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A Prognostic System for Pharmaceutical Inventory Forecasting Using the Trend Least Squares Method at Rakha Medika

Evi Yulianti[1], Indah Pratiwi Putri[1*], Dona Marcelina [1]

[1]Universitas Indo Global Mandiri, Jl. Jendral Sudirman KM.4 No. 62, 20 Ilir D. IV, Kec. Ilir Timur I, Palembang, Indonesia

*Corresponding Email: wiwid@uigm.ac.id

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ABSTRACT

This study proposes the development of a sophisticated predictive system for pharmaceutical inventory management at Rakha Medika, Palembang, aimed at addressing the prevalent challenges associated with inaccurate drug stock forecasting. Employing the Trend Least Squares method, the system leverages historical consumption data to generate precise predictions of future pharmaceutical needs, thereby facilitating optimal procurement strategies and mitigating the risks of both stockouts and surplus inventory. Developed with PHP and MySQL, the system offers a user-friendly web-based interface, providing role-specific access for administrators, warehouse personnel, and senior management, ensuring seamless integration within the existing operational framework. This research highlights the importance of data-driven decision-making in healthcare supply chain management, where the accuracy of stock forecasts directly correlates with the quality-of-service delivery. Through rigorous testing using real-world data, the system demonstrated a significant improvement in forecasting accuracy and operational efficiency, with tangible benefits including reduced administrative burdens and enhanced drug availability. The implementation of this predictive system not only optimizes inventory control but also contributes to the overall enhancement of healthcare services at the public health center.

1. INTRODUCTION

In contemporary healthcare management, the precision of pharmaceutical inventory forecasting constitutes a pivotal determinant of service quality and operational efficiency [1]. Although Rakha Medika in Palembang had previously implemented a rudimentary information system, its limitations became increasingly evident, particularly in the absence of automated modules for drug requisition and predictive inventory management. Consequently, several critical processes including drug stock prediction [2], continued to rely on manual recording methods, leading to inefficiencies, inaccuracies in procurement planning, and ultimately, suboptimal healthcare service delivery.

Drug stock forecasting within public health centers is imperative for anticipating the pharmaceutical needs of the community over specific periods [3]. Such prediction endeavors rely on historical consumption data, prevailing trends in drug utilization, disease patterns, and other influential factors [4],[5]. Accurate forecasting is essential to guarantee an uninterrupted supply of essential medicines, prevent wastage due to overstocking, and minimize the risk of critical shortages that could compromise patient care [6]. Fundamentally, prediction is an analytical endeavor to project future occurrences based on patterns and behaviors observed in the past. The significance of precise forecasting cannot be overstated, as future-oriented predictions are integral inputs for strategic planning and decision-making processes across diverse organizational contexts.

Situated at Jalan Letnan Murod, Talang Ratu, Palembang, Rakha Medika serves a vital primary healthcare provider in the region. Its strategic role encompasses not only public health outreach programs but also clinical services, thus necessitating that its operational standards align with the Ministry of Health’s Minimum Service Standards. Healthcare service quality at such institutions is evaluated through various dimensions, including human resources, operational procedures, service processes, and the delivery of medical interventions [7]. The correlation between service quality and patient satisfaction is direct and substantial, improvements in healthcare delivery invariably enhance community satisfaction levels [7],[8],[9]. Furthermore, Rakha Medika caters to both insured patients under Indonesia’s BPJS scheme and those seeking independent healthcare services, underscoring the diverse and growing demands placed upon its resources.

The urgency of developing a robust pharmaceutical stock prediction system is underscored by the high volume of daily patient encounters, averaging approximately 70 individuals. Rakha Medika currently faces persistent challenges related to discrepancies between available drug stocks and actual patient needs. These challenges stem from inadequacies in predictive methodologies, resulting in procurement quantities that either fall short of or exceed actual requirements. Insufficient drug stock can severely undermine healthcare delivery by delaying or denying patients access to necessary medications, while overstocking increases operational costs and risks drug wastage due to expiration. Therefore, precise prediction models and systematic inventory monitoring mechanisms are indispensable to bridging the gap between supply and demand.

To address these operational inefficiencies, this study designs and implements a drug stock prediction system utilizing the Trend Least Squares algorithm [10]. This statistical method, renowned for its efficacy in analyzing time-series data, offers a structured approach to forecasting by identifying underlying trends within historical datasets. The resulting predictive insights are intended to serve as a critical reference point for public health centers to submit more accurate drug requisition requests to the regional health authority [10],[11].

The primary objectives of this research are twofold. First, it seeks to construct an automated system capable of forecasting pharmaceutical stock requirements for Rakha Medika, tailored specifically to its operational context. Second, the system aims to ensure that future drug stock levels are sufficiently aligned with community healthcare needs, thereby enhancing the overall quality and efficiency of healthcare services. By integrating historical consumption data with robust statistical forecasting techniques, the proposed system aspires to transform inventory management practices, replacing outdated manual methods with a streamlined, data-driven approach [12]. Beyond immediate operational enhancements, the broader significance of this research lies in its potential to reinforce healthcare resilience at the grassroots level. Equipping healthcare centers with advanced predictive tools can better withstand fluctuations in patient demand and supply chain uncertainties.

The scope of this study includes the design, development, and implementation of a web-based information system for drug stock prediction. Data processing within the system will employ PHP for application logic and MySQL for database management, ensuring scalability, reliability, and ease of access across user roles. Specifically, the system will facilitate role-based access for administrators, warehouse personnel, and upper management, thereby promoting operational transparency and accountability.

2. LITERATURE REVIEW

The management of pharmaceutical inventories in primary healthcare facilities represents a cornerstone in the delivery of effective medical services. A well-structured inventory system ensures the uninterrupted availability of essential medicines, thereby safeguarding public health and enhancing patient satisfaction [1],[13]. Conversely, inefficiencies in stock management may trigger a cascade of adverse outcomes, ranging from stockouts that compromise treatment continuity to overstocking that leads to wastage of limited resources [14],[15]. In healthcare settings in Indonesia, these issues are further compounded by the constraints of budgetary allocations, infrastructural limitations, and fluctuating patient demands. Thus, it becomes patently clear that the deployment of an intelligent, predictive information system is not merely desirable, but imperative.

Historically, Healthcare Information Systems (HIS) have evolved from basic record-keeping tools into sophisticated platforms capable of managing diverse operational facets, including pharmaceutical inventories [16],[17],[18]. Contemporary HIS aims to integrate clinical, administrative, and logistical functions, streamlining operations while fostering evidence-based decision-making. However, many existing systems in local healthcare settings still exhibit significant functional gaps. For instance, Rakha Medika previously implemented a rudimentary information system that, while efficient in data collection, lacked modules for drug requisition and stock prediction. Consequently, certain critical operations, such as inventory forecasting, continued to rely on manual methods prone to human error. In this context, the modernization of healthcare information systems to encompass predictive analytics becomes a pressing necessity.

Forecasting stands as the linchpin of effective inventory management [19],[20]. It offers a means to anticipate future stock requirements based on historical consumption patterns, disease prevalence, and demographic shifts. Time series analysis has emerged as a pivotal tool; it captures the temporal dynamics of variables such as drug consumption rates, enabling forecasters to discern underlying patterns, cyclical behaviors, and seasonal effects. The capacity to extrapolate these patterns into the future renders time series analysis invaluable for pharmaceutical stock prediction. It provides a mechanism for healthcare administrators to not only respond to current needs but also proactively prepare for impending demand surges, thereby minimizing the risk of supply chain disruptions [21],[22],[23]. Among the panoply of techniques available for time series forecasting, the Trend Least Squares method holds promise. Rooted in the principles of regression analysis, the Least Squares approach endeavors to minimize the sum of the squares of the residuals, thereby fitting the most accurate linear trend line through the data points [10],[23]. This method is especially advantageous in scenarios where a clear, discernible trend underlies the data, as is often the case with chronic disease medication usage or vaccination programs. By applying Trend Least Squares, it becomes possible to generate reliable, data-driven projections of future drug requirements. Moreover, the computational simplicity and interpretability of the method render it eminently suitable for deployment within resource-constrained environments such as community health centers [10],[23],[24]. Therefore, its deployment must be complemented by periodic model validation and adjustment to ensure sustained predictive accuracy.

Thus, the conceptual framework for the proposed information system can be envisioned as an integration of data collection, trend analysis, and predictive modelling [25]. The system would continuously harvest data on drug dispensation, patient visits, and disease diagnoses, feeding this information into a Trend Least Squares algorithm to generate forward-looking stock forecasts. These forecasts would, in turn, inform procurement decisions, enabling healthcare administrators to order appropriate quantities of medication in a timely fashion [26]. By providing a clear, actionable view of future inventory needs, the system would not only optimize stock levels but also enhance the overall efficiency and quality of healthcare delivery at Rakha Medika.

3. RESEARCH METHODS

To achieve the desired outcomes of this study, a systematic and structured series of research stages was meticulously undertaken. These stages, depicted in Figure 1, provide a coherent framework that guides the research process from the initial problem identification to the final formulation of conclusions. Each stage is designed to ensure methodological rigor and to foster the development of a robust information system tailored to the operational needs of Rakha Medika Palembang. This research comprises five principal stages, which each stage was carefully delineated to guarantee the logical progression of the research activities and the attainment of the research goals.

Figure 1. Research Methodology

3.1 Requirement Analysis

This stage identifies the deficiencies and constraints inherent in the current processes and establishes a comprehensive specification of system requirements [27]. It was carried out through systematic data-gathering methods, and the principal analytical tool employed is the flowchart, which facilitates the visualization of process flows and system logic. The head of the clinic oversees employee data management and accesses drug prediction results, while the warehouse officer is responsible for managing drug prediction data and monitoring existing stock levels. These delineations ensure that each user group interacts with the system in a manner congruent with their operational responsibilities.

3.2 System Design

The second stage pertains to the comprehensive system design based on the previously defined requirements. This phase serves as a blueprint, translating system specifications into a tangible and high-quality software architecture before coding implementation [28]. The UML diagrams utilized include Use Case Diagrams to model system functionalities and interactions and Class Diagrams to depict the system's structural framework. Additionally, file specifications and user interface were meticulously drafted to ensure a seamless and intuitive user experience. The system development is primarily executed using the PHP programming language, in conjunction with Visual Studio Code and XAMPP, ensuring a flexible and efficient development environment. This design phase lays the essential foundation upon which subsequent development activities are predicated, guaranteeing that the system can be systematically constructed in alignment with user needs and technical specifications.

3.3 Software Development

This phase involved the actual construction of a web-based application tailored to the operational workflow of Rakha Medika Palembang. The application was designed to be user-centric, facilitating easy access for various stakeholders such as admin staff, healthcare heads, and warehouse personnel, while ensuring data integrity and system robustness, ensuring that the resulting system would be both scalable and maintainable [28].

3.4 System Testing

This stage was to ensure that all predefined inputs produce the expected outputs, thereby verifying that the system operates in strict accordance with the user requirements and performance benchmarks outlined during the requirement analysis phase. This stage provides an external validation mechanism that assures software quality from the perspective of its intended users. Instead of delving into the system's internal codebase or logic, the focus is placed exclusively on examining the system's inputs and the corresponding outputs to validate its functional behavior. Its emphasis on functional validation and real-world scenarios makes it a cornerstone of robust software engineering practices [28].

4. DISCUSSION AND RESULT

Figure 2 above models the interactions between users (actors) and a drug stock prediction system at a public health center. It depicts three main user roles: Admin, Warehouse, and head of clinic. Each user has specific system functionalities (use cases) they can access. The Admin and Warehouse roles have similar privileges, such as managing staff, drugs, incoming drug records, sales data, predictions, and generating reports. The head of the clinic primarily accesses the Reports and Drug Prediction modules to support decision-making. All roles include the basic actions of login and logout to access and exit the system securely.

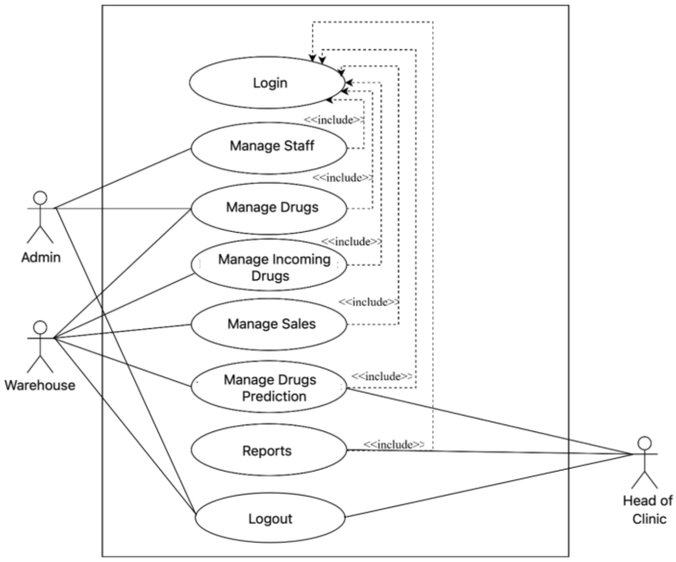

Figure 2. Use Case Diagram

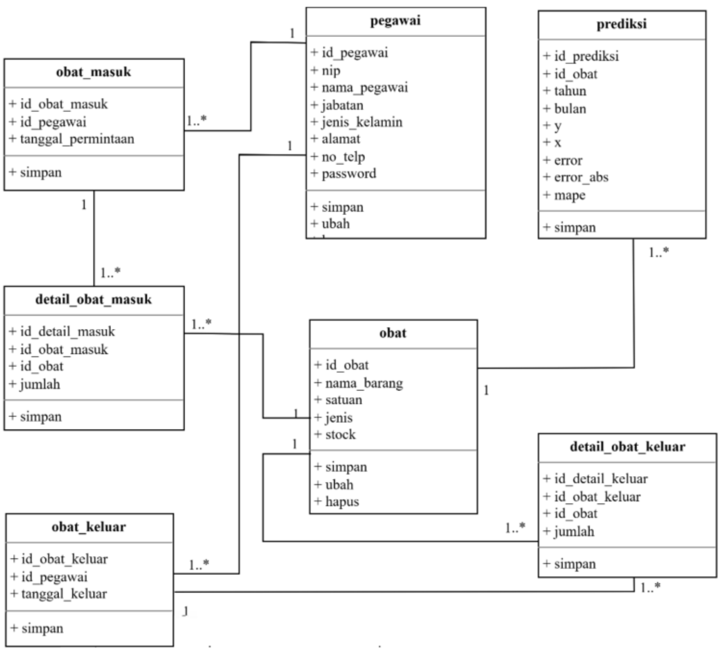

Figure 3. Class Diagram

Figure 3 above illustrates the structural blueprint of a drug stock prediction system designed for a public health center. It consists of several interconnected classes, each representing a core component of the system. The Staff class stores employee data such as employee ID, name, position, and login credentials and includes functions for saving and updating records. The Drugs class manages information about available medicines, including their names, types, units, and current stock levels. This class is central to the system, as it is linked to various other components responsible for managing stock movements and predictions.
The Drugs_Demand class records medication requests, associating each request with both a staff member and a drug item. The Stock_In and Stock_Out classes handle incoming and outgoing drug records, respectively detailing quantities and associating each transaction with specific drug items. These two classes support the tracking of inventory fluctuations. Additionally, the Sales class logs transactions involving drug distribution, linked to both the drug and the staff handling the process. The Prediction class represents the predictive module of the system, storing forecast results using the Trend Least Square method, including variables such as predicted values (y), input values (x), and forecasting errors (error, error_abs, and mape). Relationships between classes are clearly defined with cardinalities (e.g., one-to-many), ensuring a normalized and scalable database structure that supports efficient data management, traceability, and accurate stock forecasting. For prediction, calculations were carried out first before the Trend Least Square algorithm was implemented into the program coding. The following are manual calculations carried out on 12 sample data consisting of drug needs data from October 2022 to September 2023.

Table 1. Sample of Data

No.	Period	Drug's Demand
1	2022 – October	225
2	2022 – November	245
3	2022 – December	265
4	2023 – January	232
5	2023 – February	198
6	2023 – March	256
7	2023 – April	256
8	2023 – May	265
9	2023 – June	254
10	2023 – July	254
11	2023 – August	256
12	2023 – September	233

Source: Private Data, 2023

The sample data obtained will then be calculated by applying the Trend formula from the Least Square algorithm. Before calculating, the number of sample data must be seen first, if the sample data is odd, the time value (x) will start from 0 at the midpoint of the data (the number of data is divided by two) and continue as many as 1 number as many sample data. However, if the sample data is even, the time value (x) will start from 1 and -1 at the midpoint of the data and continue as many as 2 numbers until all the data each gets a time value (x) that can be used to calculate the sample data as in table 2 below.

Table 2. Trend Least Square Calculation

No	Period	Drugs Demand (y)	Time (x)	x^2	x.y
1	2022 – October	225	-11	121	2475
2	2022 – November	245	-9	81	2205
3	2022 – December	265	-7	49	1855
4	2023 – January	232	-5	25	1160
5	2023 – February	198	-3	9	594
6	2023 – March	256	-1	1	256
7	2023 – April	256	1	1	256
8	2023 – May	265	3	9	795
9	2023 – June	254	5	25	1270
10	2023 – July	254	7	49	1778
11	2023 – August	256	9	81	2304
12	2023 – September	233	11	121	2563
	Amount	**2939**	**12**	**572**	**421**

After calculating the sample data, the next step in the Trend Least Square algorithm is to find the values of a and b. Where a is the trend value in the time-period of the sample data used while b is the average value of the trend growth each year based on the sample data, where:

$$A = \frac{\sum y}{n} = \frac{2939}{12} = 244{,}917 \quad (1)$$

$$b = \frac{\sum xy}{x^2} = \frac{421}{572} = 0{,}736 \quad (2)$$

After the values needed for the prediction calculation are complete, the next step is to calculate the prediction according to the number of drug data samples used. The following is the calculation of the prediction results which can be seen in Table 3 below:

Table 3. Forecasting Result

No	Period	a	b	x	Result (y=a+b.x)	Round Up
1	2022 – October	244,917	0,736	-11	236,821	237
2	2022 – November	244,917	0,736	-9	238,293	238
3	2022 – December	244,917	0,736	-7	239,765	240
4	2023 – January	244,917	0,736	-5	241,237	241
5	2023 – February	244,917	0,736	-3	242,709	243
6	2023 – March	244,917	0,736	-1	244,181	244
7	2023 – April	244,917	0,736	1	245,653	246
8	2023 – May	244,917	0,736	3	247,125	247
9	2023 – June	244,917	0,736	5	248,597	249
10	2023 – July	244,917	0,736	7	250,069	250
11	2023 – August	244,917	0,736	9	251,541	252
12	2023 – September	244,917	0,736	11	253,013	253

The calculation of the accuracy of the prediction value is based on the percentage of error obtained. The calculation of the error in this study was carried out using MAPE (Mean Absolute Percentage Error) where MAPE has the following provisions:

Table 4. MAPE Interval

MAPE (%)	Significance
< 10	Excellent
10 – 20	Good
20 – 50	Bad
> 50	Worst

Table 5 above presents the evaluation results of a drug demand forecasting system using the Trend Least Square method. The table covers 12 months of prediction from October 2022 to September 2023, comparing the actual drug demand with the prediction results. For each period, the Error (Prediction Result − Drug Demand), Absolute Error, and Mean Absolute Percentage Error (MAPE) are calculated to assess the system's forecasting performance. From the data, the prediction model generally shows high accuracy, with most MAPE values below 10%, except for February 2023, which shows the highest error (45 units) and MAPE (23%). The average MAPE across all periods is 6%, indicating low forecasting deviation. Consequently, the overall prediction accuracy reaches 94%, demonstrating that the forecasting system is highly reliable for drug stock planning at the health center. This level of accuracy supports proactive stock management and minimizes the risk of overstocking or shortages.

Table 5. Prediction Accuracy

No	Period	Demand	Prediction Result	Error	Abs Error	MAPE (%)
1	2022 – October	225	237	-12	12	5
2	2022 – November	245	238	7	7	3
3	2022 – December	265	240	25	25	9
4	2023 – January	232	241	-9	9	4
5	2023 – February	198	243	-45	45	23
6	2023 – March	256	244	12	12	5
7	2023 – April	256	246	10	10	4
8	2023 – May	265	247	18	18	7
9	2023 – June	254	249	5	5	2
10	2023 – July	254	250	4	4	2
11	2023 – August	256	252	4	4	2
12	2023 – September	233	253	-20	20	9

MAPE (%)	**6**
Accuracy (%)	**94**

In the previous calculation, it was known that the MAPE percentage value of the Trend Least Square algorithm used was lower than 10, which means that it has excellent forecasting capabilities, so it is worthy of being used in this study. Therefore, the following are the prediction results for the next 12 months in Table 6 below for Dulcolax 5mg/5ml at Rakha Medika.

Table 6. Prediction Result for 12 Months Onwards

No	Period	a	b	x	Prediction Result	Round Up
1	2023 – October	244,917	0,736	13	254,485	254
2	2023 – November	244,917	0,736	15	255,957	256
3	2023 – December	244,917	0,736	17	257,429	257
4	2024 – January	244,917	0,736	19	258,901	259
5	2024 – February	244,917	0,736	21	260,373	260
6	2024 – March	244,917	0,736	23	261,845	262
7	2024 – April	244,917	0,736	25	263,317	263
8	2024 – May	244,917	0,736	27	264,789	265
9	2024 – June	244,917	0,736	29	266,261	266
10	2024 – July	244,917	0,736	31	267,733	268
11	2024 – August	244,917	0,736	33	269,205	269
12	2024 – September	244,917	0,736	35	270,677	271

Table 6 presents a detailed 12-month drug demand forecast from October 2023 to September 2024, calculated using the Trend Least Square (TLS) method. This method employs a linear equation $y = a + b \cdot x$, where a is the intercept (244.917), representing the base level of drug demand, and b is the slope (0.736), indicating the average monthly increase in demand. The variable x represents the time index assigned to each forecasted month, starting from 13 for October 2023 and increasing by two for each subsequent month. This approach allows the system to model gradual growth in drug consumption over time. Each row in the table shows the predicted demand result for a particular month, which is calculated by plugging the values of a, b, and x into the TLS formula. For example, in October 2023 ($x = 13$), the prediction result is 254.485 units, rounded to 254 for practical application. By September 2024 ($x = 35$), the predicted value increases to 270.677, rounded to 271. The “Round Up” column ensures the predictions are expressed as whole numbers, facilitating more precise inventory planning and procurement. Thus all of these calculations were implemented in the system as gown in figures below.

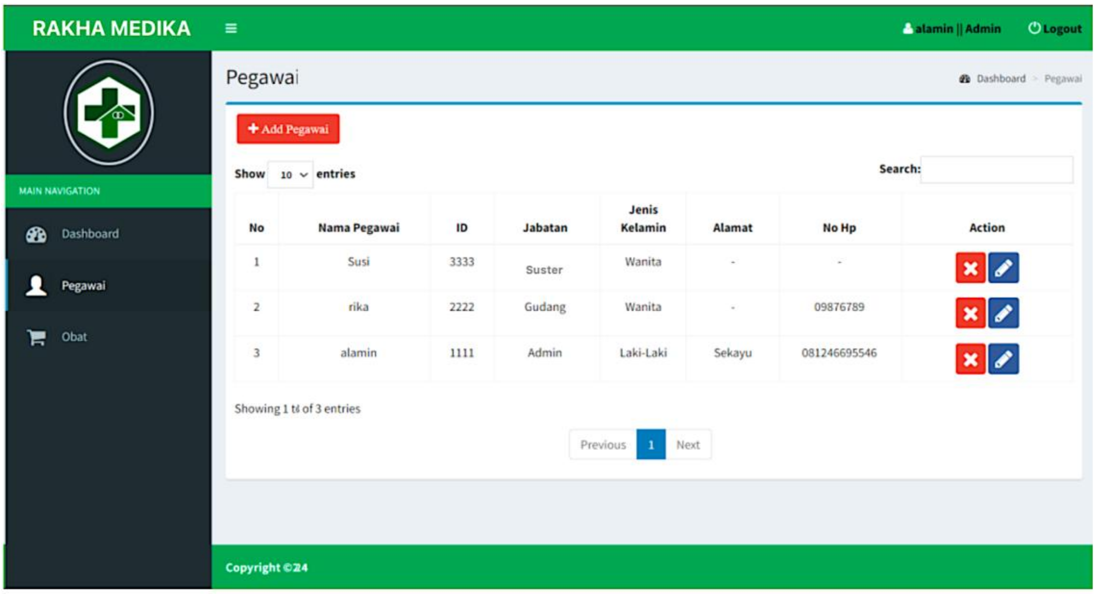

Figure 4. Staff Page

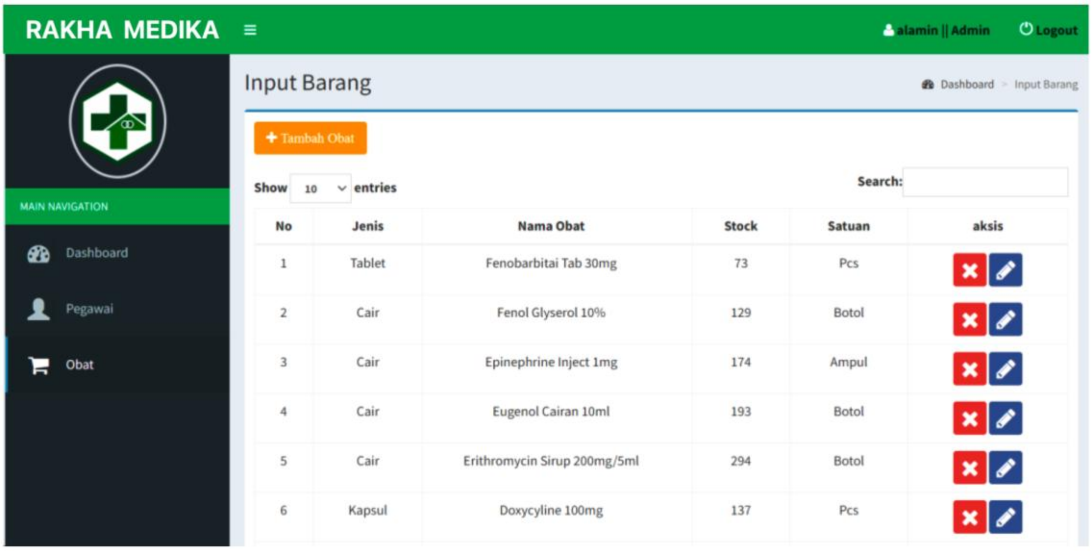

Figure 5. Input Drugs

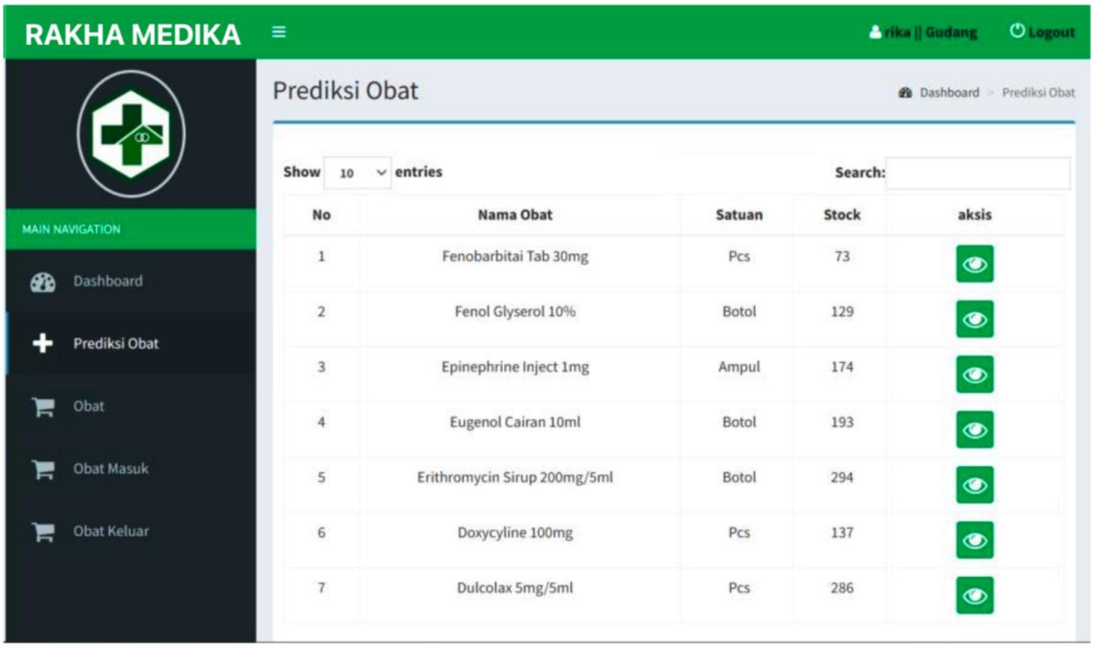

Figure 6. Drugs Prediction

After completion, some perspectives from staff say the implementation of this system has significantly reduced the burden of manual data entry and minimized forecasting errors in drug requisition. Previously, staff relied on approximate estimates, which often led to overstocking or critical shortages. With the new system in place, drug demand predictions are now automatically generated based on historical consumption data, allowing for more confident and timely procurement decisions. In addition, pharmacists benefit from the enhanced visibility of real-time stock levels and predicted needs, enabling better preparation for patient services and emergency planning. This level of automation has improved operational efficiency, reduced administrative workload, and empowered the staff with data-backed insights in daily operations.

5. CONCLUSION

A web-based information system capable of predicting future pharmaceutical stock requirements at Rakha Medika Palembang has been successfully developed using the Trend Least Squares method. This system was designed to assist the health center in anticipating medication needs for upcoming months, thereby ensuring that drug availability is maintained in a timely and efficient manner for community healthcare services. By generating reliable stock forecasts, the operational performance of Rakha Medika is expected to be significantly enhanced, particularly in terms of aligning supply with actual public health demands.

Although the system has fulfilled its primary research objectives, several areas for improvement have been identified. It has been acknowledged that the system's user interface lacks visual appeal, and thus, future iterations are encouraged to incorporate more engaging and intuitive design elements to promote sustained user interaction. Furthermore, the current database architecture has been deemed insufficient in terms of security, highlighting the necessity for strengthened data protection mechanisms. Lastly, it has been suggested that the system be expanded to include relevant health-related information, thereby broadening its utility and contributing further to public health education and awareness.

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