact of Lean Inventories

Lean inventory management is a profitable strategy for businesses. Businesses that implement JIT see improved sales and more seamless operations while holding less inventory. On the other hand, JIT companies seem to be more cyclical and prone to catastrophic occurrences. In a model of heterogeneous companies where the most productive enterprises use JIT, lean production increases wellbeing by 1.4% and long-term firm value by 1.3%. JIT also increases a company's risk because of its small inventory buffers. The production of the predicted JIT economy shrinks 15% more with an unforeseen supply disruption than it would in a counterfactual economy without JIT. Therefore, adoption results in a significant and yet unmeasured trade-off, suggesting that inventories may have an impact on overall variations (Ortiz, 2022).

Risk Management

The International Standardization Organization (ISO) 31000: 2009 strategy, which is applicable to a broad variety of businesses in any region and for every form of operation, regardless of complexity, size, or type, can be used to establish risk management. A supplemental component of internal control, risk management can take several forms based on the unique requirements of each business. The right risk management plan for a business should include determining important risks and how they affect the inventory cycle, managing risks and conducting risk assessments, and offering suggestions for mitigating risks (Alfatin & Leo, 2019).

Risk Assessment Model in Inventory Management

Inventory management's identification and hierarchy of risks enable the mapping and creation of an action plan aimed at controlling, reducing, or even eliminating risk. The analytic hierarchy process (AHP) is the technique employed to determine the optimal risk management strategy by hierarchizing. Every department inside the firm has a risk that is particularly noticeable when it comes to inventory management, which helps the business better control costs and stay in line with its low-cost production plan. The three main hazards identified in each category are stock divergence (material handling), supplier delay (supply), and excess consumption (demand) (Hung, 2011). Excessive consumption was found to be the most critical risk in the demand category, supplier delays were found to be the riskiest in the supply category, and risk divergence of inventory was found to be the most problematic in the material handling category when compared to the other issues (Sales et al., 2020).

CONCLUSION

Traditional healthcare inventory management typically involves manual tracking and replenishment processes, which can be labor-intensive and prone to errors. Challenges include inaccuracies in inventory levels, leading to stockouts or excess inventory, resulting in increased costs and inefficiencies (Opolon, 2010). Technology management models, such as RFID and barcoding systems, aim to improve inventory accuracy and streamline processes. However, they may face limitations such as high implementation costs and compatibility issues with existing systems (Azevedo & Carvalho, 2012). A comparison of a three-echelon distribution network reveals differences in efficiencies, with factors like transportation costs and lead times impacting overall performance (Heydari et al., 2016). Decision-making plays a crucial role in healthcare inventory management, influencing procurement, stocking levels, and distribution strategies (Friday et al., 2021). Literature showcases innovative approaches like automated inventory tracking systems and predictive analytics improving efficiency and patient care (Alghamdi et al., 2023). Lean principles emphasize minimizing waste and optimizing processes, highlighting aspects such as just-in-time inventory and continuous improvement in healthcare inventory management for enhanced cost-effectiveness and patient satisfaction (Panwar et al., 2015).

Driven by innovation and technology, a number of new developments are changing the face of inventory management. Predictive analytics and stock optimization are made possible by the increasing deployment of AI and machine learning. Autonomous mobile robots and RFID technology are used more and more for quick identification and data collection, while IoT devices are used for real-time tracking. The potential of blockchain technology to guarantee supply chain traceability and transparency is also being investigated. Another trend is automation through robots, which lowers human error and increases warehouse operation efficiency. Finally, the incorporation of cloud-based systems such as SMART logistics and e-logistics platforms enables distant access to inventory information, encouraging adaptability and cooperation across various sites. These creative concepts for inventory management systems and the corresponding instruments assist healthcare organizations in streamlining their processes, boosting productivity, and minimize operating costs (StartUS Insights, 2023).

By avoiding inventory mistakes, hospitals may operate more profitably and deliver the best treatment possible by freeing themselves from time, money, and manpower constraints. It is possible to manage inventories effectively. Researchers recommend customized inventory management systems for hospitals as being the best way to establish a medical inventory supply chain that benefits all stakeholders and can handle the complicated and unpredictable nature of the healthcare environment. A solution for healthcare inventory management must be able to handle its intricate needs, which include a large number of distinct suppliers, a large volume and variety of inventory products, and urgent, last-minute requests. Strong inventory management systems can function well in a medical environment. A variety of IT systems are used in modern hospitals, so any new technology must match the demands of the organization and function with its existing technological infrastructure. Although there are many obstacles to overcome, maintaining precise inventory tracking, especially at the point of use, is crucial. At the moment, the weakest link in the chain is where the majority of "inventory leakage" occurs. Since time-pressed nurses play a crucial role in item capture, any new system should reduce the amount of administrative time requires so they may spend as much time as possible supporting patients and the clinical team. When inventory is properly tracked and data is cleaned, better business decisions may be made. Through the use of data insights, the hospital may also develop a deeper understanding of its demands and regain control over the inventory management process (Lomnitz, 2023).

Research Limitations

The first limitation of this systematic research is that the evaluation of the literature identified does not fully reflect the variability in the drivers of complexity within inventory management across various healthcare systems, geographies, or types of facilities. Furthermore, since this systematic review is dependent on published papers, the outcome might be impacted by publication bias caused by non-significant results or those performed in certain areas or in a particular kind of institutions that are underrepresented in the identified literature. Moreover, the results of the systematic review might not be fully applicable to current environmental situations since they may not accurately reflect the condition of inventory management in the healthcare industry. The process of conducting a systematic review may include biases, even with the best of intentions. Examples of these biases include selection bias during the research identification and inclusion phase and interpretation bias during data synthesis. The validity and robustness of the review's conclusions might be impacted by these biases.

Contribution of the Research

This study builds upon and extends the insights gained from several previous studies, substantially advancing our understanding of inventory management in healthcare. Although earlier studies have looked at the changing trends and advancements in this field, the multifaceted drivers of its complexity are where we contribute. Through the use of systematic literature review, we unearth nine findings that contribute to the current conversation and have important ramifications for practitioners and academics in this field. This groundbreaking study broadens the field's understanding and provides a nuanced viewpoint that enhances its depth and breadth, making it an invaluable tool for academics, professionals, and decision-makers alike.

Direction of Future Research

Future areas of research that can be further explored are 1) Internet of Things (IoT) for full connectivity, 2) cloud technology for hybrid work in particular, 3) artificial intelligence/machine learning for enhancement of inventory management operation (Burakhanova et al., 2023 and lmarzoqi & Albakjaji, 2022), 4) utilizing data analytics for predictive selection (Lalou et al., 2020), 5) automating warehouses in order to reduce labor in inventory management (Jaradat et al., 2016), and 6) using AVGs and AMRs to improve automation and ensure lean operation in inventory management (Pizoń et al., 2024).

CONFLICTS OF INTEREST

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