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ENHANCING MEDICATION INVENTORY MANAGEMENT USING VENDOR-MANAGED INVENTORY: EVIDENCE FROM HEALTHCARE CLINICS IN MALAYSIA

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Abstract: Medication inventory management continues to pose a significant operational challenge for healthcare clinics, particularly where inventory monitoring and replenishment activities are conducted manually. Frequent stock shortages, inconsistent lead times, and low order fulfilment rates may disrupt treatment continuity and reduce operational efficiency. This study investigates the potential impact of Vendor-Managed Inventory (VMI) on medication inventory performance within a network of twelve company-owned healthcare clinics in the Klang Valley, Malaysia. The study adopts a quantitative case study approach using operational inventory data collected over a six-month period. Three commonly used medications; paracetamol, cetirizine, and ultra-carbon charcoal were selected for analysis. A manual Excel-based simulation was developed to represent the existing inventory system, while Arena discrete-event simulation was employed to model the proposed VMI system. Inventory performance was evaluated using three key indicators: lead time, stockout rate, and order fulfilment rate. Independent-samples t-tests were conducted to determine whether the differences between the manual and VMI scenarios were statistically significant. The findings indicate that the VMI system substantially improved inventory performance. Average lead time was reduced from approximately 31 days to 10 days, stockout rates decreased from approximately 98 percent to around 20 percent, and order fulfilment rates improved from approximately 51.8 percent to 80 percent. Statistical analysis showed that all improvements were significant at $p < 0.001$. The findings suggest that Vendor-Managed Inventory has strong potential to enhance medication inventory performance within the selected clinic network. Nevertheless, the results should be interpreted within the context of the selected case environment and are not intended to be directly generalised to all healthcare settings.

Keywords: Case Study; Discrete-event Simulation; Medication Inventory; T-Test; Vendor-managed Inventory (VMI)

1. Introduction

Medication inventory management plays a critical role in ensuring the continuity of healthcare services and maintaining operational efficiency within healthcare organisations. Healthcare facilities depend on the continuous availability of medications to support patient treatment, emergency response, and routine clinical operations. Ineffective inventory management may lead to medication shortages, excessive inventory holding, treatment

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delays, and unnecessary operational costs. Compared with many other industries, healthcare inventory systems are considerably more complex due to strict regulatory requirements, uncertain demand patterns, medication perishability, and patient safety considerations.

In many healthcare organisations, inventory replenishment decisions are still performed manually using traditional ordering approaches. Under such systems, clinic personnel monitor stock levels manually and initiate replenishment only when inventory appears insufficient. These practices often result in inconsistent ordering behaviour, limited inventory visibility, and delayed replenishment decisions. Consequently, clinics may experience frequent stock shortages and unstable supply performance. Such operational weaknesses may directly affect healthcare service delivery while simultaneously increasing the workload of healthcare personnel.

Within the company-owned clinic network examined in this study, medication ordering activities were primarily managed through manual monitoring and reactive replenishment practices. Historical operational records from twelve clinics revealed substantial variation in replenishment lead times, ranging from one day to more than sixty days, with an average lead time of approximately thirty-one days. Frequent stock shortages were also observed for several commonly prescribed medications. In addition to disrupting treatment continuity, these shortages required clinic staff to devote considerable time to monitoring stock levels, preparing purchase requests, and coordinating with suppliers.

To address these operational challenges, healthcare organisations are increasingly exploring more integrated and data-driven inventory management strategies. One approach that has received considerable attention in the supply chain management literature is Vendor-Managed Inventory (VMI). Under a VMI arrangement, suppliers assume responsibility for monitoring inventory levels and initiating replenishment decisions based on shared operational data. This collaborative structure may improve coordination between suppliers and healthcare providers, reduce replenishment delays, and enhance inventory availability.

Previous studies have shown that Vendor-Managed Inventory can improve supply chain coordination, reduce operational inefficiencies, and enhance inventory performance in manufacturing and retail industries. Within healthcare environments, VMI has also been associated with reduced stock shortages and improved medication availability. However, much of the existing literature focuses on hospitals, manufacturing supply chains, or conceptual discussions of inventory management practices. Limited empirical attention has been given to company-owned healthcare clinic networks operating under decentralised manual ordering systems. In addition, previous studies have frequently concentrated on financial performance and inventory costs rather than operational indicators such as lead time, stockout rate, and order fulfilment. Furthermore, although simulation techniques are widely used in healthcare operations research, relatively few studies have integrated simulation modelling with Vendor-Managed Inventory evaluation in clinic-based healthcare settings. Existing literature also provides limited discussion of how operational variability, such as fluctuating demand and inconsistent ordering behaviour, may influence VMI implementation in decentralised clinic environments.

Therefore, this study aims to evaluate the potential impact of Vendor-Managed Inventory on medication inventory performance within a network of company-owned healthcare clinics. The study adopts a quantitative case study approach using simulation modelling and statistical analysis to compare the existing manual inventory system with a proposed Vendor-Managed Inventory system. Specifically, the study examines whether Vendor-Managed

Inventory can reduce lead time, minimise stockout occurrences, and improve order fulfilment performance within the selected clinic network.

2. Research Problem

Medication inventory management within company-owned healthcare clinics continues to present significant operational challenges. Under the current inventory system, replenishment activities rely heavily on manual stock monitoring and reactive ordering practices. Clinics independently determine when to place medication orders, often based on visual observation of inventory levels rather than systematic forecasting or centralised inventory visibility. Consequently, replenishment practices vary considerably across clinics. Historical operational data collected from the selected clinic network revealed substantial inconsistencies in replenishment lead times, ranging from one day to more than sixty days. In many instances, clinics delayed replenishment activities until stock levels became critically low, resulting in frequent shortages of high-demand medications. The absence of integrated inventory visibility further limited management's ability to coordinate replenishment activities efficiently across clinic locations.

These operational weaknesses generate both clinical and organisational consequences. Frequent medication shortages may disrupt treatment continuity, delay patient care, and reduce service reliability. At the same time, healthcare personnel are required to devote considerable time to monitoring inventory levels, preparing purchase requests, and following up with suppliers, thereby reducing the time available for patient-related activities. Such operational inefficiencies may also contribute to higher procurement costs, emergency purchasing activities, and inconsistent inventory availability across clinic locations. Although Vendor-Managed Inventory (VMI) has been widely discussed as a collaborative inventory management strategy, limited empirical evidence exists regarding its application within company-owned healthcare clinic networks operating under decentralised inventory practices. Existing studies have primarily focused on hospitals, manufacturing industries, or broader pharmaceutical supply chains rather than clinic-based healthcare environments. In addition, relatively few studies have quantitatively examined how Vendor-Managed Inventory affects operational performance indicators such as lead time, stockout rate, and order fulfilment through simulation modelling.

Therefore, this study addresses the need to evaluate whether Vendor-Managed Inventory can improve medication inventory management performance within the selected clinic network. By comparing the existing manual inventory system with a proposed Vendor-Managed Inventory system through simulation analysis, the study seeks to provide operational evidence regarding the potential effectiveness of Vendor-Managed Inventory in healthcare clinic environments.

3. Literature Review

This section reviews the existing literature on inventory management in healthcare and the application of Vendor-Managed Inventory (VMI) as a strategy for improving medication supply management. The review begins by discussing the importance of inventory management and the operational challenges commonly faced within healthcare settings. It then examines contemporary inventory management approaches, including Just-in-Time (JIT)

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systems, real-time inventory tracking, and Vendor-Managed Inventory. Particular attention is given to the role of VMI in improving medication availability and enhancing operational efficiency within healthcare supply chains. In addition, this section explores previous studies on the benefits and implementation of VMI, particularly in healthcare environments where inventory shortages may directly affect patient care outcomes. Finally, the literature review discusses the application of simulation techniques, including Monte Carlo Simulation and Discrete-Event Simulation, as analytical tools for evaluating inventory policies and supporting decision-making in complex healthcare supply chain systems.

3.1 Inventory Management in Healthcare

Poor inventory management may lead to serious operational and clinical consequences within healthcare organisations. Stockouts of critical medications may delay treatment and compromise patient care, while excessive inventory may result in wastage due to product expiration and increased holding costs (Hossain et al., 2020; Fosu et al., 2022). These challenges highlight the need for more structured and data-driven inventory management approaches that enable healthcare organisations to balance cost efficiency with service reliability. In response to these challenges, healthcare organisations are increasingly exploring modern inventory management strategies that improve stock visibility and coordination across the supply chain. Approaches such as real-time inventory tracking, Just-in-Time (JIT) inventory systems, and Vendor-Managed Inventory (VMI) have been widely discussed as potential solutions for enhancing operational efficiency and ensuring the continuous availability of medical supplies (Gravier and Farris, 2018; Panigrahi et al., 2022).

3.2 Modern Approaches to Healthcare Inventory Management

A range of modern inventory management approaches has been proposed to address the operational challenges faced by healthcare organisations. These approaches aim to improve inventory visibility, reduce waste, and ensure the continuous availability of essential medications.

Just-in-Time (JIT) inventory management focuses on reducing inventory holding levels by synchronising product deliveries with actual demand. The approach was originally developed as part of the Toyota Production System and has since been widely adopted across various industries to support lean operations and cost efficiency (Simchi-Levi et al., 2020). In healthcare environments, JIT may be effective for predictable and non-critical items because it reduces storage costs and minimises the risk of product obsolescence. However, the application of JIT in healthcare inventory management must be approached cautiously. Demand for certain medications can be highly unpredictable, and insufficient buffer stock may increase the risk of shortages, particularly during unexpected demand surges or supply disruptions (Shukar et al., 2021).

Real-time inventory tracking technologies provide healthcare organisations with improved visibility of inventory levels and product locations. Technologies such as radio-frequency identification (RFID), barcode systems, and real-time location systems enable healthcare providers to monitor stock levels continuously and identify potential shortages before they occur. The implementation of digital inventory tracking systems can significantly improve operational efficiency by reducing manual inventory checks and improving the

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accuracy of stock data. Previous studies have shown that real-time inventory monitoring can help healthcare facilities reduce administrative workload, minimise inventory discrepancies, and support more accurate demand forecasting (Brailsford et al., 2009).

Vendor-Managed Inventory (VMI) is a collaborative inventory management strategy in which suppliers assume responsibility for monitoring and replenishing inventory levels at the customer's location. Under this arrangement, suppliers are granted access to inventory data and consumption patterns, allowing them to make replenishment decisions based on real-time demand information. Research in supply chain management has shown that VMI can significantly improve supply chain coordination and reduce inefficiencies associated with traditional ordering systems. Early studies demonstrated that VMI can reduce the bullwhip effect and improve inventory stability across supply chain networks (Disney and Towill, 2003). By facilitating information sharing between suppliers and customers, VMI enables more accurate forecasting and smoother replenishment processes.

3.3 Vendor Managed Inventory in Healthcare

Healthcare organisations frequently manage thousands of pharmaceutical items with varying demand patterns, storage requirements, and expiration dates. These complexities make inventory management particularly challenging for hospitals and clinic networks. Vendor-Managed Inventory (VMI) has emerged as a potential solution for addressing these challenges by improving coordination between healthcare providers and suppliers. Under a VMI arrangement, suppliers assume a more active role in monitoring stock levels and initiating replenishment when necessary. This approach reduces the administrative burden placed on healthcare staff and enables clinical personnel to focus more on patient-related activities (Chelwa, 2020).

Research has shown that the implementation of VMI in healthcare systems can lead to improved inventory turnover, reduced stockout rates, and enhanced financial performance. However, successful implementation requires strong collaboration between supply chain partners, reliable data-sharing mechanisms, and clearly defined contractual agreements (Keller et al., 2020; Odongo and Panga, 2021). Without appropriate governance structures, VMI systems may encounter challenges such as incomplete data sharing and misaligned incentives between suppliers and healthcare providers. Consequently, organisational readiness and technological infrastructure play critical roles in determining the success of VMI initiatives.

3.3.1 Centralised Inventory Management in Healthcare Systems

Centralised inventory management refers to an approach in which inventory decisions are coordinated by a single central unit rather than being managed independently by each clinic. In healthcare systems, this approach is commonly implemented through a central warehouse or purchasing unit that oversees stock levels and distribution across multiple facilities. Such a structure enables organisations to manage inventory more systematically and improve coordination throughout the supply chain (Simchi-Levi et al., 2021). In contrast, decentralised systems allow each clinic to manage its inventory independently. Although this may provide greater flexibility at the local level, it often results in inconsistent ordering practices and limited visibility across the network. According to Christopher (2016), fragmented decision-making reduces supply chain efficiency and makes it more difficult to

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align supply with actual demand. As a result, decentralised systems are more likely to experience both stock shortages and excess inventory across different locations.

A major advantage of centralised systems is the ability to aggregate demand across multiple clinics. When demand is consolidated, variability is reduced, resulting in more stable and predictable consumption patterns. This concept, commonly referred to as *risk pooling*, has been shown to improve forecasting accuracy and reduce overall inventory requirements (Simchi-Levi et al., 2021). By smoothing fluctuations across locations, centralisation enables organisations to operate with lower safety stock while maintaining service performance. Centralised inventory management also enhances visibility by integrating inventory data from multiple clinics into a unified system. This enables decision-makers to monitor stock levels, track consumption patterns, and anticipate replenishment needs more effectively. According to Chopra and Meindl (2019), improved visibility enhances responsiveness and supports better coordination between supply and demand. In healthcare settings, this is particularly important because delayed or inaccurate information may result in stockouts that directly affect patient care.

3.3.2 Theoretical Perspective of Vendor-Managed Inventory

This study is guided by Supply Chain Integration Theory, which emphasises the importance of coordination, collaboration, and information sharing among supply chain participants in improving operational performance (Christopher, 2016). According to the theory, supply chains achieve greater operational efficiency when inventory information, replenishment activities, and operational decisions are integrated across supply chain partners. Within a Vendor-Managed Inventory environment, suppliers and healthcare providers operate collaboratively through shared inventory visibility and coordinated replenishment processes. Rather than relying solely on manual purchase requests initiated by clinics, suppliers actively monitor inventory levels and initiate replenishment decisions based on actual operational demand.

Previous studies have suggested that integrated supply chain relationships may improve inventory responsiveness, reduce replenishment delays, and minimise operational variability (Simchi-Levi et al., 2020). In healthcare environments, where demand uncertainty and supply disruptions may directly affect patient care, improved coordination between clinics and suppliers is particularly important. Supply Chain Integration Theory therefore provides an appropriate theoretical foundation for examining how Vendor-Managed Inventory may improve lead time performance, reduce stockout rates, and enhance order fulfilment within company-owned healthcare clinic networks.

3.4 Benefits of Implementing VMI in Healthcare Inventory Management

The adoption of Vendor-Managed Inventory (VMI) can generate several benefits for healthcare organisations. These benefits generally fall into three main categories: cost reduction, improved service levels, and enhanced operational efficiency. From a cost perspective, VMI enables better alignment between inventory replenishment and actual consumption patterns. This reduces the likelihood of overstocking and minimises losses resulting from expired medications (Shah and Huat, 2021). Improved coordination with suppliers also reduces the need for emergency purchases, which are often associated with higher procurement costs.

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Service levels may also improve through the implementation of VMI. By allowing suppliers to monitor inventory levels directly, healthcare organisations can reduce the frequency of stockouts and ensure more consistent availability of essential medications. Improved medication availability contributes to better treatment continuity and enhanced patient satisfaction. In addition, VMI can enhance operational efficiency within healthcare organisations. When suppliers assume responsibility for routine inventory replenishment activities, healthcare personnel are able to devote more time to patient care rather than administrative inventory management tasks (Burgess et al., 2022).

3.5 Simulation Approaches in Healthcare Supply Chains

Simulation techniques are widely used in healthcare operations research to analyse complex systems and evaluate alternative operational policies. Two commonly applied approaches are Monte Carlo Simulation (MCS) and Discrete-Event Simulation (DES). Monte Carlo Simulation uses repeated random sampling to evaluate the impact of uncertainty on system outcomes. This method enables researchers to estimate the probability of events such as stockouts and to evaluate the variability of inventory costs under different demand scenarios (Metropolis and Ulam, 1949; Kroese et al., 2014).

3.5.1 Monte Carlo Simulation

According to Ross (2014), Monte Carlo methods rely on generating random values based on predefined probability distributions to analyse variability and risk in complex systems. This approach is particularly useful when dealing with uncertain demand patterns and lead time variability. In inventory management, Monte Carlo Simulation has been applied to evaluate reorder policies, safety stock levels, and service performance under conditions of uncertainty. By repeatedly simulating demand and supply conditions, researchers can estimate key performance indicators such as stockout probability and expected inventory levels (Silver et al., 2016). Compared with deterministic approaches, Monte Carlo Simulation provides a more flexible method for capturing real-world variability. It is commonly implemented using spreadsheet-based tools, where random number generation functions are used to simulate demand fluctuations and order arrivals. This makes the technique accessible and practical, particularly during the preliminary stages of analysis.

In this study, elements of Monte Carlo Simulation are incorporated into the data preparation and modelling process, particularly through the use of random sampling techniques to represent order arrivals and demand variability. These inputs are subsequently integrated into the discrete-event simulation model, allowing for a more realistic representation of system behaviour. Discrete-Event Simulation (DES) models systems as sequences of events occurring over time. This approach is particularly suitable for healthcare environments because it can capture the interactions among patient flows, resource availability, and operational processes (Brailsford et al., 2009). DES has been widely applied in the evaluation of hospital workflows, patient scheduling systems, and supply chain operations. Simulation models provide valuable decision-support tools for healthcare managers by enabling them to evaluate alternative inventory policies before implementing them in actual operational settings.

3.5.2 Discrete Event Simulation

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As explained by Banks et al. (2010), Discrete-Event Simulation (DES) provides a structured approach for representing real-world operations by modelling key components such as entities, processes, queues, and resources. In an inventory management context, entities may represent orders or products, while processes include activities such as order placement, replenishment, and delivery. This approach enables the system to be analysed in a manner that closely reflects actual operational conditions.

One of the principal strengths of DES is its ability to incorporate variability into the simulation model. Rather than assuming fixed values, elements such as demand patterns, order intervals, and lead times can be represented using probability distributions. This is particularly relevant in clinic environments, where demand is rarely constant and ordering decisions may differ across locations. By capturing such variability, the simulation provides a more realistic representation of system performance. Simulation software such as Arena Simulation Software is widely used because it supports both visual modelling and flexible logic development. Within Arena, it is possible to model decision rules, such as reorder point triggers, as well as operational constraints including limited delivery resources. This makes it a practical tool for analysing inventory systems that involve multiple interacting variables.

Beyond modelling the existing system, DES is also valuable for evaluating potential operational improvements. Researchers frequently use simulation techniques to compare alternative inventory strategies, such as manual inventory systems and Vendor-Managed Inventory (VMI), without disrupting actual operations (Sargent, 2013). This enables organisations to examine alternative approaches and assess their potential impact prior to implementation.

3.6 Advantages of Simulation for Inventory Management

One of the key advantages of simulation modelling is its ability to represent complex and uncertain systems more realistically than many traditional analytical models. Healthcare systems frequently involve stochastic demand patterns, variable lead times, and multiple interacting processes that are difficult to capture using simple mathematical models. Simulation enables researchers to evaluate different operational policies within a controlled virtual environment without disrupting actual healthcare services. This makes it possible to test alternative inventory strategies, such as Vendor-Managed Inventory (VMI) systems, before implementing them in practice (Brailsford et al., 2009). In addition to supporting policy evaluation, simulation models also improve communication among stakeholders. Visual outputs, including flow diagrams and simulation animations, help managers and clinicians better understand system behaviour and assess the potential impact of operational changes. Consequently, simulation has become an important tool for supporting evidence-based decision-making in healthcare operations management.

Although previous studies have reported that Vendor-Managed Inventory improves inventory coordination and medication availability, much of the existing literature has focused on hospitals, manufacturing industries, and pharmaceutical distribution systems rather than decentralised clinic networks. Furthermore, many studies have concentrated primarily on financial outcomes, such as inventory cost reduction, while relatively limited attention has been given to operational indicators including stockout rate, lead time, and order fulfilment. Consequently, limited empirical evidence exists regarding the operational

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impact of Vendor-Managed Inventory within company-owned healthcare clinics operating under fragmented ordering practices.

4. Methodology

This study adopts a quantitative case study approach to evaluate the effectiveness of Vendor-Managed Inventory (VMI) in improving medication inventory management within company-owned healthcare clinics. A simulation-based approach was employed to compare the performance of the existing manual inventory system with that of a proposed Vendor-Managed Inventory system.

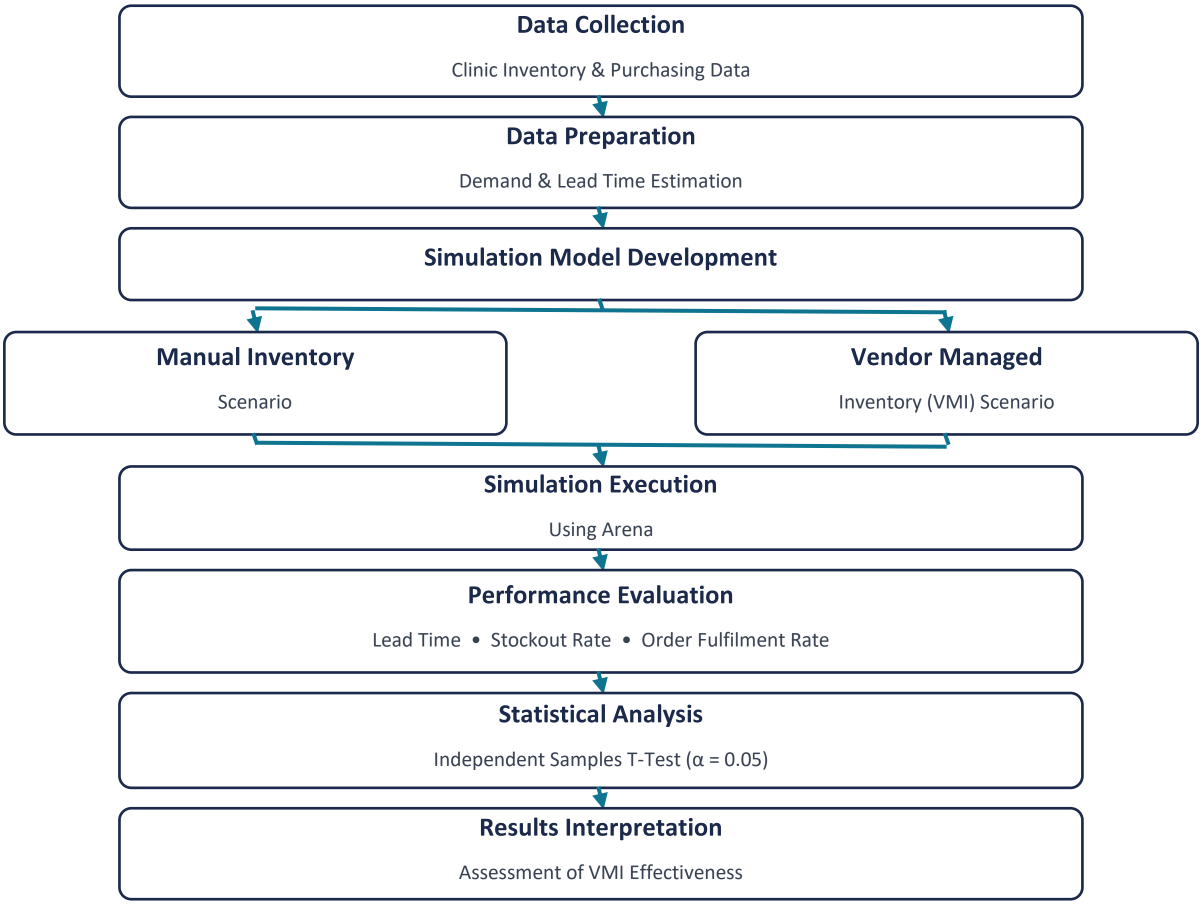

Figure 1. Research framework

Figure 1 presents the research framework adopted in this study. The framework begins with the collection of clinic inventory and purchasing records from selected healthcare clinics. The collected historical data were subsequently prepared through demand and lead time estimation to support the simulation modelling process. Two inventory management scenarios were then developed, namely the existing manual inventory system and the proposed Vendor Managed Inventory (VMI) system using Arena simulation software. The simulation execution phase was conducted to evaluate the inventory performance under both scenarios. The evaluation focused on key performance indicators including lead time, stockout rate, and order fulfilment rate. Subsequently, statistical analysis using an independent samples t-test at a significance level of $\alpha = 0.05$ was performed to determine

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whether significant differences existed between the two inventory systems. Finally, the results were interpreted to assess the effectiveness of the VMI system in improving inventory management performance among company-owned healthcare clinics.

4.1 Study Setting and Data

This study was conducted using operational data obtained from twelve company-owned healthcare clinics located in the Klang Valley region of Malaysia. Three commonly prescribed medications; paracetamol, cetirizine, and ultra-carbon charcoal were selected for analysis because they represent high-usage pharmaceutical items with differing demand patterns across clinics. These medications provide a suitable basis for examining inventory behaviour under varying demand conditions. Secondary data were obtained from clinic inventory records and central purchasing documents covering a six-month period. The data utilised in this study were collected from 12 company-owned healthcare clinics located in the Klang Valley, Malaysia. Historical inventory and purchasing records covering a six-month period from October 2025 to February 2025 were obtained for analysis. The collected data included medication demand, stock balance, order quantity, order date, delivery date, lead time, and stockout occurrences for selected medications, namely paracetamol, cetirizine, and ultracarbon charcoal. These historical records were subsequently used as input parameters for the Arena simulation model to evaluate and compare the performance of the manual inventory system and the proposed Vendor Managed Inventory (VMI) system.

4.2 Performance Measures

Inventory performance was evaluated using three key indicators: lead time, stockout rate, and order fulfilment rate. These indicators were selected because they capture important aspects of medication availability and supply chain efficiency within healthcare settings. Lead time was measured as the number of days between order placement and the receipt of medication at the clinic. Stockout rate refers to the proportion of demand periods during which inventory levels were insufficient to satisfy demand. Order fulfilment rate represents the percentage of total demand successfully supplied to patients. Collectively, these indicators provide a comprehensive assessment of inventory performance under different inventory management approaches.

4.3 Simulation Model

A simulation-based approach was employed to evaluate the potential impact of Vendor-Managed Inventory (VMI) in comparison with the existing manual inventory system. Two scenarios were developed: a baseline scenario representing the current manual ordering process and a VMI scenario representing the proposed vendor-managed replenishment system. The manual scenario was implemented using an Excel-based simulation model designed to replicate the historical ordering behaviour observed in the dataset. The model incorporated irregular ordering intervals, variations in order quantities, and supplier lead times derived from historical records. This scenario served as the baseline for evaluating the performance of the current inventory management system.

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For the VMI scenario, a discrete-event simulation model was developed using Arena Simulation Software. The model represents the vendor-managed replenishment process, including demand arrivals, monitoring of clinic inventory levels, reorder decisions based on predefined stock thresholds, central warehouse inventory checks, supplier ordering, and delivery to clinics. Demand and lead-time distributions were estimated from historical operational data to reflect real-world uncertainty. This enabled the simulation model to capture operational variability, where demand patterns and delivery lead times may fluctuate over time. Incorporating such variability enhances the realism and practical relevance of the simulation results.

Each scenario was simulated over a 66-day operational period corresponding to the duration of the observed dataset. This alignment ensured that the simulation results were directly comparable with actual operational observations. To reduce the influence of randomness within the simulation outputs, five replications were performed for each scenario. The average values obtained from these replications were then used to represent the overall performance of each inventory system. The performance of both scenarios was evaluated using three key indicators: lead time, stockout rate, and order fulfilment rate. These measures were selected because they reflect the responsiveness of the inventory system to demand, the frequency of inventory shortages, and the effectiveness of order completion. By comparing these indicators across the two scenarios, the study is able to assess whether the proposed Vendor-Managed Inventory system offers meaningful improvements over the existing manual inventory approach.

4.4 Statistical Analysis

To determine whether the differences between the manual inventory system and the Vendor-Managed Inventory (VMI) scenario were statistically significant, independent-samples t-tests were conducted. The analysis compared the mean values of lead time, stockout rate, and order fulfilment rate obtained from the simulation outputs. The null hypothesis stated that there was no significant difference between the manual and VMI scenarios, while the alternative hypothesis proposed that the VMI system would improve inventory performance. A significance level of 0.05 was applied for all statistical tests. *p*-values were calculated using the T.TEST function in Microsoft Excel based on the simulation results obtained from the five replications of each scenario. Independent-samples t-tests were selected because the study compares mean performance between two independent inventory scenarios, namely the manual inventory system and the Vendor-Managed Inventory scenario. As the objective was to evaluate differences between two operational conditions rather than among multiple treatment groups, the t-test was considered an appropriate statistical technique for the analysis.

5. Result and Discussion

This section presents the results of the simulation analysis comparing the performance of the existing manual inventory system with the proposed Vendor-Managed Inventory (VMI) approach. The findings are discussed using three key performance indicators: lead time, stockout rate, and order fulfilment rate. First, the baseline performance of the manual inventory system is examined to establish the existing operational conditions. The

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results of the VMI simulation are then presented and compared with the baseline scenario. Finally, statistical analysis using independent-samples t-tests is conducted to determine whether the observed differences between the two systems are statistically significant.

5.1 Baseline Performance of the Manual Inventory System

The simulation results for the manual inventory system confirmed the operational problems observed in the empirical clinic data.

Table 1. Manual Inventory System Results

Replication	LeadTime_Manual (days)	Stockout Manual (%)	Fulfilment Manual (%)
1	31	98.2	51.82
2	30	99.48	56.7
3	32	97.42	51.03
4	29	99	55.67
5	33	98.45	43.8
Average	**31**	**98.51**	**51.80**

As shown in Table 1, the average stockout rate reached 98.51 percent, indicating that shortages occurred during almost every demand period for at least one of the medications analysed. The average lead time was 31 days, reflecting slow and inconsistent replenishment processes. In addition, the average order fulfilment rate was only 51.80 percent, suggesting that nearly half of the medication demand could not be fully satisfied. These findings indicate that the existing manual inventory system is unable to maintain reliable medication availability. The high stockout rates, combined with lengthy replenishment lead times, suggest that the current system operates in a highly reactive manner and depends heavily on manual stock monitoring. Such conditions frequently contribute to medication shortages and operational inefficiencies within healthcare inventory systems.

5.2 Performance of the VMI Simulation

When Vendor-Managed Inventory (VMI) was introduced into the simulation model, inventory performance improved substantially.

Table 2. VMI Simulation Result

Replicatio n	LeadTime VMI (days)	Stockout VMI (%)	Order Fulfilment VMI (%)
1	8	20.56	79.44
2	11	20	80
3	11	17.22	82.78
4	11	21.11	78.89
5	8	21.11	78.89
Average	**10**	**20.0**	**80**

As presented in Table 2, the average lead time decreased from 31 days under the manual system to approximately 10 days. This reduction indicates that vendor-managed

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replenishment can significantly accelerate the ordering cycle and improve supply responsiveness. The stockout rate also declined markedly, decreasing from approximately 98 percent in the manual system to around 20 percent under the VMI scenario. Although stock shortages were not completely eliminated, they occurred far less frequently compared with the existing system. At the same time, the order fulfilment rate improved from 51.80 percent to approximately 80 percent, indicating that a considerably larger proportion of medication demand could be satisfied. These findings demonstrate how a more structured and data-driven replenishment approach can stabilise inventory availability and enhance overall supply performance.

5.3 Statistical Comparison Between Manual and VMI Systems

To determine whether the observed improvements were statistically significant, independent-samples t-tests were conducted for the three key performance indicators which are lead time, stockout rate, and order fulfilment rate.

Table 3. T-Test Results Comparing Manual and VMI Scenarios

Metric	Manual System (Avg)	Arena Simulation (Avg)	Result of t-test	Conclusion
Lead Time	31 days	10 days	$p < .0001$	Reject H_0 - VMI significantly reduces lead time
Stockout Rate	98.20%	20%	$p < .0001$	Reject H_0 - VMI significantly reduces stockouts
Order Fulfillment	51.80%	80%	$p < .0001$	Reject H_0 - VMI significantly improves order fulfillment

Table 3 shows the differences between the manual inventory system and the Vendor-Managed Inventory (VMI) scenario are highly significant. For all three performance indicators, the *p*-values were below 0.001, suggesting that the improvements observed in the simulation are unlikely to have occurred by chance. The reduction in lead time suggests that VMI transforms the inventory process from a slow and reactive system into a faster and more coordinated replenishment mechanism. Shorter and more predictable lead times enable clinics to manage inventory more efficiently and minimise delays in medication supply. The reduction in stockout rates is particularly significant from a healthcare perspective. Under the manual system, the extremely high stockout rate indicates frequent shortages of essential medications. In contrast, the VMI scenario substantially improves medication availability, thereby reducing the likelihood of treatment delays caused by unavailable stock.

Similarly, the improvement in order fulfilment demonstrates that clinics are able to satisfy a substantially larger proportion of patient demand under the VMI system. Increasing the fulfilment rate from 51.80 percent to 80 percent represents a considerable enhancement in inventory performance and may contribute to more consistent and reliable healthcare service delivery. Overall, the findings indicate that the implementation of Vendor-Managed Inventory has strong potential to improve medication inventory management within healthcare clinics. Nevertheless, successful implementation in practice would require reliable

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information sharing between clinics and suppliers, clearly defined replenishment procedures, and appropriate technological infrastructure to support the VMI process.

6. Conclusion

This study examined the potential impact of Vendor-Managed Inventory (VMI) on medication inventory management within a network of healthcare clinics. Using operational data collected from twelve clinics in the Klang Valley, a simulation model was developed to compare the performance of the existing manual inventory system with a proposed Vendor-Managed Inventory approach. The analysis focused on three key performance indicators: lead time, stockout rate, and order fulfilment rate. The findings indicate that the implementation of Vendor-Managed Inventory can significantly improve inventory performance in healthcare clinics. Compared with the manual system, the simulation results demonstrated a substantial reduction in lead time, decreasing from an average of 31 days to approximately 10 days. At the same time, the stockout rate declined considerably from 98.20 percent to 20 percent, while order fulfilment improved from approximately 51.80 percent to 80 percent. Statistical testing confirmed that these improvements were highly significant, indicating that the adoption of a more structured and data-driven replenishment approach can enhance medication availability and operational efficiency.

The findings also contribute to addressing an important gap in the existing literature. Although Vendor-Managed Inventory has been widely studied in manufacturing and retail supply chains, empirical evidence relating to its application in healthcare clinic inventory systems remains limited. Furthermore, relatively few studies have used simulation modelling to evaluate the operational impact of Vendor-Managed Inventory on key inventory performance indicators at the clinic level. By developing and analysing a simulation model based on actual clinic data, this study provides quantitative evidence of how Vendor-Managed Inventory may improve medication supply performance in healthcare settings.

From a practical perspective, the findings suggest that Vendor-Managed Inventory has strong potential to reduce medication shortages and improve supply reliability within healthcare clinics. Allowing suppliers to monitor inventory levels and manage replenishment decisions may streamline the ordering process, improve coordination between clinics and suppliers, and support more consistent medication availability for patients. Nevertheless, several limitations should be acknowledged. The simulation model was based on data from a limited number of clinics and focused on only three commonly used medications. In addition, the model assumed consistent data sharing and stable supplier performance, conditions which may vary in actual operational environments. Future research could extend the analysis by including a wider range of medications, longer observation periods, and additional operational factors such as supplier capacity and transportation variability. Overall, the findings highlight the potential of Vendor-Managed Inventory as a practical strategy for improving medication inventory management and strengthening supply reliability within healthcare clinics.

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