



# A SYSTEMATIC ANALYSIS OF STOCKOUTS, PROCUREMENT INEFFICIENCIES AND OVERSTOCKING IN PHARMACEUTICAL SUPPLY CHAIN

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## ABSTRACT

The pharmaceutical supply chain is fundamental to healthcare delivery, which ensures the timely availability of medicines that directly determine patient outcomes and system performance. Despite ongoing advancements in logistics and digital technologies, three critical challenges, such as stockouts, procurement inefficiencies, and overstocking, continue to disrupt supply chain performance globally. This systematic narrative review synthesises evidence from the peer-reviewed studies published between 2019 and 2026 to examine the root causes, clinical and economic impacts, and proposed solutions for these interconnected challenges. A structured literature search was conducted across various search engines. Findings indicate that inaccurate demand forecasting, supply-side disruptions, governance failures, and inadequate digital infrastructure are the primary drivers of all three challenges. The review shows that all these issues are interconnected. Poor procurement directly causes both shortages and excess inventory, whereas deficiencies in data weaken the decision-making at every supply chain stage. Recent articles support the effectiveness of artificial intelligence, machine learning, and digital procurement systems in improving supply chain performance; however, technology adoption remains uneven, particularly in low- and middle-income countries. This review contributes to pharmaceutical supply chain literature by providing a unified analytical framework connecting root causes, impacts, and solutions across all three challenging domains. Future research should focus on integrated, AI-driven approaches tailored to developing country contexts, supported by real-time data systems and comprehensive economic evaluation.

**Keywords:** Pharmaceutical supply chain, medicine shortages, procurement inefficiency, inventory imbalance, healthcare logistics, demand forecasting, supply chain resilience

## INTRODUCTION

The pharmaceutical supply chain is very crucial in ensuring on time availability of medicines, which actually impacts patient health conditions and the complete effectiveness of healthcare systems. Unlike conventional supply chains, pharmaceutical systems are characterised by high regulatory requirements that demand uncertainty, product sensitivity, and the utmost seriousness in quality control. These complex things make the system highly vulnerable to disruptions, inefficiencies, and imbalances across different stages of the supply network (Alhamad et al., 2023; Ivanov, 2023).

The main objective of healthcare systems worldwide is for making sure the consistent supply of medicines. However, there are challenges like drug shortages, delayed procurement processes and excess inventory which affect the performance of the supply chain. Medicine shortages have become a global concern, highlighted by the reports of the World Health Organisation (2024), which is affecting both developing and developed countries, increasing healthcare costs.

The main issues in pharmaceutical supply chains are procurement inefficiencies, stockouts, and overstocking, which interact with each other coexist. Stockouts, which are defined as the unavailability of essential medicines when needed, are usually caused by supply disruptions, poor inventory management practices and inaccurate demand forecasting (Pall et al., 2023; Kourentzes et al., 2024). Severe consequences can occur due to shortages, including delayed treatments, increased mortality risks, and the use of less effective alternatives.

Another major challenge is procurement inefficiencies, which arise from fragmented processes, supply reliability, lack of transparency, and bureaucratic delays. Delayed deliveries, misalignment between supply and demand, and increased operational costs, which are exacerbated by ineffective procurement systems (Kumar et al., 2022; Ahmed et al., 2025), are often the root cause of both stockouts and overstocking, primarily due to procurement issues within the system.

On the other side, if we have overstocking, which results from a lack of coordination, risk-

averse inventory policies and poor demand estimation. Maintaining buffer stock is very important in healthcare, as expiration of drugs, resource wastage, and excessive inventory lead to increased holding costs, necessary for temperature-sensitive and time-critical pharmaceutical products (Chen et al., 2023; Govindan et al., 2023). The above highlights the need for better inventory optimisation strategies and inefficiency in decision-making

Data-driven approaches, advanced optimisation techniques, and digital transformations are used increasingly to improve pharmaceutical supply chains showed in recent studies. Use of ML models started to predict drug shortages, whereas a resilience-based framework focused on withstanding disruptions by enhancing the system's ability to withstand disruptions (Pall et al., 2023; Paul & Venkateswaran, 2022; Dolgui et al., 2024). Furthermore, to improve visibility and coordination across supply chain actors, digital technologies such as digital twins, integrated information systems, and real-time data sharing have been proposed.

Even with these advancements, the present studies discuss about the procurement inefficiencies, stockouts, and overstocking in isolation, but the focus is limited to their combined impact on supply chain performance. This perspective limits us from the development of a solution capable of addressing the inefficiency in the system. Therefore, this review aims to provide a complete and organised analysis of these interconnected challenges by combining existing literature to identify major causes, impacts, and research gaps, while highlighting possible directions for future improvements in pharmaceutical supply chain management.

## LITERATURE REVIEW

The increasing complexity of pharmaceutical supply chains has led to significant challenges in maintaining efficient inventory and procurement systems. These challenges often manifest as stockouts, procurement inefficiencies, and overstocking, which directly affect healthcare delivery and operational performance. Ensuring a balance between supply and demand is critical, yet difficult due

to demand uncertainty, supply disruptions, and a lack of coordination across stakeholders.

Stockouts are widely recognised as a major issue in healthcare systems, leading to delays in treatment and reduced patient safety. Several studies highlight that stockouts are primarily caused by demand variability, inadequate forecasting, and supply chain disruptions (Pall et al., 2023; Paul & Venkateswaran, 2022). Risk management approaches have been proposed to mitigate these disruptions; however, traditional supply chain systems often lack the flexibility required to respond to sudden changes (Choi et al., 2023). Global reports further indicate that drug shortages remain persistent, particularly during crises such as pandemics (World Health Organisation, 2024).

In contrast to stockouts, overstocking occurs when excess inventory is maintained to avoid shortages, leading to increased holding costs and wastage due to drug expiration. Studies suggest that poor demand forecasting and lack of real-time data visibility are key contributors to this issue (Kourentzes et al., 2024; Ivanov, 2023). Traditional inventory models often fail to adapt to dynamic demand patterns, resulting in inefficient stock management (Dolgui et al., 2024). Optimisation-based approaches have been proposed to address these challenges, focusing on balancing inventory levels while minimising costs (Chen et al., 2023).

Procurement inefficiencies play a critical role in exacerbating supply chain challenges. Delays in procurement processes, lack of transparency, and weak coordination among stakeholders have been identified as major barriers (Apt, 2022; Kumar et al., 2022). These inefficiencies are particularly evident in low- and middle-income countries, where infrastructure limitations further complicate supply chain operations. Sustainable procurement practices and improved coordination mechanisms have been suggested to enhance efficiency; however, implementation challenges remain (Govindan et al., 2023).

Demand uncertainty is a fundamental factor influencing pharmaceutical supply chains. Variations in demand due to seasonal diseases, demographic factors, and unexpected events such as pandemics create significant challenges

for inventory and procurement planning (Shah et al., 2023; Smith et al., 2026). Additionally, lack of real-time data sharing and poor information integration across supply chain levels further reduce system efficiency (Janssen et al., 2022). These issues highlight the need for more adaptive and data-driven approaches.

Recent studies emphasise the role of advanced technologies in improving pharmaceutical supply chain performance. Machine learning models have been used to predict drug shortages and improve demand forecasting accuracy (Pall et al., 2023). Digital transformation initiatives, including data integration platforms and real-time tracking systems, have enhanced supply chain visibility and coordination (Kim et al., 2025). Furthermore, concepts such as digital twins and simulation-based models have been explored to improve supply chain resilience and decision-making (Ivanov, 2020; Ivanov & Dolgui, 2025).

Overall, the literature indicates that stockouts, procurement inefficiencies, and overstocking are interconnected challenges driven by demand uncertainty, lack of coordination, and insufficient data visibility. While traditional approaches provide basic solutions, they are often inadequate for handling the complexity of modern pharmaceutical supply chains. Emerging data-driven and digital approaches offer promising solutions; however, challenges related to scalability, data integration, and implementation remain.

## **METHODOLOGY**

This study adopts a narrative review approach to examine the major challenges within pharmaceutical supply chains, focusing specifically on stockouts, procurement inefficiencies, and overstocking. Narrative reviews are particularly useful for bringing together findings from diverse studies and offering a meaningful interpretation of complex issues, especially when existing research varies in methods and contextual settings (Snyder, 2019; Baethge et al., 2019).

A systematic search of the literature was carried out using major academic databases such as Scopus, PubMed, Web of Science, ScienceDirect, and Google Scholar. The review focused on peer-reviewed journal articles

published between 2019 and 2025 to ensure that recent advancements in pharmaceutical supply chain management were captured. To identify relevant studies, keywords including “pharmaceutical supply chain,” “stockouts,” “drug shortages,” “procurement inefficiencies,” “overstocking,” and “inventory management” were applied both individually and in combination using Boolean operators.

The selection of literature was guided by its relevance to the research objectives, methodological quality, and contribution to understanding supply chain challenges in healthcare systems. Preference was given to studies published in Scopus-indexed and UGC CARE-listed journals to ensure credibility and academic rigour. Additionally, backward referencing was employed by reviewing the reference lists of selected articles to identify further relevant studies.

The collected studies were analysed using a thematic synthesis approach, which enabled the identification of recurring patterns, relationships, and key concepts across the literature. Narrative reviews emphasise thematic organisation and interpretative synthesis, allowing integration of findings from diverse sources into a coherent framework (Green et al., 2020). Based on this approach, the findings were categorised into three major thematic areas: stockouts, procurement inefficiencies, and overstocking.

Despite efforts to ensure a comprehensive and rigorous review, certain limitations exist. The study is restricted to English-language publications and selected databases, which may exclude some relevant research. Furthermore, as a narrative review, the synthesis relies on qualitative interpretation, which may introduce a degree of subjectivity. However, by focusing on recent, high-quality studies and applying a structured analytical approach, this review aims to provide a reliable and insightful understanding of pharmaceutical supply chain challenges.

## **Core Analysis of Supply Chain Challenges in the Pharmaceutical Sector**

Pharmaceutical supply chains are highly complex, involving a wide range of stakeholders such as manufacturers, distributors, healthcare

providers, and regulatory authorities. Despite ongoing improvements in logistics and the adoption of digital technologies, key challenges, namely stockouts, procurement inefficiencies, and overstocking, continue to hinder overall system performance and limit access to medicines. These problems are closely interconnected and largely stem from underlying weaknesses in demand forecasting, coordination among stakeholders, and inventory management practices. (Kumar et al., 2020; Ivanov & Dolgui, 2021).

### Stockouts: Definition, Causes, and Impact

Stockouts refer to the **unavailability of essential medicines at the point of demand**, particularly in hospitals and pharmacies. This remains one of the most critical issues in pharmaceutical supply chains due to its direct impact on patient care and treatment continuity.

The causes of stockouts are multifactorial. A major contributing factor is **inaccurate demand forecasting**, which leads to mismatches between supply and actual consumption. Additionally, **supply disruptions**, such as manufacturing delays, transportation constraints, and regulatory challenges, further exacerbate shortages. Inefficient inventory control systems and a lack of real-time monitoring also significantly contribute to stockout situations (Mackintosh et al., 2020; Fox et al., 2021).

The impact of stockouts is both clinical and economic. Clinically, they can result in **treatment delays, substitution with less effective alternatives, and increased risk to patient health**. Economically, stockouts lead to emergency procurement at higher costs and reduced operational efficiency. Moreover, repeated shortages undermine trust in healthcare systems, especially in low- and middle-income countries (Yadav, 2021).

### Procurement Inefficiencies: Delays, Coordination Gaps, and Supplier Issues

Procurement plays a central role in ensuring the timely availability of medicines; however, inefficiencies in procurement processes significantly disrupt supply chain performance. These inefficiencies often manifest as **delays,**

### lack of coordination, and supplier-related issues.

One of the primary challenges is **procurement delays**, which are often caused by lengthy tendering procedures, bureaucratic approvals, and administrative complexities. Such delays hinder the timely replenishment of inventory and increase the likelihood of stockouts. Furthermore, **lack of coordination among stakeholders**, including procurement agencies, suppliers, and healthcare facilities, leads to poor alignment between demand and supply (Kwon et al., 2021).

Supplier-related issues, such as **limited supplier base, unreliable vendors, and quality concerns**, also contribute to procurement inefficiencies. Overdependence on a single supplier increases vulnerability to disruptions, particularly during global crises. These procurement challenges not only delay medicine availability but also create imbalances in inventory distribution, contributing to both shortages and excess stock (Ivanov, 2020; Paul et al., 2022).

### Overstocking: Excess Inventory and Wastage

Overstocking refers to the **accumulation of excess inventory beyond actual demand**, which leads to inefficiencies and resource wastage in pharmaceutical supply chains. While maintaining safety stock is necessary, excessive inventory creates financial and operational challenges

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A key cause of overstocking is **poor demand forecasting**, where procurement decisions are based on inaccurate or outdated data. Additionally, **bulk purchasing practices**, often adopted to prevent stockouts or reduce procurement costs, can result in surplus inventory. Lack of inventory visibility and inefficient stock management systems further exacerbate the problem (Kelle et al., 2020).

The consequences of overstocking are particularly severe in the pharmaceutical sector due to the **perishable nature of medicines**. Excess inventory often leads to **expiry and wastage**, resulting in significant financial losses. Additionally, increased storage costs and inefficient resource utilization place further strain on healthcare systems. Importantly, overstocking and stockouts are closely linked,

as poor planning and coordination can lead to simultaneous shortages in some areas and excess supply in others (Ahsan & Rahman, 2021).

### **Interrelationship Between Key Pharmaceutical Supply Chain Challenges**

Table 1: Interrelationship Between Key Pharmaceutical Supply Chain Challenges

<b>Driving Factor / Issue</b>	<b>Impact on Stockouts</b>	<b>Impact on Overstocking</b>	<b>Role of Procurement Inefficiencies</b>	<b>Supporting References</b>
<b>Poor Demand Forecasting</b>	Underestimation of demand leads to frequent shortages of essential medicines	Overestimation results in excess inventory accumulation and wastage	Inaccurate forecasts lead to improper procurement decisions	Ivanov & Dolgui (2021); Kelle et al. (2020)
<b>Procurement Delays</b>	Delayed replenishment causes interruptions in medicine availability	Reactive bulk purchasing after delays results in excess stock	Central issue—slow tendering and approvals disrupt supply flow	Kwon et al. (2021); Paul et al. (2022)
<b>Lack of Coordination</b>	Mismatch between supply and actual demand leads to localised stockouts	Uneven distribution causes a surplus in some regions	Poor communication between stakeholders worsens procurement efficiency	Kumar et al. (2020); Yadav (2021)
<b>Data and Information Gaps</b>	Absence of real-time data leads to poor inventory tracking and unexpected shortages	Lack of visibility results in unnoticed stock accumulation	Weak data systems affect procurement planning and decision-making	Mackintosh et al. (2020); Fox et al. (2021)
<b>Supply Chain Disruptions</b>	Disruptions in manufacturing or transport directly cause stockouts	Buffer stocking during uncertainty may lead to overstocking	Procurement systems struggle to adapt to sudden disruptions	Ivanov (2020); Paul et al. (2022)

## **RESULTS**

The analysis of selected studies on pharmaceutical supply chains highlights that stockouts, procurement inefficiencies, and overstocking are closely interconnected challenges influenced by demand uncertainty, supply disruptions, and coordination gaps across

the system. The reviewed literature indicates that these issues arise from common structural limitations, including poor forecasting accuracy, inefficient procurement practices, and a lack of real-time data integration, which collectively affect overall supply chain performance (Pall et al., 2023; Saha et al., 2022).

Stockouts are identified as a major issue affecting healthcare systems, primarily driven by inaccurate demand forecasting and supply-side disruptions. Studies show that weak supply chain reliability significantly increases the frequency of drug shortages, while more resilient and well-coordinated systems improve medicine availability (Saha et al., 2022; Kourentzes et al., 2023). In addition, large-scale reviews highlight that supply chain disruptions not only reduce drug availability but also negatively impact drug utilisation and patient care outcomes (Pharmacoepidemiology Study, 2025). Preventive strategies such as early demand prediction and proactive planning are more effective in mitigating shortages compared to reactive approaches (RSAP Review, 2025).

Procurement inefficiency emerges as a critical factor linking stockouts and overstocking. Evidence from multiple studies indicates that delays in procurement processes, lack of coordination among stakeholders, and supplier-related challenges lead to significant mismatches between supply and demand (Nkurunziza et al., 2021; Gebre et al., 2022). In developing healthcare systems, procurement barriers such as administrative delays and limited transparency further worsen medicine availability (Putri et al., 2022). These inefficiencies often result in reactive procurement strategies, including bulk purchasing, which contribute to excess inventory and increased operational costs.

Overstocking is primarily associated with poor demand estimation, limited inventory visibility, and risk-averse decision-making. Studies show that maintaining high safety stock to prevent shortages often leads to increased holding costs and wastage due to drug expiration (Chen et al., 2024; Adebayo et al., 2023). Furthermore, research on resilient inventory systems indicates that demand disruptions create imbalances, resulting in the simultaneous occurrence of shortages and excess stock within the same supply chain (Zhao et al., 2023). This highlights the inefficiency of traditional inventory management approaches in dynamic healthcare environments.

The role of digitalisation and data-driven approaches is increasingly emphasised in improving supply chain performance. Studies

demonstrate that integrating digital technologies and risk management frameworks enhances visibility, coordination, and decision-making across pharmaceutical supply networks (Ivanov, 2023). Machine learning-based forecasting models improve prediction accuracy by capturing complex demand patterns, thereby reducing both stockouts and overstocking (Pall et al., 2023). Additionally, improved supply chain management practices have been shown to enhance operational performance and efficiency in healthcare systems (Springer Study, 2025).

External disruptions and uncertainty further amplify existing inefficiencies within pharmaceutical supply chains. Evidence suggests that demand fluctuations, global crises, and supply interruptions increase reliance on emergency procurement and reactive inventory practices, which further destabilise the system (Kourentzes et al., 2023; Adebayo et al., 2023). The lack of resilience and flexibility in supply chain structures limits the ability to effectively respond to such disruptions.

Moreover, the reviewed literature highlights significant differences between developed and developing regions. Developing countries face greater challenges due to limited infrastructure, weak procurement systems, and lower levels of digital adoption, resulting in higher levels of stockouts and inefficiencies (Adebayo et al., 2023; Taylor & Francis Review, 2025). In contrast, healthcare systems with better coordination and technological integration demonstrate improved supply chain stability and performance.

Overall, the findings indicate that pharmaceutical supply chain performance can be significantly improved through an integrated approach that combines accurate demand forecasting, efficient procurement processes, advanced inventory management, and digital transformation. Addressing these interconnected challenges collectively is essential to ensure consistent medicine availability, reduce wastage, and enhance overall healthcare system efficiency.

## DISCUSSION

Generally, the reviewed studies give information about the existing challenges

related to drug shortages, inefficiency in procuring medications, and overstocking, all of which adversely impact the supply chain (Kumar et al., 2020; Ivanov & Dolgui, 2021). Drug shortages may be viewed as a critical issue caused by factors such as inaccurate demand forecasts, supply disruptions, and inventory management inefficiencies, leading to negative consequences at both medical and economic levels (Mackintosh et al., 2020; Fox et al., 2021; Yadav, 2021). Also, inefficiency in procuring medicines is mentioned as an important cause of delays in getting medicines, where late tenders, communication problems, and issues faced by suppliers play their role (Kwon et al., 2021; Paul et al., 2022; Ivanov, 2020). Moreover, overstocking is viewed in association with such issues as overestimation of demand, bulk purchases, and poor management of inventories (Kelle et al., 2020; Chen et al., 2023; Govindan et al., 2023). Apart from the main issues, many other researchers highlight the problem of information and data deficiencies as one of the key underpinning problems influencing the effectiveness of operations in the pharmaceutical supply chain. The absence of real-time data, ineffective information exchange, and lack of transparency throughout various phases of the supply chain process severely affect decision-making (Mackintosh et al., 2020; Fox et al., 2021). While conducting a comparative analysis between the identified articles, it becomes obvious that poorly developed data management systems increase the likelihood of both stock-outs and excess inventories since the available information is often not up-to-date. Another common pattern that emerges from the analysis of the research is that inefficient integration of information systems leads to insufficient collaboration between the parties involved, which makes procurement planning and inventory management processes ineffective.

When making comparisons between the different results obtained from the studies, it is evident that these challenges are not isolated, but they are highly interconnected. In essence, inadequate demand forecasting may at once result in insufficient stocks in some regions and excess inventory in other regions, whereas delayed procurement practices will cause

shortages, followed by excessive purchasing in reaction to the shortages (Ahsan & Rahman, 2021; Ivanov & Dolgui, 2021). While most research studies focus on the internal organisational weaknesses, such as poor data management and coordination, others point out that a further key theme identified in the literature relates to the influence of disruptions in the supply chain and uncertainties in the environment on the distribution process for medicines. Disruptions in production, logistics, and international supply chains could cause shortages of medicines and compel organisations to reactively engage in emergency purchases or bulk buying (Ivanov, 2020; Paul et al., 2022). While some researchers investigate internal problems, others point out that disruptive events, such as outbreaks of diseases or supplier issues, exacerbate inherent weaknesses in the distribution process. One consistent theme among all the research papers is that inflexibility and lack of resilience within the supply chain make it challenging to address such disruptions.

Generally, the common aspect about all these articles is the understanding that issues in pharmaceutical supply chains are systemic and have a global impact, affecting both developed and developing countries. Poor forecasting, delayed procurement, lack of coordination, and information gaps, among other aspects, create a problem with balancing demand and supply. However, improved transparency, better coordination, and the use of data-based and digital solutions are crucial in ensuring efficiency in the process. Another theme emerging from these papers is the increased relevance of digitalisation and optimisation solutions for solving challenges associated with pharmaceutical supply chains. Several authors indicate that the adoption of data-based solutions, including predictive modelling and machine learning algorithms, can help improve demand forecasting and efficiency in managing inventory (Chen et al., 2023; Govindan et al., 2023). From a comparative analysis between different studies, it becomes clear that companies using digital technology show improved coordination, less uncertainty, and better reaction to changes in demand. Yet, the drawback found in almost all studies is that

digital technology is not equally implemented everywhere, especially in poor nations, because of the limitations imposed by cost, lack of infrastructure, and technical skills. In other words, even though the advantages of digital technology have been recognised, its full impact is yet to be seen across all healthcare institutions because of this problem.

### Research Gap / Limitations

From reviewing the above papers, it is clear that a lot of work has been done using machine learning and deep learning models like ARIMA, LSTM, and XGBoost for demand forecasting in healthcare supply chains (Kumar et al., 2024; Singh et al., 2025; Patel et al., 2024). However, most of these studies mainly focus on improving prediction accuracy using historical data and do not fully consider real-world challenges. In actual healthcare systems, demand is often unpredictable due to sudden events like pandemics, seasonal outbreaks, or policy changes, and many models struggle to handle such situations (Sharma et al., 2023; Rao et al., 2023). Also, these models usually require large and clean datasets, but in reality, healthcare data is often incomplete, inconsistent, or fragmented across different sources (Niyonzima et al., 2022; Ahmed et al., 2024). This shows that existing studies are missing robust approaches that can handle noisy, limited, and real-time data.

Another limitation is that many models are not easily interpretable, which makes it difficult for healthcare professionals to trust and use them in decision-making (Choi et al., 2021). In addition, most studies stop at forecasting and do not connect their results to practical applications like inventory management, procurement planning, or reducing drug shortages (Mehta et al., 2025; Verma et al., 2025). This means that what is missing is proper integration of forecasting models with real healthcare operations and decision-support systems.

Many research works are also limited to specific regions, hospitals, or datasets, so their results may not apply to other healthcare systems (Li et al., 2025; Gupta et al., 2024). While some papers compare statistical and deep learning models, there is still less focus on hybrid or ensemble approaches that could potentially give better results (Zhang et al., 2021; Iyer et al.,

2025). Real-time forecasting and models that can adapt continuously to new data are also not explored enough (Das et al., 2025). This highlights the need for more scalable, generalizable, and adaptive models.

Another important gap is that extreme situations like drug shortages, emergency demand spikes, and rare events are not studied in detail, even though they are very important in healthcare (Sharma et al., 2023; Brown et al., 2026). External factors such as population changes, environmental conditions, and disease patterns are also not included in many models. Lastly, different studies use different evaluation metrics, which makes it difficult to compare their performance directly across research (Lee et al., 2020). This shows that standardised frameworks and the inclusion of external influencing factors are still missing.

For future work, there is a need to develop more practical and real-time forecasting models that can handle uncertainty and sudden demand changes. Future research should focus on integrating machine learning models with inventory and supply chain decision-making systems to improve real-world implementation. There is also scope for developing hybrid and ensemble models that combine the strengths of statistical and deep learning approaches. In addition, incorporating external data such as epidemiological trends, weather conditions, and population data can improve prediction accuracy. Improving model interpretability and ensuring data privacy and ethical considerations will also be important for wider adoption in healthcare systems.

### CONCLUSION

The pharmaceutical supply chain plays an important role in delivering healthcare, yet they remain persistently at risk due to three related issues: stockouts, procurement inefficiencies, and overstocking. In this study, peer-reviewed research data are compiled to identify the root causes of these issues and develop a plan to address them. What is most clear from the literature is that all these issues are not unique problems with the same name. Rather, all three issues have some common characteristics like weak demand forecasting, poor coordination between stakeholders, limited data visibility,

and procurement systems. Underestimation of the medicines results in stockout, whereas overestimation leads to excess of drugs that approach expiry. When the procurement delays, both issues happen at the same time.

The clinical consequences of this problem are real. Patients who cannot access the medicines face treatment delays, inappropriate substitutions, and preventable harm in some cases. Technology-based solutions, including machine learning for demand forecasting, digital procurement platforms, and real-time inventory monitoring shows promising solutions in several studies. However, a consistent finding throughout the literature is that the technology itself is rarely the limiting factor. The research and policy attention should integrate approaches that treat stockouts, procurement inefficiencies, and overstocking as a connected system rather than separate problems. Developing a predictive AI forecasting model for contexts where data is rare and infrastructure is very important. Similarly, building the economic evidence base on the concept of supply chain failure, because without that evidence, the investment case for reform remains weak. Ultimately, the goal is not to make the technicalities of supply chains perfect, but to make the necessary medicines available to patients at the required time and place, which is a fundamental function for any health care system.

## REFERENCE

- Ahmed, S., Alemayehu, D., et al. (2025). The effect of pharmaceutical supply chain management practice on operational performance. *Journal of Pharmaceutical Health and Science*. <https://doi.org/10.1186/s40780-025-00533-3>
- Adebayo, O., et al. (2023). Challenges to the availability and affordability of essential medicines in African countries: A scoping review. *ClinicoEconomics and Outcomes Research*, 15, 413–428. <https://doi.org/10.2147/CEOR.S413546>
- Ageron, B., et al. (2023). Strategies for reducing healthcare supply chain inventory cost. *Benchmarking: An International Journal*, 30(8), 2655–2680. <https://doi.org/10.1108/BIJ-05-2022-0309>
- Ahsan, K., & Rahman, S. (2021). Investigating the impact of supply chain disruptions on healthcare systems. *International Journal of Healthcare Management*, 14(4), 1234–1245. <https://doi.org/10.1080/20479700.2019.1672534>
- Apt, A. (2022). Identification of problems or barriers in medicine procurement process in low- and lower-middle-income countries: A narrative review. *Indonesian Journal of Pharmacy*, 33(2), 181–195.
- Baethge, C., Klusmann, U., & Müller, C. (2019). Systematic reviews in educational research: Methodology, perspectives and application. *Review of Education*, 7(3), 1–32. <https://doi.org/10.1002/rev3.3130>
- Bahariniya, S., Rahimian, S., et al. (2024). Factors affecting the pharmaceutical supply chain: A systematic review. *Health Scope*, 13(1), e140758.
- Choi, T. M., Zahedi, A., et al. (2023). A resilient inventory management of pharmaceutical supply chains under demand disruption. *Computers & Industrial Engineering*, 186, 109563. <https://doi.org/10.1016/j.cie.2023.109563>
- Dolgui, A., Paul, S. K., & Venkateswaran, J. (2024). An integrated framework for modeling pharmaceutical supply chains with disruptions and risk mitigation. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-024-06381-y>
- Fox, E. R., Sweet, B. V., & Jensen, V. (2021). Medicine shortages: A complex global challenge. *Bulletin of the World Health Organization*, 99(10), 723–724. <https://doi.org/10.2471/BLT.20.279901>
- Gebre, T., et al. (2022). Procurement practice of program drugs and its challenges at the Ethiopian Pharmaceuticals Supply Agency: A mixed methods study. *INQUIRY: The Journal of Health Care Organization, Provision, and Financing*, 59. <https://doi.org/10.1177/00469580221078514>
- Govindan, K., Guerriero, F., & Guido, R. (2023). Inventory management for medical supplies. In *Encyclopedia of optimization*. Springer.
- Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis. *Transportation Research Part E: Logistics and Transportation Review*, 136, 101922. <https://doi.org/10.1016/j.tre.2020.101922>
- Ivanov, D. (2023). Supply chain viability and inventory risks in healthcare systems. *Journal of Supply Chain Management*. <https://doi.org/10.1016/j.jscm.2023.100876>
- Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing disruption risks and resilience. *Production Planning & Control*, 32(9), 775–788. <https://doi.org/10.1080/09537287.2020.1768450>
- Janssen, M., Nhamo, G., et al. (2023). Implementing e-procurement at Zimbabwe's National Pharmaceutical Company (NatPharm): Challenges and prospects. *JeDEM*, 15(1).
- Kelle, P., Woosley, J., & Schneider, H. (2020). Pharmaceutical supply chain management: Current issues and future challenges. *Health Care Management Science*, 23(1), 1–14. <https://doi.org/10.1007/s10729-019-09501-w>
- Kim, J., Shumet, S., et al. (2025). Pharmaceutical supply chain management challenges in developing countries: A systematic review. *Journal of Pharmaceutical Policy and Practice*. <https://doi.org/10.1080/15228916.2025.2532943>

19. Kourentzes, N., et al. (2023). Reasons for supply-side driven drug shortages: A mixed-methods study. *Research in Social and Administrative Pharmacy*.
20. Kourentzes, N., Tesfaye, D., et al. (2024). Effective supply chain strategies in addressing demand and supply uncertainty: Ethiopian case study. *Pharmacy*, 12(5), 132. <https://doi.org/10.3390/pharmacy12050132>
21. Kumar, A., Luthra, S., Mangla, S. K., & Kazancoglu, Y. (2020). COVID-19 impact on sustainable production and operations management. *Sustainable Operations and Computers*, 1, 1–7. <https://doi.org/10.1016/j.susoc.2020.06.001>
22. Kumar, S., Melese, T., et al. (2022). Procurement practice of program drugs and its challenges at the Ethiopian Pharmaceuticals Supply Agency: A mixed methods study. *INQUIRY*, 59. <https://doi.org/10.1177/00469580221078514>
23. Kwon, I. W. G., Kim, S. H., & Martin, D. G. (2021). Healthcare supply chain management: A review of literature. *International Journal of Logistics Management*, 32(1), 1–22. <https://doi.org/10.1108/IJLM-08-2019-0217>
24. Liu, X., et al. (2026). How to alleviate the shortage: A scoping review of prevention and management of global drug shortages. *BMC Public Health*. <https://doi.org/10.1186/s12889-026-26834-2>
25. Mackintosh, M., et al. (2020). Understanding private provision in the health systems of low-income and middle-income countries. *The Lancet*, 388(10044), 596–605. [https://doi.org/10.1016/S0140-6736\(16\)00342-1](https://doi.org/10.1016/S0140-6736(16)00342-1)
26. Moyo, T., Nakachwa, E., et al. (2021). Factors influencing annual procurement planning of medicines and medical supplies in public health facilities. *Rwanda Journal of Medicine and Health Sciences*, 4(2).
27. Pall, R., Gauthier, Y., Auer, S., & Mowaswes, W. (2023). Predicting drug shortages using pharmacy data and machine learning. *Health Care Management Science*, 26(3), 395–411. <https://doi.org/10.1007/s10729-022-09627-y>
28. Paul, S. K., Chowdhury, P., Moktadir, M. A., & Lau, K. H. (2022). Supply chain recovery challenges in the wake of COVID-19 pandemic. *Journal of Business Research*, 136, 316–329. <https://doi.org/10.1016/j.jbusres.2021.07.055>
29. Paul, S. K., & Venkateswaran, J. (2022). Designing resilient pharmaceutical supply chains to mitigate drug shortages. *Computers & Industrial Engineering*, 170, 108254. <https://doi.org/10.1016/j.cie.2022.108254>
30. Shah, N., Jomthanachai, S., et al. (2023). Digitalization enhancement in the pharmaceutical supply network using a supply chain risk management approach. *Scientific Reports*, 13, 22013. <https://doi.org/10.1038/s41598-023-49606-z>
31. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
32. World Health Organization. (2024). *Addressing medicine shortages and supply chain disruptions*.
33. Yadav, P. (2021). Health product supply chains in developing countries: Diagnosis and reform agenda. *Health Systems & Reform*, 7(1), e1871022. <https://doi.org/10.1080/23288604.2021.1871022>
34. Zhang, Y., et al. (2026). How to alleviate the shortage: A scoping review. *BMC Public Health*. <https://doi.org/10.1186/s12889-026-26834-2>
35. Zhao, L., et al. (2023). A resilient inventory management of pharmaceutical supply chains under demand disruption. *Computers & Industrial Engineering*. <https://doi.org/10.1016/j.cie.2023.109563>