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A Review of Supply Chain Management Practices in Pharmacies and Small-Scale Clinics

Mrs. Sreeja A. K[1], Shreyas S Tikotikar[2], Smaran Nanjundiah G[3], Vishruth M V[4]

[1,2,3,4]Student, Department of CSE, BNM Institute of Technology, Bengaluru, Karnataka, India
Email: sreejaak@bnmit.in[1], tikotikarshreyas@gmail.com[2], [3]smaran.ng@gmail.com, [4]vishruth.mv10@gmail.com

ABSTRACT-

The healthcare supply chain plays a crucial role in ensuring that patients receive timely and affordable access to medicines and medical services. While large hospitals and pharmaceutical corporations have adopted advanced supply chain models, small-scale stakeholders such as medical shops and local clinics face unique challenges in managing medicine inventories, avoiding stockouts, and maintaining compliance with regulatory frameworks. The fragmented nature of healthcare distribution, rising demand for essential medicines, and the risk of counterfeit drugs necessitate efficient supply chain practices. This review synthesizes existing literature on healthcare supply chain management with a particular focus on pharmacies and small-scale clinics. It highlights inventory management challenges, the impact of digitalization, and the role of technology such as Enterprise Resource Planning (ERP), Artificial Intelligence (AI), Blockchain, and Internet of Things (IoT) in improving transparency and reliability. Future research directions are discussed, emphasizing last-mile delivery models, rural access, and sustainable supply chain practices.

Keywords: Healthcare Supply Chain, Pharmacies, Small-scale Clinics, Inventory Management, Stockouts, Digitalization, Drug Logistics, Counterfeit Medicines

1. INTRODUCTION

The healthcare supply chain (HSC) encompasses all activities required to produce, transport, and deliver medicines and medical products to patients. Unlike conventional supply chains, the HSC requires high accuracy and timeliness since inefficiencies can directly affect patient safety. Medical shops (pharmacies) and small clinics represent the last-mile providers in this chain, acting as critical intermediaries between patients and suppliers.

However, these small-scale stakeholders often face challenges such as stockouts, overstocking, poor forecasting, and risks of counterfeit or expired medicines [1]. Unlike large hospitals that may rely on centralized procurement systems, pharmacies and clinics usually depend on distributors and wholesalers, making their supply chain highly vulnerable to disruptions.

In this review, we'll explore the challenges, technological interventions, and research gaps in healthcare SCM, with emphasis on pharmacies and small clinics.

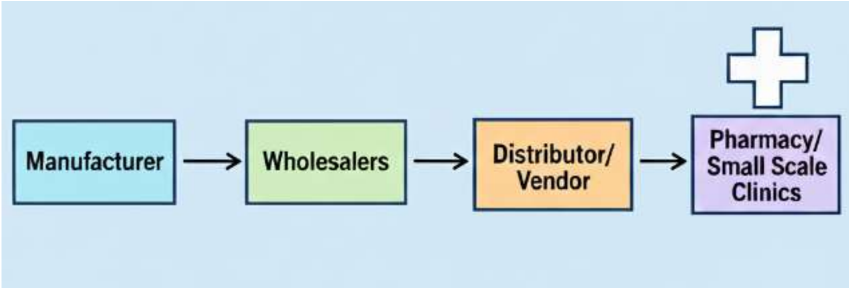

***Figure 1**: Example workflow of the healthcare supply chain, demonstrating the movement of medicines from manufacturer to the pharmacy.*

2. BACKGROUND STUDY

The pharmaceutical supply chain (PSC) is a critical component of healthcare systems, ensuring timely and affordable access to essential medicines for patients. It comprises manufacturers, wholesalers, distributors, pharmacies, and regulatory authorities, all working together to maintain continuous medicine availability and safeguard patient health. At the downstream level, pharmacies and medical shops serve as the last mile in medicine delivery, directly connecting patients with healthcare products. However, literature shows that while large hospitals and healthcare institutions have embraced advanced inventory management systems, many small-scale pharmacies and clinics continue to rely on manual, paper-based systems that hinder efficiency and transparency (Mwangi, 2021; Aiyavoo et al., 2019).

Mwangi (2021) examined inventory management practices in private healthcare facilities in Nairobi and reported that poor record-keeping, lack of staff training, and weak supplier coordination led to frequent stockouts and inefficiencies in procurement cycles. Similarly, Aiyavoo et al. (2019) analyzed pharmacy store management in India and found that although basic inventory techniques such as ABC and HML analyses were known, implementation was inconsistent due to limited awareness among pharmacists. These findings highlight the persistent dependence on manual methods in pharmacy operations, particularly in resource-constrained settings.

Research further emphasizes the potential role of digital tools and ERP systems in improving supply chain efficiency. Bhattacherjee and Hikmet (2001) showed that ERP adoption could optimize procurement and stock visibility in healthcare, but its implementation in rural or small-scale organizations remains limited due to cost and expertise barriers. In Bahrain, George and Elrashid (2023) demonstrated that effective inventory control in hospital pharmacies significantly improved overall supply chain performance, suggesting that structured systems can yield measurable benefits even in smaller setups.

Emerging technologies, such as IoT and data-driven systems, are also gaining attention. Kamble et al. (2021) identified regulatory issues, infrastructure gaps, and resistance to change as key barriers to IoT adoption in the Indian pharmaceutical supply chain. However, when successfully applied, IoT-enabled systems can improve medicine traceability and enable real-time monitoring of stock movements. Gupta et al. (2023) also proposed pharmacy-specific digital inventory solutions, highlighting that automation in ordering, receiving, and monitoring medicines reduces human error and enhances efficiency.

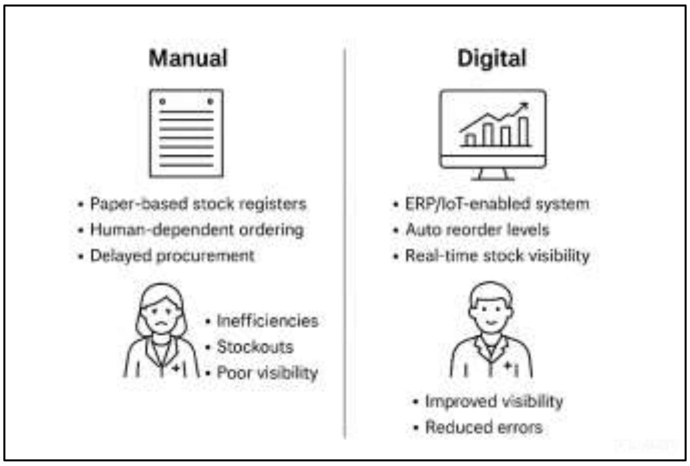

Figure 2: *Comparative representation of manual versus digital inventory management in pharmacies, showing inefficiencies in paper-based systems alongside the improved visibility, reduced errors, and enhanced resilience achieved through ERP/IoT-enabled approaches.*

Another key trend is the integration of retail pharmacies into public sector medicine delivery in low- and middle-income countries (LMICs). A recent scoping review emphasized the role of retail pharmacies in bridging access gaps for essential medicines, while also noting regulatory and contractual challenges in aligning them with national supply systems (JOPPP, 2023). Papalexi et al. (2022) discussed innovation in pharmaceutical supply chains, showing how lean management, reverse logistics, and IT systems could strengthen pharmacy operations and reduce waste.

At the strategic level, resilience in the pharmaceutical supply chain has also become a major research theme. Gill (2023) and recent models in *Transportation Research Part E* have argued that disruptions such as fluctuating demand, pandemics, or supply delays can be mitigated by adopting resilient inventory management strategies tailored for pharmacies and small-scale clinics. IdentiMedical (2022) similarly noted that outdated manual systems in rural hospitals obscure stock visibility, underscoring the urgent need for digital adoption to strengthen resilience.

Taken together, these studies reveal that small pharmacies and clinics remain the weakest link in the pharmaceutical supply chain, largely due to their reliance on outdated processes and limited access to digital infrastructure. The literature suggests that introducing affordable digital inventory management systems, IoT-enabled tools, and policy-driven integration of retail pharmacies could help bridge the efficiency gap, ensuring medicine availability and improving patient outcomes.

3. CHALLENGES

Although digital technologies promise to improve efficiency and resilience in healthcare supply chains, their adoption in small-scale pharmacies and clinics is hindered by several challenges that cut across operational, technical, and regulatory domains.

A. *Fragmented Supply Networks and Stock Management:* Unlike large hospitals that rely on centralized procurement systems, pharmacies and local clinics often depend on multiple wholesalers and distributors. This fragmented supply structure results in inconsistent delivery schedules, poor coordination with vendors, and limited visibility of inventory status. Stockouts, overstocking, and expired medicines are common outcomes, especially when manual record-keeping is still practiced.

B. *Limited Digital Adoption and Infrastructure Gaps:* Despite the proven benefits of ERP systems and IoT-enabled tools, small-scale stakeholders face cost barriers, lack of technical expertise, and inadequate infrastructure for reliable adoption. Many pharmacies continue to use paper-based or ad-hoc digital records, which restricts real-time monitoring and weakens forecasting accuracy. Resistance to technology adoption, compounded by insufficient training, further slows the transition to digitalized systems.

C. *Regulatory Compliance and Counterfeit Risks:* Ensuring adherence to drug regulations and maintaining reliable audit trails is particularly challenging for smaller pharmacies. Weak enforcement of digital prescription validation, poor traceability of drug batches, and lack of integration with national regulatory systems increase the risk of counterfeit or substandard medicines entering the supply chain. For clinics operating in rural or resource-constrained environments, ensuring compliance often adds additional administrative burden

D. *Operational Sustainability and Last-Mile Delivery:* Pharmacies and local clinics operate under financial and logistical constraints that limit their ability to sustain advanced supply chain systems. High costs of digital infrastructure, unreliable electricity or internet connectivity, and the complexity of managing multiple service providers hinder long-term adoption. Furthermore, ensuring medicine availability in rural and underserved regions remains a challenge, with last-mile delivery delays directly affecting patient care and outcomes.

4. EXISTING RESEARCH TRENDS:

Aiyavoo et al. investigated pharmacy store management practices in India, focusing on the implementation of ABC and HML analyses for inventory classification. Their study found that although these methods were known by pharmacists, adoption was inconsistent due to lack of awareness and systematic training. The results indicate that inventory optimization techniques are underutilized in small-scale pharmacy settings, contributing to inefficiencies and stockouts [1].

Bhattacherjee and Hikmet conducted one of the earliest studies on ERP implementation in rural healthcare. Their case study demonstrated that ERP systems improved procurement efficiency and inventory visibility, but cost and expertise barriers limited adoption in smaller facilities. The authors concluded that rural and resource-constrained clinics need tailored ERP-lite solutions to benefit from digitalization [2].

George and Elrashid assessed the impact of inventory control practices on hospital pharmacy supply chain performance in Bahrain. Their findings revealed a strong correlation between structured inventory methods and system-wide efficiency, with improvements in stock accuracy, medicine availability, and procurement cycles. This work highlights the transferable benefits of formal inventory control for smaller clinics [3].

Gill examined pharmaceutical supply chain resilience in the context of COVID-19, analyzing how disruptions to logistics and demand amplified vulnerabilities in medicine availability. The study emphasized the need for resilience strategies such as multi-sourcing, flexible procurement, and adaptive inventory rules. The findings underline the importance of resilience-building for pharmacies operating in uncertain environments [4].

Gupta et al. proposed pharmacy-specific digital inventory management platforms tailored for small medical shops. Their study showed that digital automation of ordering, receiving, and expiry monitoring significantly reduced human error and improved stock visibility. This demonstrates the potential of low-cost, pharmacy-focused digital tools to strengthen last-mile supply chains [5].

IdentiMedical reported on resilience challenges in rural healthcare supply chains, particularly the persistence of outdated manual record-keeping systems. The report emphasized that poor stock visibility and lack of digital traceability contributed to frequent shortages. It argued that digital adoption, even at a minimal scale, could substantially improve resilience in rural facilities [6].

Papalexi et al. reviewed innovations in pharmaceutical supply chains, including lean practices, reverse logistics, and digital solutions. Their findings showed that these approaches reduced wastage, improved sustainability, and enhanced responsiveness. Importantly, the study demonstrated how reverse logistics could minimize medicine expiry in pharmacies [10].

Walton et al. evaluated integrated HIV care models in rural Haiti, showing that strengthened supply chains were central to sustaining primary care delivery. The study emphasized that supply chain improvements, including inventory visibility and distribution efficiency, enabled broader healthcare system strengthening [11].

Elrashid, George, and Ali used structural equation modeling to analyze hospital pharmacy supply chains in Bahrain. Their study confirmed that effective inventory management had a significant positive impact on overall supply chain performance, including procurement efficiency and medicine availability. This evidence supports the case for structured inventory systems in smaller-scale setups [12].

Jasti and Kodali studied service quality in the pharmaceutical supply chain in Andhra Pradesh, India. They found that customer satisfaction and service quality were strongly linked to the robustness of inventory and logistics practices. Their findings reinforce the importance of supply chain management as a determinant of patient satisfaction [13].

Tadeg et al. assessed the performance of essential medicine inventory management in public facilities in Ethiopia. Their study identified gaps in medicine availability and weaknesses in monitoring, leading to shortages and procurement inefficiencies. The authors recommended stronger inventory tracking mechanisms to improve patient access [14].

Tshuma et al. examined medicine redistribution practices in South Africa, identifying predictors that influenced redistribution efficiency. Their results showed that structured redistribution policies reduced wastage and improved medicine availability across facilities, demonstrating the value of coordinated inter-facility supply chain mechanisms [15].

Al-Arifi et al. presented a case study of pharmacy inventory systems in Saudi Arabia. Their findings indicated limitations in automation, reliance on manual practices, and a lack of standardization, which constrained efficiency. The study highlighted the urgent need for digital adoption to strengthen pharmacy operations [16].

Siregar et al. documented an inventory information system project in Indonesian pharmacies, demonstrating how effective project management, governance, and staff training were critical for success. Their case emphasized the organizational dimension of inventory system adoption [17].

Debnath et al. conducted a case study in Eastern India analyzing pharmacy inventory control mechanisms at a national institute. They identified inefficiencies due to poor monitoring and weak processes, and recommended systematic frameworks for inventory control. The findings reinforce the role of structured systems in reducing inefficiencies [18].

Pratama and Harahap performed a literature review on logistics inventory management in pharmacy services. They summarized gaps in digital transformation, identifying research opportunities for low-cost and scalable digital tools in small-scale pharmacy settings [19].

Dhamija and Bag developed a risk assessment framework for the Indian pharmaceutical supply chain using an FMEA approach. Their framework identified supplier dependency, transportation fragility, and inadequate monitoring as critical risks. The authors suggested that systematic risk assessment can guide targeted interventions for supply chain resilience [20].

Figure 4 illustrates the redistribution and resilience of pharmaceutical supply chain.

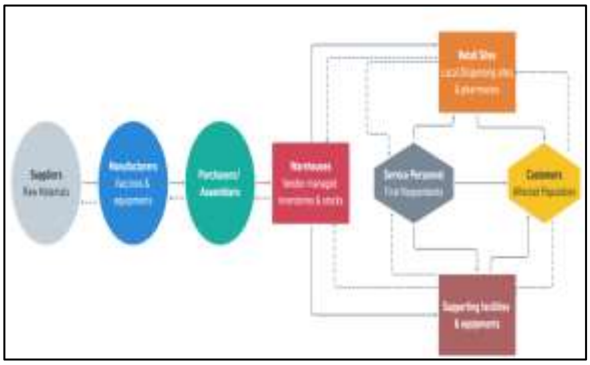

Figure.4: Pharmaceutical Supply Chain Redistribution and Resilience

5. RESEARCH GAP

ML in agriculture throws a large domain for research for the betterment of agricultural produce. Another ML challenge is improving the classification performance of the algorithms' autonomous cycles of data analysis tasks. Deployment of the model in the real-time application is recommended to help the intended users in their mundane work. Automatic ML is a state-of-the-art approach that can be used to build more accurate, high-quality ML models in less time.

Our study indicated that there is a need to follow the machine learning pipeline with standard experimental methods. Researchers should create their own dataset and make this available to others through different platforms so that others can use it for testing and validation of their own models. From the survey, it is also observed that Single-Shot Convolution Neural YOLO (You only look once) is a state-of-the-art, real-time object detection system that must be used for detection and localization to increase classification accuracy.

The study focuses on ML applications in analysing the data, and less attention is paid to how the data from different innovative technologies is captured, stored, analysed, and shared across the different phases in Advanced Scientific Computing (ASC). More research is required in this direction. Studies on identifying the relationships between the various barriers to implementing ML in ASCs are required. Identifying the driving and dependence barriers will help expedite the ML implementation.

6. CONCLUSION AND FUTURE WORK

While progress has been made in developing epilepsy monitoring technologies and the prospect of seizure prediction is conceivable, there are considerable barriers blocking real-time wearable implementation. Existing work has largely focused on single modalities, mainly EEG for detecting seizures, with limited utilization of multimodal physiological signals such as ECG, EDA, and accelerometer data. This makes the accuracy and reliability of seizure prediction models limited.

In addition, real-time processing and analyzing of continuous high-volume data from multiple sensors poses a challenge. Many of the seizure detection ML models have been trained, tested, and evaluated on offline datasets where the dataset could be controlled. The practical use of these trained models usually fails when applied to patients under real-world conditions, as seizures vary between patients (and patients do not always comply with medical advice) as well as the noise in signals and location of placement of sensors.

Further, while AI models for seizure prediction have been created, there are few supporting studies that examine the integration of these models into wearable devices with seamless mobile or web-based visualizers and actionable alert systems. Current studies lack secure and effective caregiver notifications with the ability to isolate notifications down to specific geolocation, which is important for swift intervention.

Lastly, there is a lack of standardized datasets that include EEG, ECG, EDA, and motion data, which causes challenges in reproducibility and comparative evaluation of ML algorithms. Improvements could be made in upcoming studies by using multimodal analysis, real-time processing, predictive AI models, and user-friendly alert systems to improve the safety and quality of life for people

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