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A Laravel-Powered Web Application for Streamlining Medical Device Management at Prima Medika Hospital

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ABSTRACT

Prima Medika Hospital manages a diverse array of medical instrumentation, spanning from fundamental diagnostic tools to sophisticated technological systems. To uphold safety and operational standards for both clinicians and patients, a robust management framework is indispensable. Addressing the current system's misalignment with accreditation benchmarks, this research proposes the architecture and prototype implementation of a web-based management information system. Developed using the Laravel (PHP) framework under a Waterfall methodology, the platform digitizes lifecycle processes including procurement, inventory tracking, maintenance, and calibration, with IoT-based real-time equipment monitoring. Data integrity and user flow were mapped via DFD and ERD models. Following rigorous Black Box testing and User Acceptance Testing (UAT) with 20 participants, the system achieved a 93.8% satisfaction rating (average score 4.69 out of 5.00), validating its utility and effectiveness in a clinical environment. The system offers a practical and low-cost solution for small-to-medium hospitals seeking to improve equipment management and meet accreditation standards.

1. INTRODUCTION

Hospital resources encompass physical infrastructure, workforce, medical equipment, medicines, treatment methods, and information technology. Medical equipment serves as a fundamental pillar in the delivery of hospital healthcare services, playing an indispensable role in diagnostics, therapeutic interventions, and general patient care [1]. To maintain safety, operational efficiency, and adherence to established regulatory standards, hospitals are required to manage their medical assets effectively. As a Class C general hospital, Prima Medika Hospital offers a range of services, including outpatient, inpatient, and medical support. In accordance with national regulations, all Indonesian healthcare facilities are obligated to implement a Hospital Management Information System (SIMRS) that is fully integrated with the Ministry of Health (Kemenkes) infrastructure [2]. Although Prima Medika Hospital currently utilizes an information system for equipment management within its service units, the platform has not yet aligned with the benchmarks established by the Hospital Accreditation Committee (KARS). This discrepancy creates hurdles for Electromedical professionals in equipment analysis and maintenance. Furthermore, the hospital's multi-story architectural layout and the physical distance between its buildings add complexity to asset management. Routine maintenance in the Intensive Care Unit (ICU) is also hindered by restricted access and the necessity of mandatory personal protective equipment. Healthcare providers must guarantee that all medical devices fulfill criteria for quality, safety, efficacy, and operational viability [3]. Web-based systems for managing inpatient medical equipment have been developed by Suyasa et al. [4], demonstrating the feasibility of digital solutions in hospital settings. Digital management systems have been shown to accelerate administrative tasks, minimize asset loss, and enhance maintenance quality [5]. Inventory-focused systems have similarly optimized data processing and reporting workflows at district health services [6]. In pharmacy contexts, web-based inventory management has reduced losses from expired stock and improved operational efficiency [7]. However, a critical gap remains: no existing system has been specifically designed to support real-time equipment analysis, monitoring, and maintenance tracking for Electromedical professionals within a multi-building hospital environment that must also comply with KARS accreditation standards. The present study addresses this gap by architecting and implementing a prototype web-based medical equipment management system at Prima Medika Hospital. The key contribution of this research is the development of a low-cost, practically deployable platform—integrating IoT-based monitoring, lifecycle tracking (procurement, maintenance, calibration, repair), and QR code-based identification—that can assist small-to-medium hospitals in meeting accreditation requirements and improving audit data quality. The application is engineered using the PHP language and the Laravel framework, selected for its robust MVC architecture, built-in security features, and active community support [8]. The development environment is managed via LARAGON, utilizing PHP, MySQL for data storage, and Apache as the web server [9]. The design process incorporates Data Flow Diagrams (DFD) to map internal data movement [10] and Entity-Relationship Diagrams (ERD) to structure data interactions prior to deployment [11]. By leveraging modern communication technology, hospitals can better integrate medical tools with administrative management, ultimately driving higher service efficiency and effectiveness [12].

2. METHOD

This study adopts the Waterfall model as the primary framework for software development [13]. This methodology was selected because the system requirements for Prima Medika Hospital were clearly defined and stable from the outset, making a sequential, phase-gated approach appropriate. The Waterfall model follows a systematic, step-by-step progression where the project advances through a fixed sequence—starting from the requirements analysis and planning stage, moving through system modeling, implementation (construction), and final testing—as illustrated in Figure 1. It is important to note that this research covers the development and prototype testing phase; full institutional deployment falls outside the scope of this study. The system was tested as a functional prototype with actual users from Prima Medika Hospital. In terms of data privacy and security, the system handles operational equipment data rather than patient records. All user accounts are role-based (admin and employee), and the system enforces authentication at every access point. Future work should incorporate formal security testing (penetration testing) to further strengthen compliance with health data governance standards.

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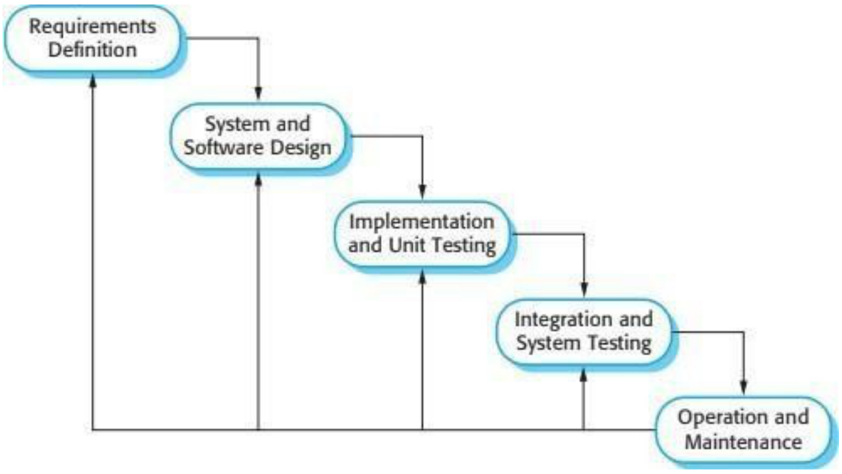

Figure 1 - Waterfall Method.

3. RESULT AND DISCUSSION

3.1. Functional Requirements Analysis

Functional requirements define the specific functions performed by the system, covering all its features. The system includes authentication, where admins can log in, log out, and manage user accounts by adding, editing, and deleting data, while employees can log in, log out, and edit user data. In master data management, admins manage users, units, Internet of Things (IoT) devices, vendors, and medical equipment, whereas employees can only edit user data. For procurement management, admins can CRUD (Create, Update, Delete) procurement data, while employees can only edit it. Inventory management allows admins to manage inventory, print reports, and generate QR codes, while employees can add or edit inventory and print QR codes. In monitoring management, admins manage and generate reports, while employees can only generate them. Similarly, in maintenance, repair, calibration, and recall management, admins handle data and generate reports, while employees have restricted permissions, primarily generating reports and, in some cases, adding or editing data. The system also reads sensor data from IoT devices installed on medical equipment, enabling monitoring of temperature, humidity, and voltage, fire detection, and remote control for turning medical equipment on or off. In addition to functional requirements, the system was designed with several non-functional requirements in mind. In terms of performance, the web application was developed to support concurrent multi-user access without significant response degradation, leveraging Laravel's built-in query optimization and MySQL indexing. For usability, the interface follows a role-based dashboard layout, ensuring that each user type (admin and employee) sees only the features relevant to their responsibilities. Regarding scalability, the modular MVC architecture of Laravel allows additional modules (e.g., new equipment categories or additional IoT sensor types) to be integrated without restructuring the existing codebase. The IoT integration component uses NodeMCU ESP8266 microcontrollers equipped with DHT22 sensors (for temperature and humidity), voltage sensors, and flame detection modules installed on selected medical equipment units. Sensor data is transmitted via HTTP requests to the Laravel backend at regular polling intervals, where it is stored in the MySQL database and displayed in real-time on the monitoring dashboard. The system also supports remote relay control, allowing authorized users to power medical equipment on or off through the web interface. This approach enables prototype deployment at an estimated low cost per monitored device, making it practical for small-to-medium hospitals seeking affordable accreditation-ready solutions.

3.2. System Design

This stage focuses on designing a web-based system to manage medical equipment at Prima Medika Hospital. The researcher will develop a system to help determine hardware and system requirements while defining the overall architecture. This stage involves the design process for the planned system.

a. Context Diagram

The context diagram of the system to be developed consists of two external entities: Admin and Employee, along with a single process that represents the overall system operation. This diagram illustrates how these entities interact with the system by exchanging data and requests. The context diagram can be seen in Figure 2.

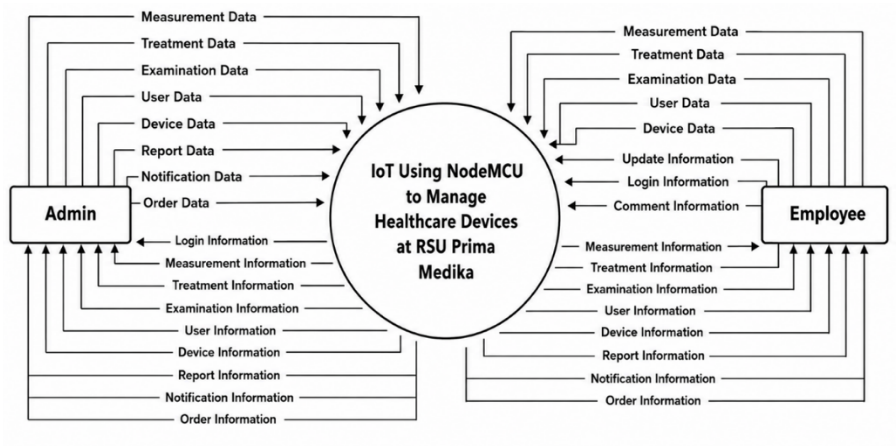

Figure 2 - The Healthcare Device Context Diagram

b. Data Flow Diagram (DFD)

DFD Level 0 is a breakdown of the context diagram, consisting of nine processes, namely: login, master data management, procurement management, inventory management, monitoring management, maintenance management, repair management, calibration management, and withdrawal management. The Level 0 Data Flow Diagram can be seen in Figure 3.

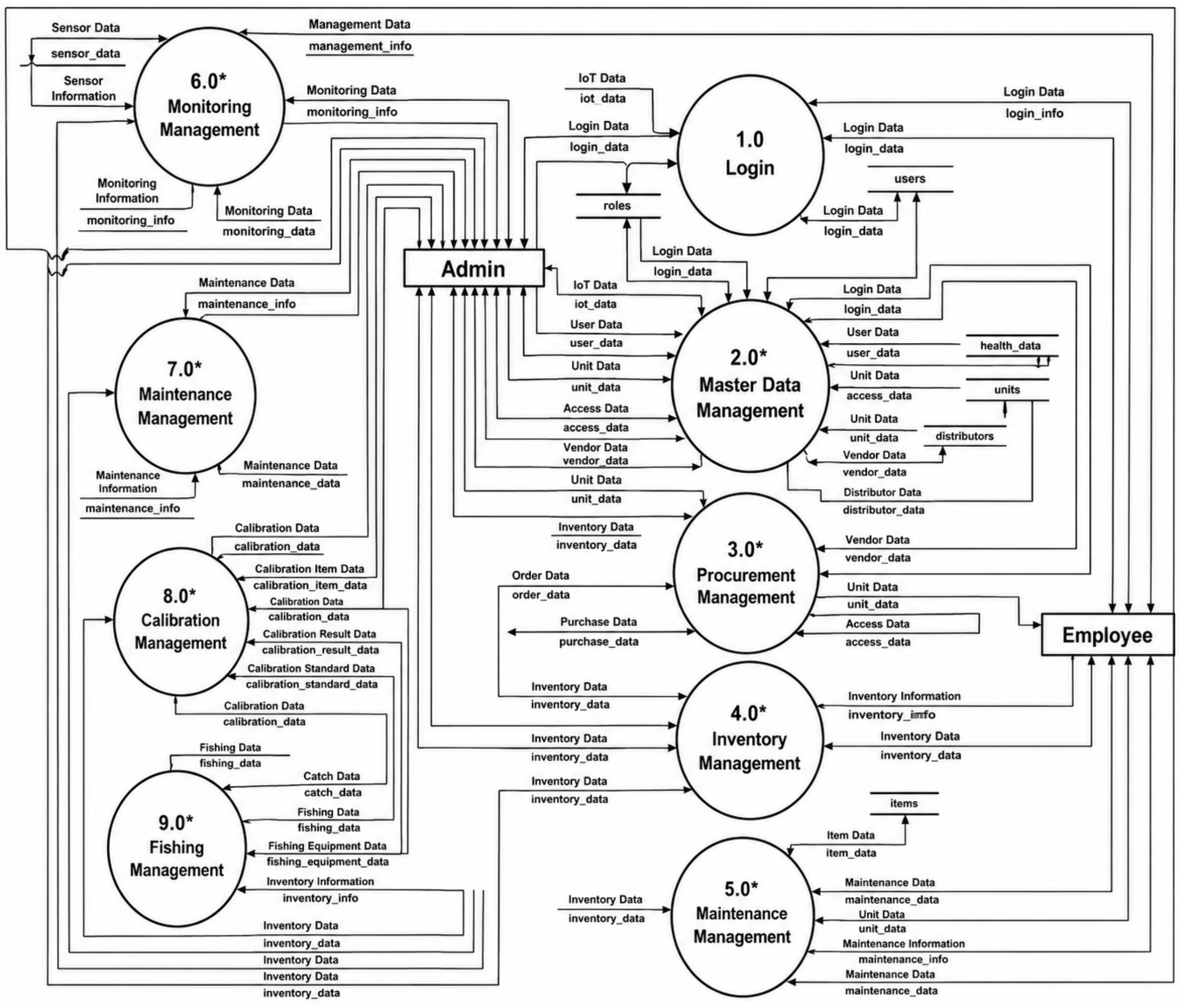

Figure 3 - The Level 0 Data Flow Diagram (DFD)

c. The Entity Relationship Diagram (ERD).

The ERD represents the relationships between tables and serves as a reference for database table creation. In this system engineering process, there are sixteen interconnected entities: users, calibration, withdrawal, repair, maintenance, inventory, model_has_roles, roles, calibration items, IoT, monitoring, procurement, unit, medical equipment, sensor, and distributor. The ERD design for the system to be developed can be seen in Figure 4.

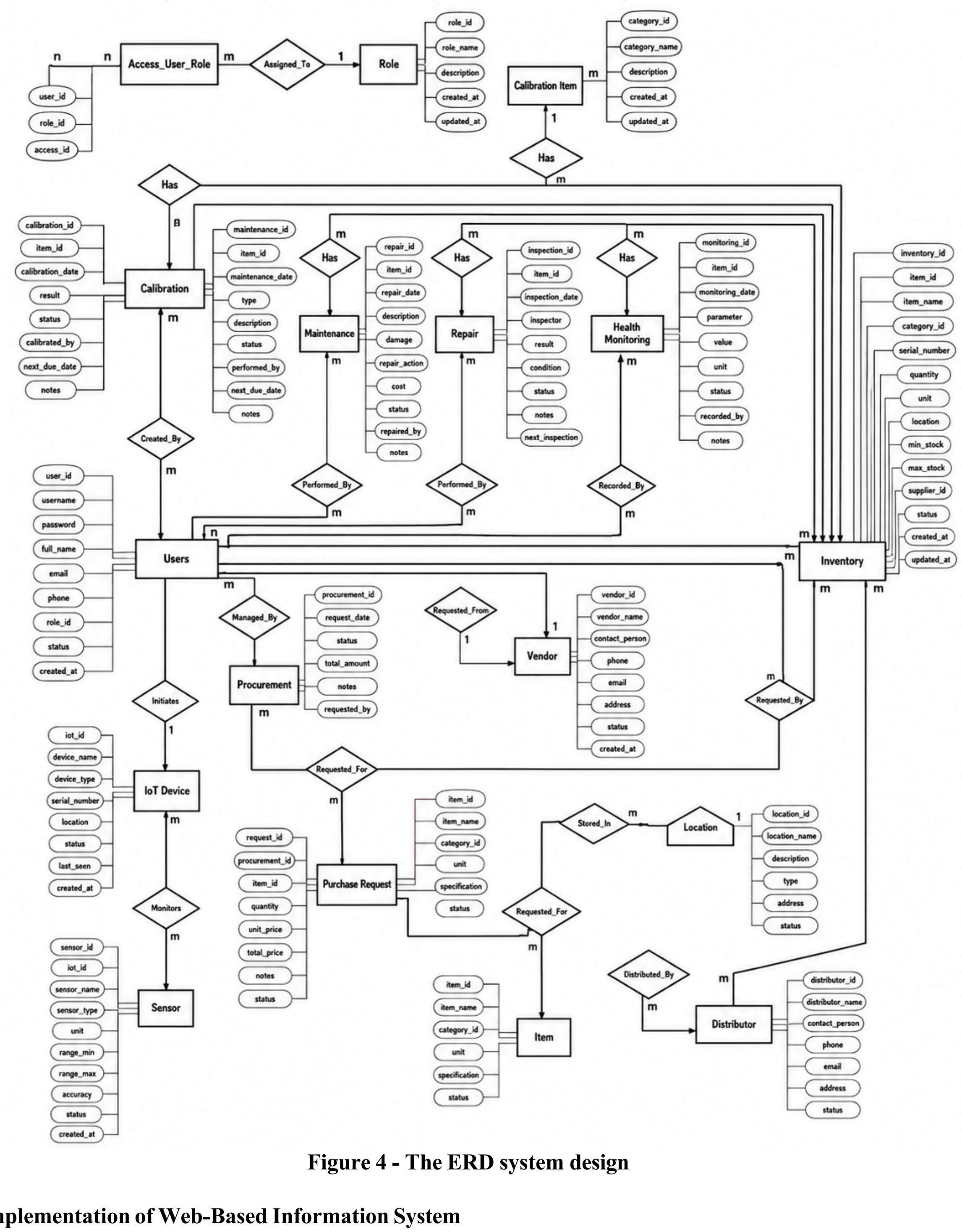

Figure 4 - The ERD system design

3.3. Implementation of Web-Based Information System

The coding phase is the implementation of the design into a functional interface. The result of this web-based application is for managing medical equipment at Prima Medika Hospital. The implementation of the login page can be seen in Figure 5.

Figure 5 – The Implementation of The Login Page

The home page is displayed, showcasing its layout, navigation elements, and key functionalities. This page is designed to provide users with an intuitive and efficient experience, allowing them to interact with the system seamlessly. The implementation ensures that the interface aligns with the planned UI/UX design, maintaining consistency in visual elements and user accessibility. The implementation of the home page can be seen in Figure 6.

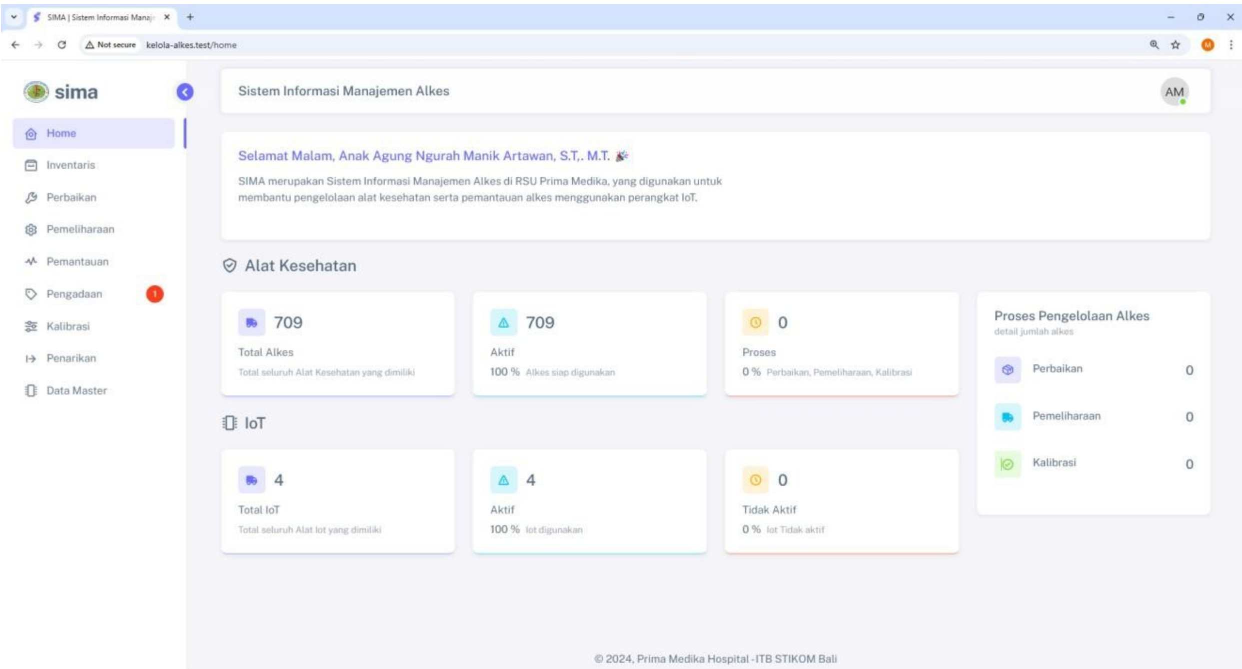

Figure 6 – The Implementation of The Home Page

The implementation of the medical equipment inventory data page allows users to manage inventory-related information efficiently. This page enables admins to add, edit, delete, and generate reports on medical equipment inventory, while employees can update and print inventory data as needed. The interface design and functionality of this inventory data page are implemented according to the system's requirements and can be seen in Figure 7.

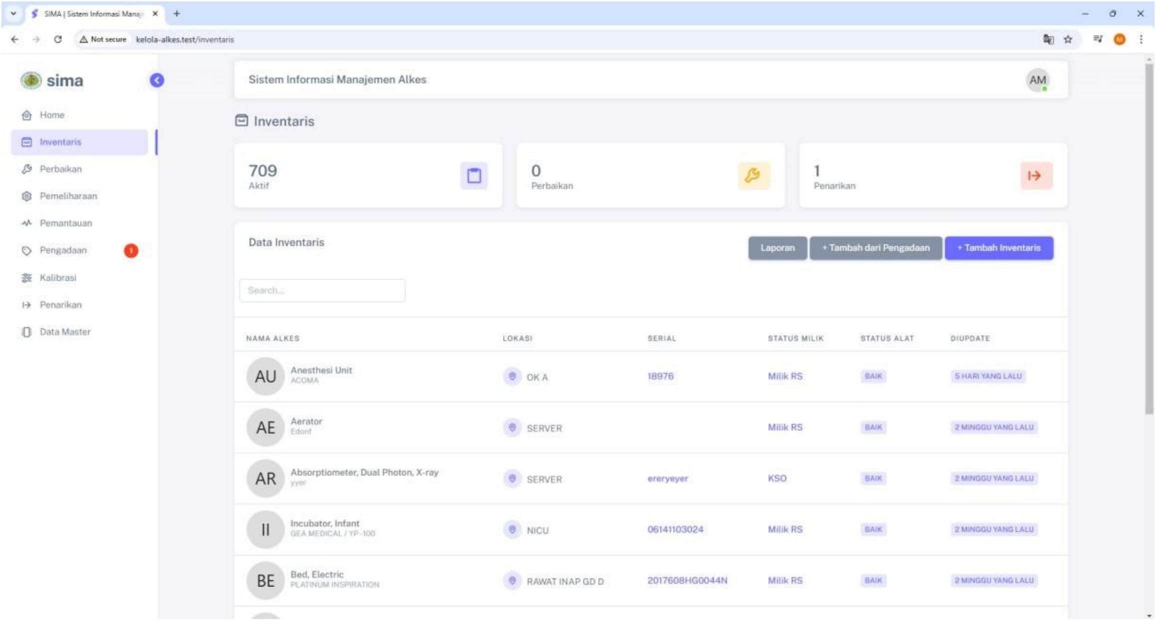

Figure 7 – The Implementation of The Medical Equipment Inventory Data Page

The medical equipment withdrawal data page is implemented to manage the process of withdrawing or recalling medical equipment from the inventory. This page allows admins to add, edit, delete, and generate reports on withdrawn equipment, while employees can generate reports as needed. The interface design and functionality of this page have been developed based on system requirements and can be seen in Figure 8.

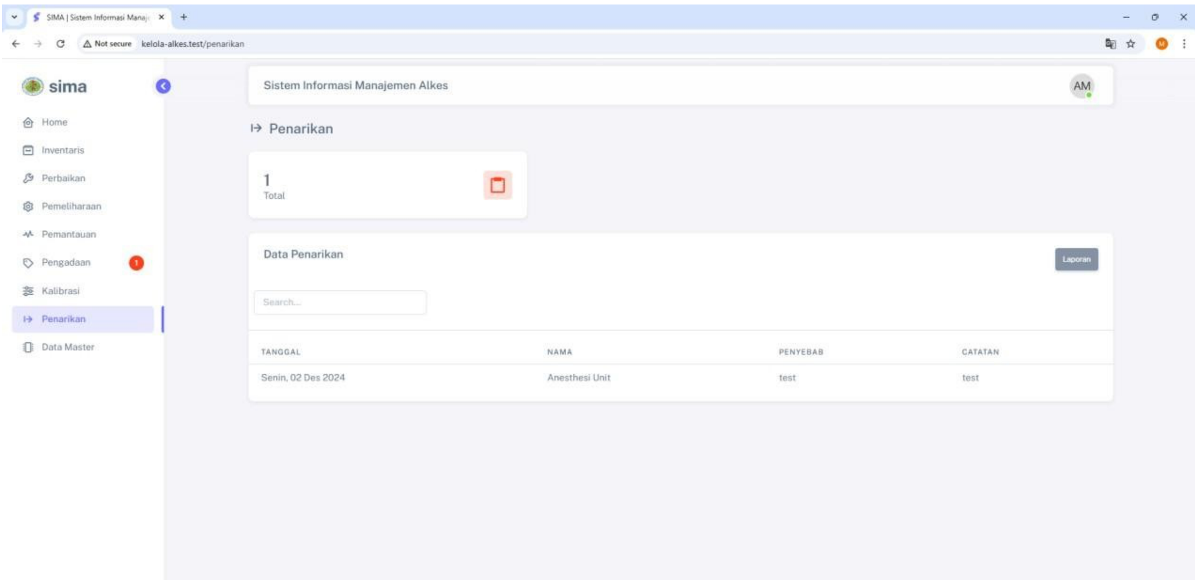

Figure 8 – The Medical Equipment Withdrawal Data Page

The medical equipment procurement data page is implemented to facilitate the management of medical equipment procurement records. This page enables admins to add, edit, delete, and generate reports on procurement activities, while employees can update procurement data as required. The interface design and functionality of this page are developed according to system specifications and can be seen in Figure 9.

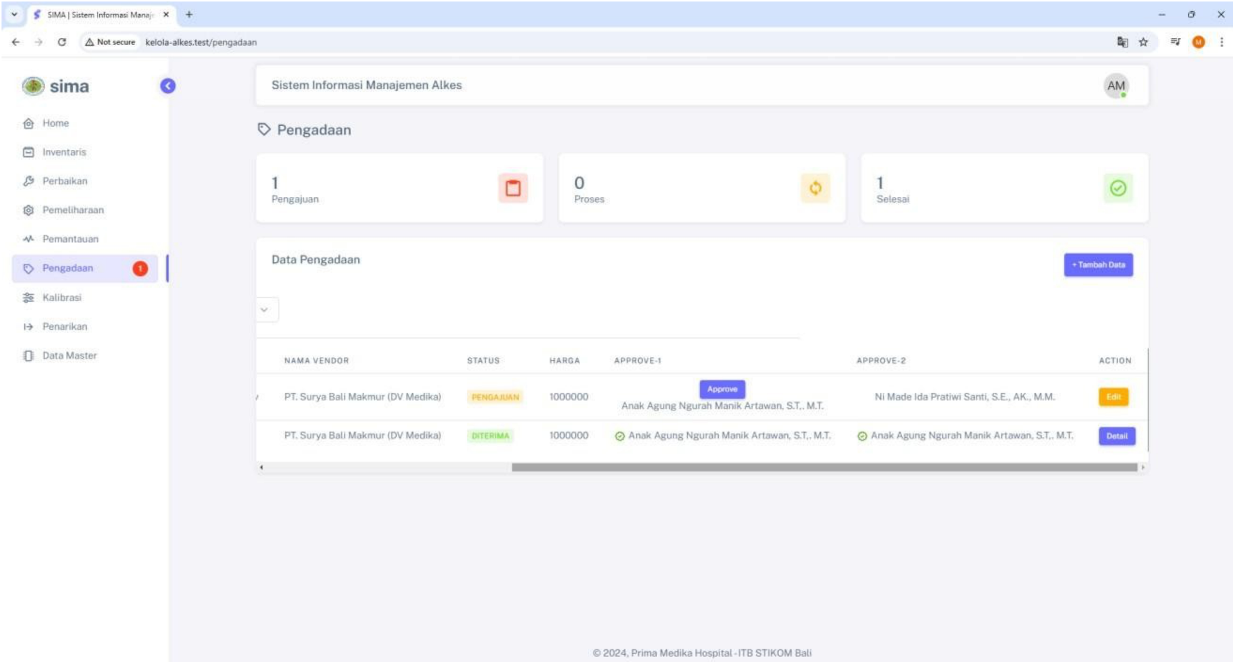

Figure 9 – The Medical Equipment Procurement Data Page

The medical equipment repair data page is implemented to manage and track repair activities for medical equipment. This page allows admins to add, edit, delete, and generate reports on repair records, while employees can update and generate reports as needed. The interface design and functionality of this page are developed based on system requirements and can be seen in Figure 10.

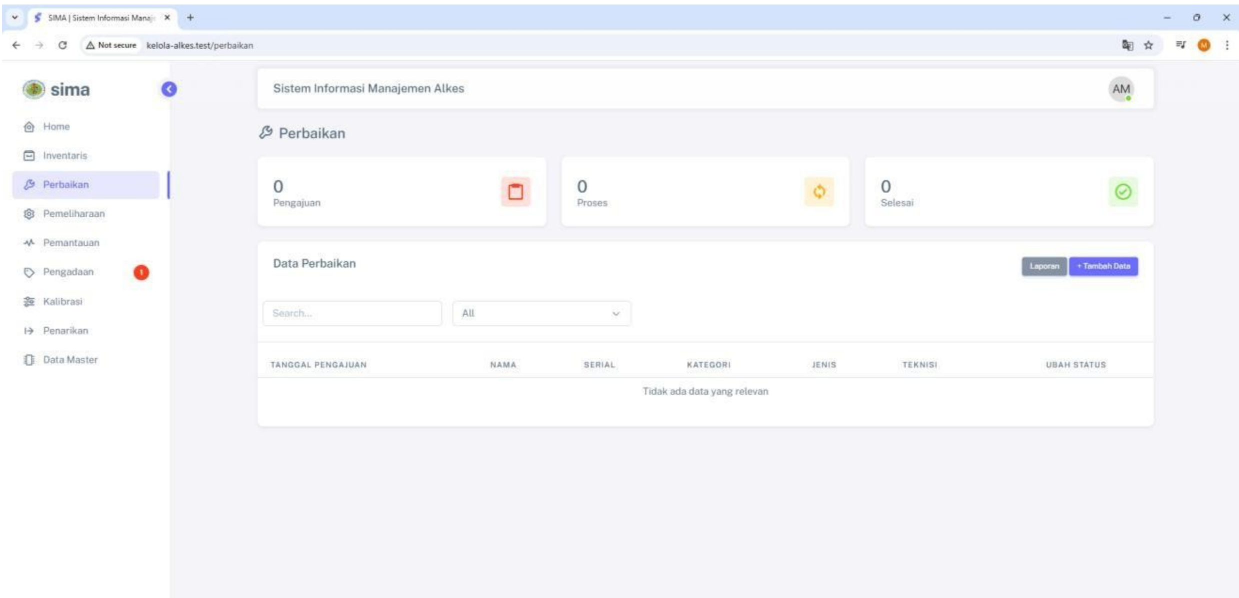

Figure 10 – The Medical Equipment Repair Data Page

The medical equipment maintenance data page is implemented to manage scheduled maintenance and upkeep of medical equipment. This page allows admins to add, edit, delete, and generate reports on maintenance activities, while employees can generate maintenance reports as needed. The interface design and functionality of this page are developed according to system specifications and can be seen in Figure 11.

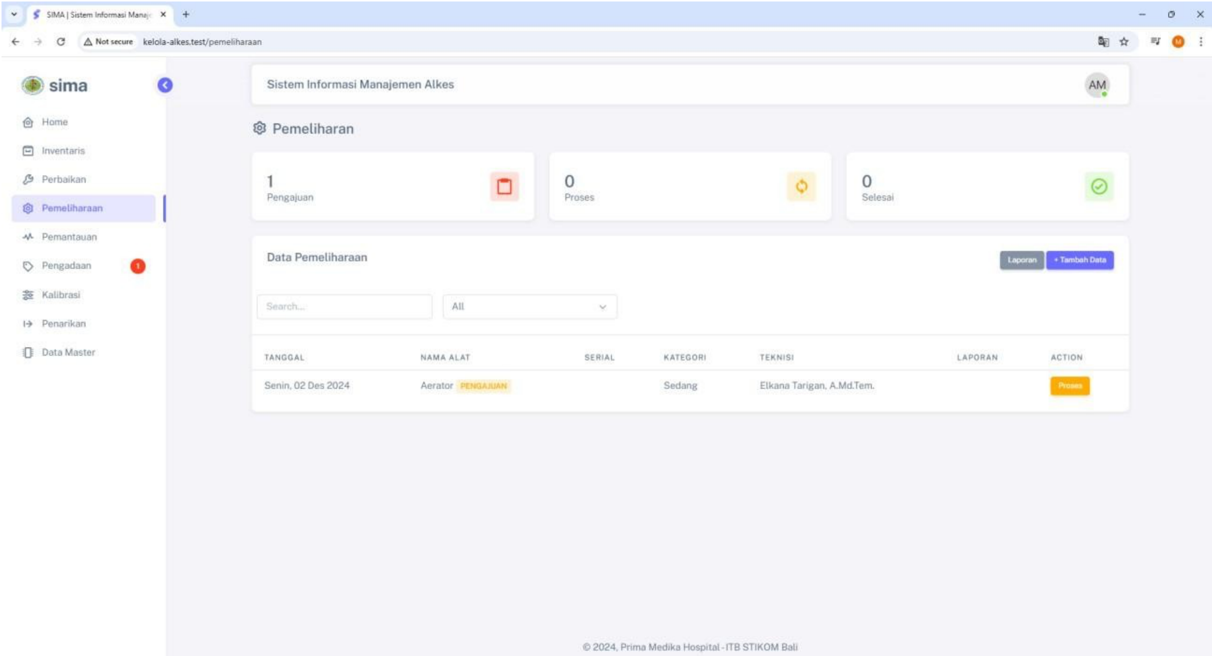

Figure 11 – The Medical Equipment Maintenance Data Page

The medical equipment calibration data page is implemented to manage and document the calibration process of medical equipment. This page enables admins to add, edit, delete, and generate reports on calibration activities, while employees can generate calibration reports as needed. The interface design and functionality of this page are developed according to system requirements and can be seen in Figure 12.

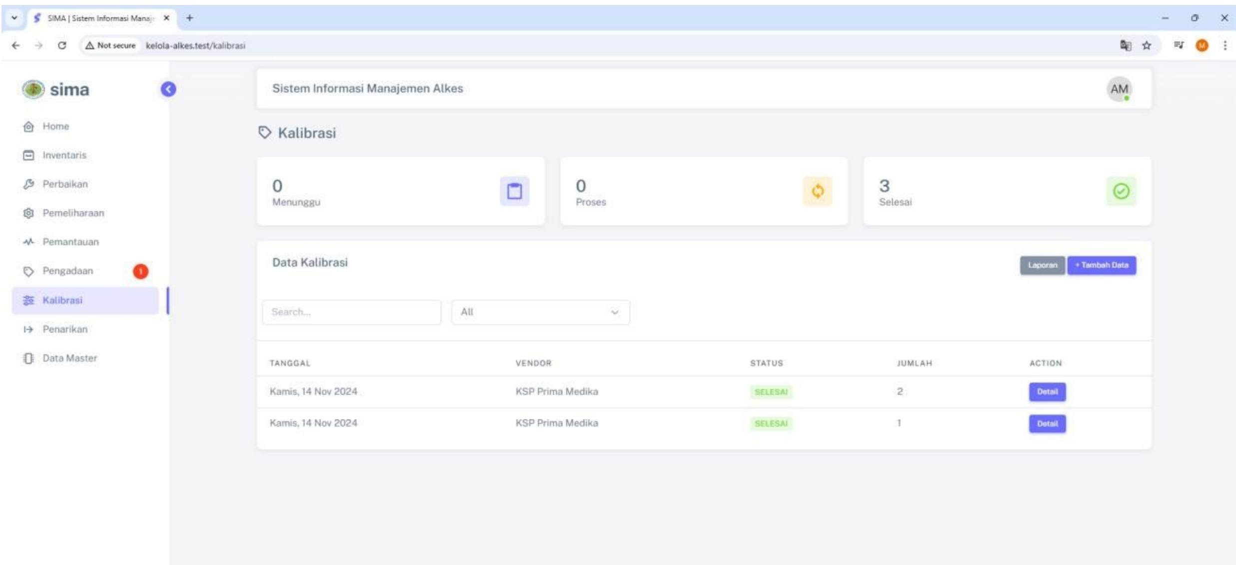

Figure 12 – The Medical Equipment Calibration Data Page

The medical equipment monitoring data page is implemented to track and display real-time monitoring data of medical equipment. This page allows admins to add, edit, delete, and generate reports on monitoring activities, while employees can generate monitoring reports as needed. The interface design and functionality of this page are developed according to system requirements and can be seen in Figure 13. To support real-time monitoring, the system integrates IoT sensors via NodeMCU ESP8266 microcontrollers. Each device reads sensor values and transmits them to the server using an HTTP POST request to the Laravel API endpoint. On the server side, the controller receives and stores the data into the monitoring table in the MySQL database using the following representative query pattern: INSERT INTO monitoring (device_id, temperature, humidity, voltage, flame_detected, created_at) VALUES (?, ?, ?, ?, ?, NOW()). The monitoring dashboard then retrieves the latest reading per device using: SELECT * FROM monitoring WHERE id IN (SELECT MAX(id) FROM monitoring GROUP BY device_id). This approach ensures low-latency data display without requiring a WebSocket infrastructure, making it deployable in environments with basic internet connectivity.

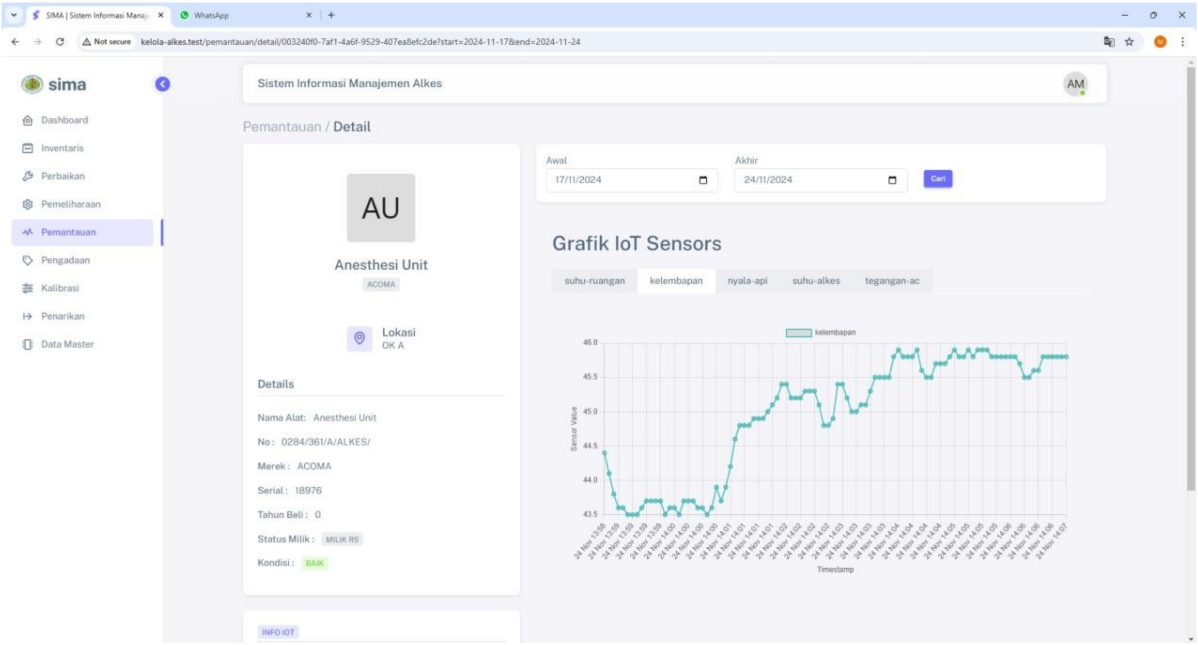

Figure 13 – The Medical Equipment Monitoring Data Page

3.4. System Testing

System testing for the application for medical equipment management at Prima Medika Hospital was conducted using Black Box Testing and User Acceptance Testing (UAT). Black Box Testing was used to evaluate system functionality by testing inputs and expected outputs without examining internal code structures [14]. This table outlines the results of system testing conducted to evaluate its functionality and performance in managing medical equipment at Prima Medika Hospital. Each test scenario was assessed based on expected outcomes, observations, and conclusions to ensure the system operates as intended. UAT involved collecting feedback from users to assess whether the system meets their needs and expectations before full implementation. A questionnaire was used as an instrument to gather user feedback, ensuring the system's effectiveness and usability [15]. This testing was conducted using a questionnaire distributed to 20 respondents at Prima Medika Hospital. Each respondent was given 10 questions to assess the system's usability, functionality, and overall effectiveness. The UAT results were calculated using the questionnaire as an evaluation instrument to determine user satisfaction and acceptance of the developed system. The results of the User Acceptance Testing (UAT) can be seen in Table 1. The UAT results indicate strong user acceptance across all ten evaluation criteria. However, several limitations of this study should be acknowledged. First, the system's IoT features are dependent on a stable internet or local network connection; disruptions to connectivity could affect real-time monitoring reliability. Second, as this research covers a prototype phase, a longitudinal comparison of equipment management efficiency before and after system deployment was not conducted. Future studies could measure quantitative indicators such as maintenance response time, calibration schedule compliance rate, and reduction in unplanned equipment downtime to provide empirical evidence of impact. Third, the current UAT sample consisted of 20 staff members at Prima Medika Hospital; broader validation across multiple healthcare facilities would strengthen the generalizability of results. Fourth, formal security and penetration testing have not yet been conducted and are recommended prior to full production deployment.

Table 1 - The results of the User Acceptance Testing (UAT)

Respondent	UAT Results										Total	Average
	1	2	3	4	5	6	7	8	9	10		
R01	5	5	4	4	5	5	4	4	5	5	46	4.6
R02	5	5	4	4	5	5	5	5	5	4	47	4.7
R03	5	4	5	5	5	5	5	5	5	5	49	4.9
R04	5	4	4	5	5	4	5	4	5	4	45	4.5
R05	5	5	5	5	5	4	5	5	4	5	48	4.8
R06	5	5	4	5	5	5	5	4	5	5	48	4.8
R07	5	4	5	5	4	5	5	4	5	5	47	4.7
R08	5	4	4	5	4	5	5	5	5	5	47	4.7
R09	4	5	4	5	5	5	5	5	5	5	48	4.8
R10	5	5	5	5	5	4	4	5	5	5	48	4.8
R11	4	5	5	5	4	4	4	5	5	5	46	4.6
R12	4	4	4	5	5	5	5	5	5	4	46	4.6
R13	4	4	4	5	5	5	5	5	5	4	46	4.6
R14	5	5	4	4	4	5	5	5	4	4	45	4.5
R15	4	5	5	4	5	5	5	4	4	4	45	4.5
R16	5	5	5	4	4	5	5	5	4	4	46	4.6
R17	4	5	5	5	5	5	5	5	4	4	47	4.7
R18	5	5	5	4	4	4	5	5	5	5	47	4.7
R19	5	5	5	5	4	5	5	5	5	5	49	4.9
R20	4	5	5	5	5	5	5	5	5	4	48	4.8
Average											4,69	
Percentage = 4,70/5 *100											93,8	

4. CONCLUSION

Based on the research conducted, a prototype web-based system for managing medical equipment at Prima Medika Hospital has been successfully developed and tested. This research utilized the Waterfall methodology for system development and Black Box testing to verify functional correctness according to specified requirements. UAT analysis conducted with 20 system users yielded an average satisfaction score of

4.69 on a maximum scale of 5.00, achieving a user satisfaction rate of 93.80%. To enhance this research, the system can be expanded into a more comprehensive medical equipment management platform, covering calibration, repair, maintenance, withdrawal, and procurement processes. Implementing real-time notifications through an alarm system that forwards alerts via email, WhatsApp, or Telegram can improve responsiveness. Lastly, developing a mobile application for Android and IOS would provide users with greater accessibility and flexibility in managing medical equipment efficiently.

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