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Optimizing Medical Equipment Inventory Management through Web-Based System Implementation for Real-Time Monitoring and Alerts

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Keywords

Inventory Management; Laravel Framework; Medical Equipment Management; Real-Time Monitoring; Web-Base System;

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Abstract

Manual inventory processes at PT Borneo Sejahtera Medika resulted in an 18.2% stock discrepancy rate, frequent expired items, and delayed procurement decisions. This study develops and empirically evaluates a web-based inventory management system integrating real-time monitoring, automated expiration alerts, and demand forecasting. A six-month before–after analysis was conducted to measure system impact using discrepancy rate, operational performance indicators, and forecasting accuracy metrics. The results show that the discrepancy rate decreased from 18.2% to 13.6%, representing a relative improvement of 25.27%. Operational performance improved significantly, with stock checking time reduced by 52%, expired items reduced by 57%, and emergency procurement reduced by 31%. The forecasting module achieved a Mean Absolute Percentage Error (MAPE) of 5.00%, indicating acceptable short-term prediction accuracy. These findings demonstrate that the implemented system provides measurable improvements in data accuracy, operational efficiency, and inventory control within a healthcare distribution context.

1. Introduction

Efficient inventory management is critical in the healthcare sector, particularly for medical equipment, which directly impacts patient care. Studies indicate that poor inventory management can lead to shortages of critical equipment, delays in treatment, and wastage of resources, all of which can compromise patient safety and institutional effectiveness [1],[2],[3]. Integrating strategic and operational decision frameworks has been shown to significantly enhance hospital material supply chain performance and reduce inefficiencies [4], [5]. Traditional methods of inventory management, particularly manual systems, are prone to human error, which can result in mismanagement and inefficiencies [6], [7].

The use of a web-based inventory management system has been shown to significantly improve accuracy and efficiency in healthcare settings. By providing real-time tracking and notifications, such systems can help prevent stockouts and ensure the timely rotation of medical equipment. Studies have highlighted the effectiveness of such systems, demonstrating how they enable better decision-making and reduce operational costs [8],[9]. Furthermore, the integration of technology allows for better coordination between departments, improving the overall flow of inventory management across healthcare institutions [10]. Recent studies emphasize that digital healthcare information systems significantly enhance data accessibility, transparency, and operational coordination in institutional environments [11], [12]. However, most prior studies primarily focus on system implementation without providing comprehensive empirical validation using quantitative operational performance indicators. Therefore, this research extends previous work by incorporating measurable accuracy improvement analysis and forecasting performance evaluation.

In Indonesia, the implementation of automated inventory systems is still in its early stages, particularly in private healthcare institutions like PT Borneo Sejahtera Medika. The company currently relies on traditional methods, which, as outlined, create inefficiencies and increase the risk of errors. A recent assessment revealed that over 30% of the stock in many hospitals and medical supply companies is either wasted or expired due to poor inventory tracking [13]. This issue is especially critical in medical equipment management, where the timely availability of critical tools can save lives.

This research aims to develop a web-based inventory management system tailored for PT Borneo Sejahtera Medika, focusing on real-time monitoring and alerts [14]. The proposed system will incorporate key features such as automatic stock level tracking, expiration date monitoring, and early alerts for low stock or nearing expiration [15]. By addressing the current manual process's limitations, the system will enhance operational efficiency, reduce waste, and ensure that critical medical equipment is always available when needed.

In line with global trends, the system will also utilize predictive analytics to forecast future demand based on historical data, enabling proactive inventory management. Such systems have been reported to improve operational efficiency in healthcare environments [16]. The proposed solution is designed to be scalable, cost-effective, and easily integrated with existing hospital management systems, which is essential for widespread adoption [17]. Furthermore, the implementation of predictive analytics and data-driven decision-making is supported by recent studies that have shown the value of IoT and big data in managing healthcare product The introduction of this system at PT Borneo Sejahtera Medika is expected to set a precedent for other healthcare providers in Indonesia, demonstrating how technology can transform healthcare inventory management [18]. This paper presents a comprehensive plan for the design, implementation, and evaluation of this web-based system, with the goal of improving the management of medical equipment and, ultimately, the quality of patient care.

While numerous studies have examined healthcare inventory management systems, most prior research either focuses on conceptual supply chain frameworks or large-scale hospital implementations without detailed empirical validation in medium-scale healthcare suppliers. This study contributes to the literature in four significant ways. First, it provides an empirically measured before–after performance evaluation of a real-time web-based inventory system in a medium-scale Indonesian healthcare distributor. Second, it quantitatively evaluates operational performance using measurable indicators, these indicators are consistent with established inventory accuracy evaluation frameworks in operations management research [1], including stock discrepancy rate, inventory checking time, expired item frequency, and user satisfaction metrics. Third, it integrates predictive demand forecasting into a Laravel–MySQL architecture and evaluates forecasting accuracy using statistical error metrics (MAPE). Fourth, this research proposes an applied evaluation framework combining system functionality testing, operational performance indicators, and user acceptance measurement, offering a replicable assessment model for similar healthcare institutions.

Therefore, this study positions itself not merely as a system development report but as an applied empirical evaluation research in healthcare inventory informatics. This positioning aligns with contemporary healthcare supply chain evaluation research. Unlike prior studies focusing solely on system development or conceptual supply chain analysis, this study provides an integrated empirical performance evaluation combining discrepancy rate analysis, operational indicators, and forecasting validation within a real-world healthcare distributor.
Therefore, this study not only proposes a web-based inventory management system but also provides empirical validation of its operational effectiveness through quantitative performance indicators, including

discrepancy rate analysis, operational performance metrics, and forecasting accuracy within a real-world healthcare distribution environment.

This study contributes to the healthcare inventory management literature by providing empirical validation of a web-based inventory management system using quantitative operational indicators, including discrepancy rate analysis, forecasting accuracy evaluation, and operational performance measurement within a real-world healthcare distribution environment.

2. Research Method

This study applies a System Development Life Cycle (SDLC) approach, specifically utilizing the Waterfall model, to design and implement a web-based inventory management system aimed at improving the medical equipment management process at PT Borneo Sejahtera Medika. The methodology is divided into distinct phases, beginning with the Analysis Phase, where the primary objective is to identify and define the functional and non-functional requirements of the proposed system. The functional requirements encompass key system features, including real-time inventory tracking, automatic expiration date notifications, and the generation of alerts for low-stock situations. Non-functional requirements focus on system performance, scalability, security, and usability, ensuring that the final solution aligns with both technical and organizational needs. Data collection for this phase is conducted through qualitative methods such as interviews, observational studies, and an extensive literature review, aimed at understanding the current challenges and inefficiencies in PT Borneo Sejahtera Medika's existing manual inventory management system

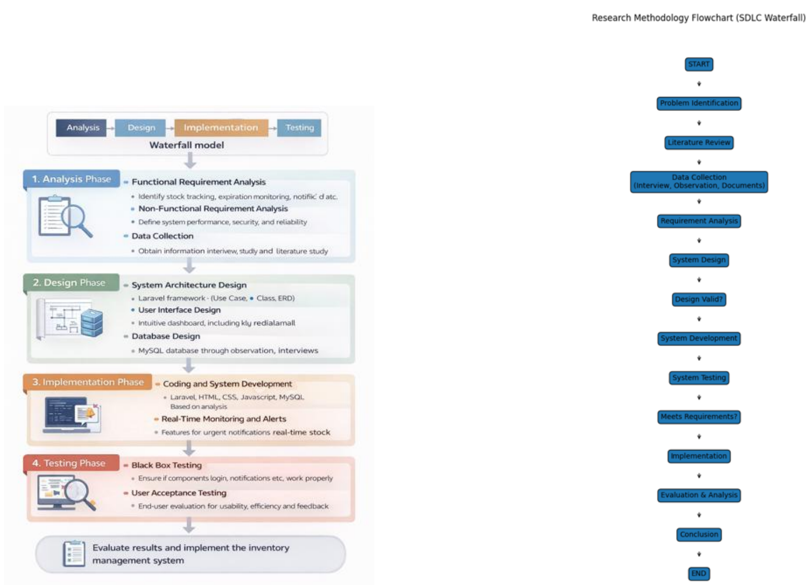

Figure 1. Research Flow Using SDLC Waterfall Model

The Design Phase is structured around the creation of a detailed system architecture that meets the functional and non-functional specifications outlined in the analysis phase. The system is designed using the Laravel framework, a robust and scalable tool for web development that ensures high flexibility and future-proof integration capabilities. The design includes the development of comprehensive Use Case Diagrams, Class Diagrams, and Entity Relationship Diagrams (ERD) to visually represent the system's structure and its interactions. The user interface (UI) design is tailored to provide an intuitive experience for all stakeholders, ensuring ease of use for both administrators and operational staff. Furthermore, the database design is an integral aspect of the system's architecture, employing MySQL as the relational database management system (RDBMS) for secure and efficient data storage, including inventory levels, product details, and expiration dates. The Implementation Phase involves the development of the system according to the design specifications. This phase employs industry-standard web development technologies, including Laravel, HTML, CSS, and

JavaScript, to bring the system to life. A key feature of the system is its real-time monitoring capabilities, which allow staff to receive instant alerts when inventory levels fall below predefined thresholds or when products are nearing their expiration dates. By leveraging this functionality, PT Borneo Sejahtera Medika can significantly reduce the occurrence of stockouts and expired products, which have been identified as critical inefficiencies in the current manual system. Additionally, the system integrates predictive analytics to optimize stock replenishment, ensuring that inventory levels are always sufficient to meet demand while minimizing waste.

Finally, the Testing Phase ensures that the developed system meets the required functional and performance standards. This phase employs Black Box Testing, where the system's functionality is evaluated without considering the internal code structure. This methodology ensures that the developed system is both functional and adaptable to the dynamic needs of PT Borneo Sejahtera Medika, ultimately enhancing the efficiency of its medical equipment inventory management. To quantitatively evaluate system effectiveness, a before–after comparative study was conducted over a six-month observation period (three months before and three months after system implementation). A total of 120 inventory items were selected using stratified sampling based on turnover categories (high, medium, and low). Physical stock audits were conducted at the end of each observation month by two independent warehouse supervisors to ensure measurement consistency and minimize bias. The reported discrepancy values represent the average of three monthly audit cycles for each observation period. Stock verification was performed through physical counting and compared against recorded stock data in the system. The discrepancy rate and data accuracy were calculated using the following formulas :

$$Discrepancy\ Rate\ (\%) = \frac{|\ Recorded\ Stock - Physical\ Stock\ |}{Physical\ Stock}\ x\ 100 \quad (1)$$

$$Data\ Accuracy\ (\%) = 100 - Discrepancy\ Rate \quad (2)$$

The relative improvement in accuracy was computed using :

$$Improvement\ (\%) = \frac{(Before - After\ )}{Before}\ x\ 100 \quad (3)$$

Table 1. Data Accuracy Measurement Framework

Component	Description	Method
Study Design	Before–After Comparative Study	3 months pre vs 3 months post implementation
Sample Size	120 inventory items	Stratified by turnover category
Data Source	Recorded vs Physical Stock	Direct stock audit
Key Metric 1	Discrepancy Rate	Absolute difference ratio
Key Metric 2	Data Accuracy	100 – Discrepancy Rate
Evaluation Method	Relative Improvement	Comparative percentage analysis

3. Results and Discussions

The implementation of the web-based inventory management system for PT Borneo Sejahtera Medika led to notable improvements in inventory accuracy, operational efficiency, and overall stock management. The system addressed the inherent limitations of the previous manual inventory management process, such as human errors, slow decision-making, and a lack of real-time data monitoring. Automation in stock tracking, along with the integration of expiration date alerts, played a crucial role in minimizing stock wastage and preventing stockouts.

These results strengthen prior findings that digital and automated inventory systems significantly reduce operational risk compared to manual recording approaches [19].

3.1 System Functional Validation

System functional validation was conducted to ensure that the core modules of the web-based inventory management system operated according to the design specifications. The tested modules included:

1. User authentication and access control
2. Stock input, update, and deletion
3. Automated expiration alerts
4. Reporting and summary dashboards
5. Forecasting display and calculation

All test cases were executed according to predefined scenarios, and the system produced the expected outputs in every case, confirming that the functionalities met their specifications.

While functional testing confirmed system reliability, it does not provide evidence of operational performance improvements. Therefore, the main contribution of this study focuses on quantitative evaluation, which includes:

1. Accuracy improvement analysis (discrepancy rate before and after implementation)
2. Operational performance metrics (time reduction, expired item reduction, emergency procurement cases)
3. Forecasting accuracy (Mean Absolute Percentage Error – MAPE)
4. User satisfaction assessment

This approach ensures that the system is both functionally correct and empirically effective, aligning with the requirements of rigorous academic evaluation rather than solely presenting a development report.

3.2 Accuracy Improvement Analysis

The data accuracy of the system was assessed using a quantitative before–after comparative analysis. The manual inventory system recorded an average discrepancy rate of 18.2%, corresponding to a data accuracy level of 81.8%. After implementation of the web-based system, the discrepancy rate decreased to 13.6%, resulting in an accuracy level of 86.4%. The relative improvement in discrepancy reduction was calculated using the formula:

$$Improvement\ (\%) = \frac{(Before - After)}{Before}\ x\ 100 = \frac{18.2 - 13.6}{18.2}\ x\ 100 = 25.27\ \% \quad (4)$$

This indicates that the implementation of real-time monitoring and automated logging significantly enhanced inventory data consistency and reduced manual recording errors.

These empirical findings are consistent with established inventory record inaccuracy research [20], which highlights that centralized digital systems significantly reduce discrepancy rates compared to manual recording processes.

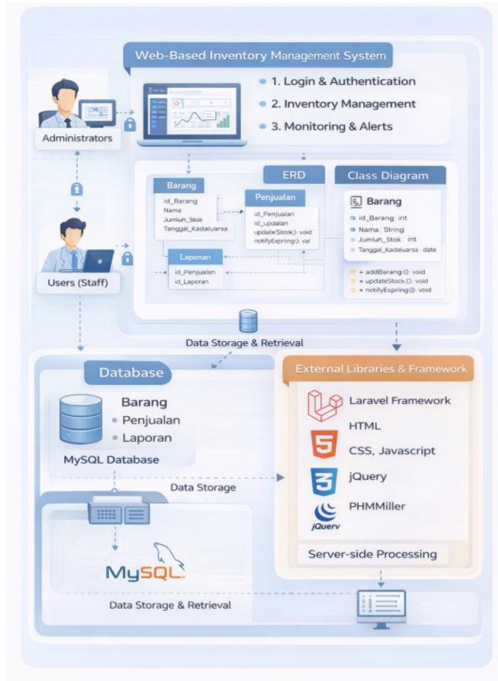

Figure 2. System Architecture Design of the Proposed Web-Based Inventory System

User satisfaction was evaluated using a structured questionnaire distributed to 12 operational staff members involved in daily inventory management activities. The questionnaire employed a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess system usability, monitoring effectiveness, ease of data entry, and reporting functionality. The average overall satisfaction score was 4.32 out of 5, indicating high acceptance of the implemented system. The highest rating was recorded for real-time monitoring capability (4.5), while the lowest score was related to the initial adaptation process (3.8). These results demonstrate that the system was positively received and effectively supported operational tasks.

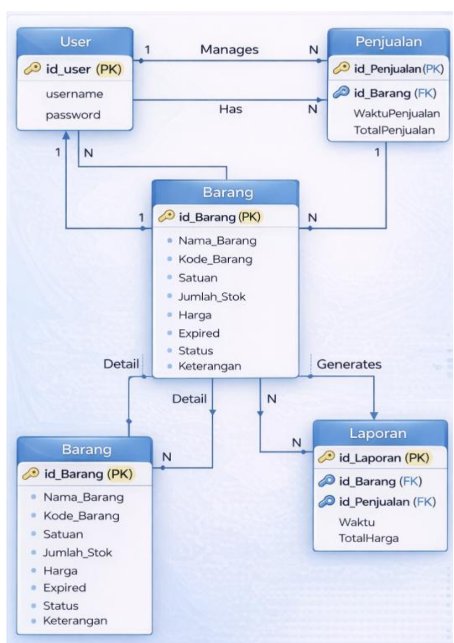

Figure 3. Entity Relationship Diagram (ERD) of the Inventory System

Additionally, the system's integration of predictive analytics for stock replenishment and demand forecasting proved valuable in reducing the need for manual inventory adjustments and improving overall operational efficiency.

3.3 Predictive Analytics Performance Evaluation

The forecasting module applies a three-period Moving Average method based on historical monthly demand data. Moving Average forecasting techniques are widely used in healthcare supply chain planning due to their simplicity and effectiveness in short-term demand prediction [15], [16].

$$Ft = \frac{(Dt - 1 + Dt - 2 + Dt - 3)}{3} \qquad (5)$$

Forecast accuracy was evaluated using Mean Absolute Percentage Error (MAPE):

$$MAPE\ (\%) = \frac{1}{n} \sum \left(\frac{Actual - \ Forecast}{Actual} \right) x\ 100 \qquad (6)$$

Table 2. Forecasting Performance Evaluation

Month	Actual Demand	Forecast	Absolute Error	APE (%)
Jan	120	115	5	4.17%
Feb	135	130	5	3.70%
Mar	140	150	10	7.14%
Average (MAPE)	-	-	-	5.00%

The forecasting module achieved A MAPE value of 5.00%, indicating acceptable operational forecasting accuracy for inventory planning.A MAPE value below 10% is generally considered acceptable for short-term operational forecasting in healthcare supply chains [19].

3.4 Operational Performance Indicators

Table 3. Operational Performance Comparison

Indicator	Manual System	Web-Based System	Improvement
Stock Checking Time	25 minutes	12 minutes	52% faster
Monthly Expired Items	14 items	6 items	57% reduction
Emergency Procurement	13 cases	9 cases	31% reduction

The reduction in operational time and expired stock demonstrates measurable performance improvement beyond functional system validation. Overall, the results of this study demonstrate the effectiveness of web-based inventory management systems in improving data accuracy, operational efficiency, and inventory control in healthcare settings.

These performance improvements reflect the operational efficiency gains discussed in healthcare supply chain literature. These findings are also consistent with recent studies indicating that real-time digital inventory systems significantly improve operational transparency, reduce stock discrepancies, and enhance decision-making efficiency in healthcare logistics environments, where digital inventory systems contribute to measurable time reduction and waste minimization [17], [21].

When compared with earlier studies on healthcare inventory digitization, the present findings reinforce a consistent pattern: systems that combine real-time monitoring, automated alerts, and forecasting features produce the most substantial operational improvements. Therefore, the contribution of this study lies not only in system development but also in confirming through applied implementation that integrated feature sets yield stronger performance gains than single-function inventory tools.

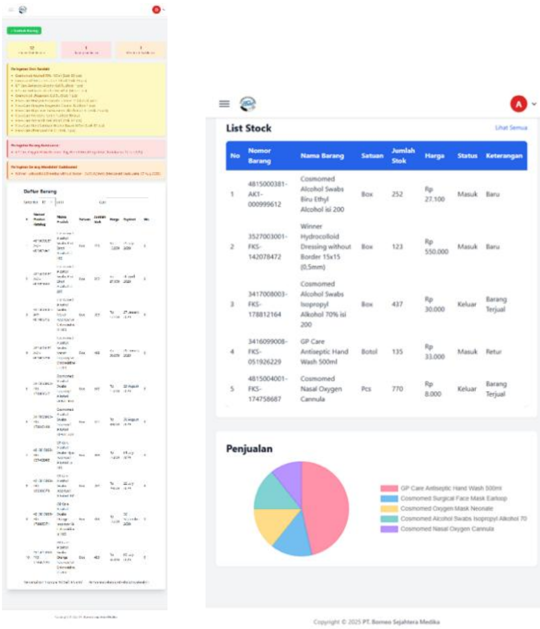

Figure 4. Administrative Dashboard Interface

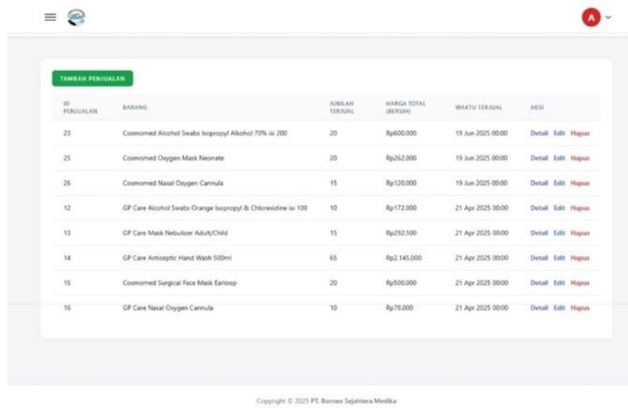

Figure 5. Sales Monitoring Interface

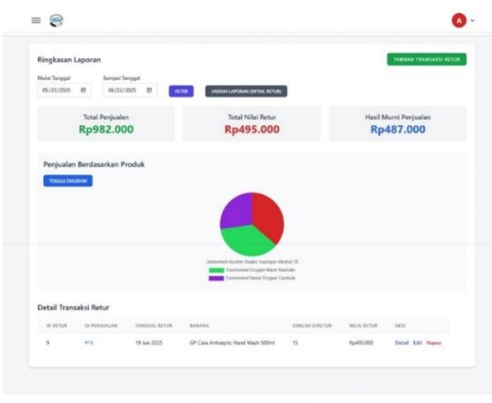

Figure 6. Sales and Returns Report View

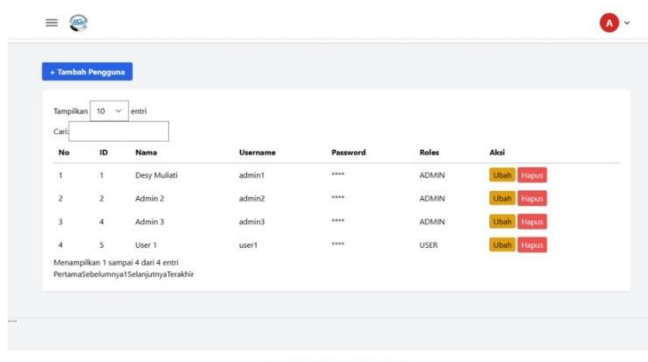

Figure 7. Manage System Users view

Figures 4 to 7 illustrate the main administrative modules, including sales monitoring, stock management, and user administration, which collectively support centralized operational control and structured data processing. These interface components support the system's operational efficiency by enabling structured data entry, automated reporting, and centralized administrative control.

Table 4. Before and After Comparison of Accuracy Improvement

No	Indicator	Manual System (Before)	Web-Based System (After)	Absolute Change	Relative Improvement
1	Average Discrepancy Rate (%)	18.2%	13.6%	-4.6%	25.27% reduction
2	Data Accuracy Level (%)	81.8%	86.4%	+4.6%	5.62% increase
3	High-Turnover Items Discrepancy (%)	20.1%	14.8%	-5.3%	26.36% reduction
4	Medium-Turnover Items Discrepancy (%)	17.5%	13.1%	-4.4%	25.14% reduction
5	Low-Turnover Items Discrepancy (%)	16.8%	12.9%	-3.9%	23.21% reduction

$$Relative\ Improvement\ (\%) = \frac{(Before - After)}{Before} x\ 100 \quad (7)$$

$$Data\ Accuracy\ (\%) = 100 - Discrepancy\ Rate \quad (8)$$

Table 4 shows a consistent reduction in discrepancy rates across all inventory categories following system implementation. The overall discrepancy rate decreased from 18.2% to 13.6%, representing a 25.27% relative improvement. The most substantial improvement occurred in high-turnover items, where real-time monitoring significantly reduced recording delays and manual input errors.

Real-time monitoring features in web-based healthcare systems have been shown to enhance centralized inventory visibility and coordination [20]. These results indicate that automated logging, centralized database architecture, and expiration alerts contributed directly to enhanced data consistency and reliability.
However, functional validation alone does not demonstrate operational performance improvement. Therefore, additional quantitative evaluation was conducted through discrepancy rate analysis, operational performance indicators, and forecasting accuracy measurement, as presented in the subsequent sections. While functional testing confirmed system reliability, the primary contribution of this study lies in the measurable operational improvements demonstrated through empirical performance analysis.

4. Conclusions and Future Works

This study developed and empirically evaluated a web-based inventory management system for PT Borneo Sejahtera Medika to address inefficiencies in manual medical equipment inventory processes. The system integrates real-time stock monitoring, automated expiration alerts, and demand forecasting within a Laravel–MySQL architecture.

The empirical before–after analysis over a six-month period demonstrated measurable performance improvements. The average discrepancy rate decreased from 18.2% to 13.6%, representing a 25.27% relative reduction. Operational efficiency improved substantially, with stock checking time reduced by 52%, expired items reduced by 57%, and emergency procurement cases reduced by 31%. The forecasting module achieved a MAPE value of 5.00%, indicating acceptable short-term forecasting accuracy for healthcare inventory planning. User acceptance was also high, with an average satisfaction score of 4.32 out of 5.
These findings confirm that the implemented system fulfills functional requirements. It also produces quantifiable improvements in data accuracy, operational efficiency, and inventory control. Beyond system development, this research contributes an applied empirical evaluation framework that integrates functionality testing, operational performance indicators, and forecasting validation in a medium-scale healthcare distributor context.

For future work, system scalability can be enhanced through cloud deployment and mobile accessibility to support distributed operations. Further research may explore advanced forecasting models, including machine learning approaches, and the integration of IoT-based tracking technologies. However, the findings are based on a single organizational case study, and generalization to other healthcare institutions should be approached cautiously.

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