

Development and Evaluation of a Cloud-Based Electronic Medical Record Application to Improve Healthcare Service Efficiency

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ABSTRACT

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The problem often encountered in medical record services at hospitals is the inefficiency and ineffectiveness of processing registration data due to the continued use of manual bookkeeping as an archive. This leads to obstacles such as difficulties in retrieving patient data and the risk of data redundancy. When patients do not bring their medical cards, there is a risk of damage or loss of patient data, as well as the risk of data accumulation that requires special storage space. Therefore, this study developed a medical record information system using the waterfall method, which consists of requirements, design, implementation, verification, and maintenance phases. Based on the results of white box testing, the cyclomatic complexity is 21, region = 21, and independent path = 21, indicating that the system is functioning well without errors. Furthermore, User Acceptance Testing (UAT) resulted in a percentage of 81.5% from 10 respondents, indicating the system received positive feedback from users.

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I. Introduction

The use of information technology in the healthcare industry has significantly transformed how healthcare services are provided. One of the primary aspects of this transformation is the management of medical data through an Electronic Medical Record (EMR) system. EMRs play a central role in enabling healthcare providers to offer more efficient and patient-focused care. By providing quick and accurate access to patient medical records, EMRs have revolutionized how hospitals and other healthcare facilities manage medical information.

However, despite the successes of EMRs, significant challenges remain. The volume of medical data continues to increase exponentially, including patient history, lab test results, prescriptions, surgical records, and more. Managing this increasingly complex and abundant data requires better and more efficient solutions.

One promising solution is the adoption of cloud-based technology in medical record management. Cloud computing offers significant advantages, including centralized data storage, quick accessibility from various locations, and ease of updates and scalability. However, alongside its potential benefits, challenges also arise, particularly regarding data security and compliance with strict privacy regulations in the medical environment.

This study aims to develop a Cloud-based application for managing the Hospital Management Information System (HMIS) in the context of a hospital and then evaluate its performance. The main objective of the research is to understand how cloud-based technology can improve the efficiency, accessibility, and security of medical data in healthcare services.

In the development of information technology, efficient and secure management of medical data is crucial to ensuring that patients receive quality care. By achieving the objectives of this research,



we hope to provide valuable guidance and insights for healthcare institutions looking to leverage cloud-based technology to optimize medical record management and accelerate the overall transformation of healthcare services. Additionally, this study will also consider the aspects of data security and privacy regulations that are key concerns in managing patient medical records.

II. Method

The research method applied in this study adopts the waterfall development model. The stages begin with a requirements analysis, identifying user needs and system requirements for the Cloud-based Electronic Medical Record application in detail. Next, the team carries out system design, including database design and application structure, which forms the basis for the implementation phase. Implementation involves developing the program code according to the established design. Testing is conducted after the implementation phase to ensure the consistency and reliability of the application. White-box testing is conducted to evaluate the system's logical flow and ensure alignment with the program code.

Next, User Acceptance Testing (UAT) with Black Box Testing is conducted to gather feedback from end-users, namely hospital staff/admin at the registration counter and doctors, regarding the system's functionality and suitability for their needs as shown in Figure 1. Implementation and maintenance planning are then drafted to deploy the Cloud-based EMR application within the hospital environment and plan for ongoing maintenance and improvements. This approach follows a linear and sequential waterfall development model, ensuring each stage is tested and completed before moving on to the next stage, while prioritizing data security and user satisfaction.

III. Results and Discussion

A. Cloud-Based Electronic Medical Record Dropdown Menu

The dropdown menu presented in this application consists of several modules developed according to needs, which are displayed in Table 1 below:

Table 1. Nusa Medis Menu and Submenu

No	Module	Description
1	Registration	Patient identity such as Name, Place of Birth, Date of Birth, Gender, Religion, Drug Allergy, Blood Type, Rhesus, ID Card Number/Identity, Subdistrict, Address, Phone Number, Education, Occupation, Nationality, Marital Status
2	Outpatient	Subjective: Anamnesis, Objective: Patient's General Condition, Systolic Blood Pressure, Diastolic Blood Pressure, Pulse, Respiration, Temperature, Weight, Height, Assessment: Diagnosis, Planning: Action, Executor, BHP, Therapy, Compounded Therapy, Transfer, Lab Results, Radiology Results, Sales
3	Pharmacy	General Sales, Guaranteed Sales, Over-the-Counter Sales, Sales Returns, Reprint Sales Receipts, Reprint E-Tickets, Reprint Return Receipts, Medication Preparation Process, Pharmacy LCD
4	Medical Records	Patient Data, ICD 9 Master, ICD 10 Master, Diagnosis Input
5	BPJS	Pcare Log
6	Cashier	Patient Payment, Guaranteed Patient Payment, Reprint Receipt
7	Management	Configuration: Configuration, Tariff Configuration, Service Configuration, User: Employee Management, Organizational Structure, Position, User Login, Change Password, Tariff: Registration Fee, Examination Fee, Procedure Tariff, Medical: Poli Setup, Doctor Schedule, Education Master, Occupation Master, ICD Category, Diagnosis Master, Procedure Master, Import: Employee Import, Patient Import
8	Admin	User Login, Change Password

B. System Implementation

The system is divided into several main modules, each functioning to handle specific tasks within the hospital information system. The main modules are shown in Figure 2, while other modules are illustrated in Figures 3-9.

- **Registration Module (Figure 2):** This module is responsible for collecting and managing patient identity information. The data managed includes patient name, place of birth, date of birth, gender, religion, drug allergy, blood type, rhesus, ID card/identity number, subdistrict, address, phone number, education, occupation, nationality, and marital status. This information is crucial for creating a comprehensive patient profile that can be accessed across different departments.
- **Outpatient Module (Figure 3):** The outpatient module handles patient interactions during their visits to the hospital. This module begins with the collection of subjective data through anamnesis, followed by objective data such as the patient's general condition, blood pressure (systolic and diastolic), pulse, respiration, temperature, weight, and height. The module also facilitates diagnosis and treatment planning, including medical actions, executors, consumables (BHP), as well as general and compounded therapy. Additionally, this module records patient transfers, lab results, radiology results, and sales transactions that occur during the patient's visit.
- **Pharmacy Module (Figure 4):** This module manages hospital pharmacy operations, including general sales, guaranteed sales, over-the-counter sales, and sales returns. This module also handles reprinting of sales receipts, e-tickets, and return receipts. The pharmacy module also oversees the medication preparation process and includes a pharmacy LCD display to track and manage the medication preparation process.
- **Medical Records Module (Figure 5):** The medical records module is dedicated to managing patient data, including ICD-9 and ICD-10 codes, and inputting diagnoses. This module ensures that patient records are accurately maintained and accessible for future reference and ongoing care.
- **BPJS Module (Figure 6):** The BPJS module records activities related to the Indonesian health insurance program (BPJS), particularly Pcare, which is essential for managing and tracking insurance claims and patient eligibility.
- **Cashier Module (Figure 7):** The cashier module facilitates patient payments, including those made through insurance. This module also allows for the reprinting of receipts, ensuring that all financial transactions are accurately recorded and documented.
- **Management Module (Figure 8):** This module is very comprehensive, covering various administrative aspects of the hospital. It includes configuration settings for services and tariffs, user management for employees, organizational structure, positions, and login credentials. Additionally, this module manages registration fees, examination fees, procedure tariffs, and medical services. This module also includes features for setting up clinics, doctor schedules, and managing various educational and occupational data. Import functionalities allow for the bulk entry of employee and patient data.
- **Admin Module (Figure 9):** The admin module focuses on user account management, allowing users to log in and change passwords. This module is critical for maintaining the security and integrity of the hospital information system.



Fig 1. Dashboard

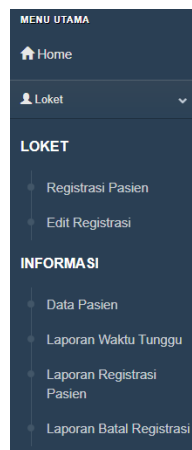


Fig 2. Modul Registration



Fig 3. Outpatient



Fig 4. Pharmacy



Fig 5. Medical Record

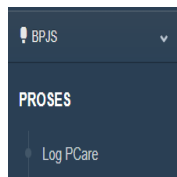


Fig 6. BPJS



Fig 7. Cashier



Fig 8. Management

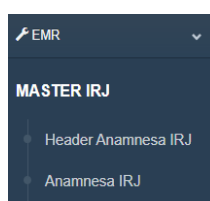


Fig 9. Admin

Each of these modules is designed to handle specific tasks within hospital operations, ensuring that all aspects of patient care, administrative processes, and financial transactions are managed efficiently and effectively.

C. Testing

In this study, testing was conducted using two methods: White-box testing was performed to examine the internal structure of the system by calculating cyclomatic complexity, region, and independent path. The results showed consistent values with cyclomatic complexity = 21, region = 21, and independent path = 21. Cyclomatic complexity measures the structural complexity of a program by counting the number of different paths through the code. With a cyclomatic complexity of 21, it can be asserted that the system developed has moderate complexity (21 out of 100); the higher the cyclomatic complexity, the more complex the program and the more paths that need to be tested to cover all possibilities. Region is a group of statements or code blocks that form a functional unit within a program. In this test, a region value of 21 was obtained, indicating that there are 27 program regions tested independently to ensure their functional correctness. Independent path is an execution path that does not depend on other paths in the program. In white box testing, independent path testing is conducted to test each execution path separately to ensure the correctness of logic and data processing in each possible path.

Thus, the results of white box testing help identify and test various execution paths within the code, thereby improving the quality and reliability of the software. This also confirms the alignment of the system logic with the program code, demonstrating accuracy and suitability in its operation.

Table 2. Summary of White-box Testing Results

No	Flowchart	Cyclomatic Complexity	Region (R)	Independent Path
1	Login	2	2	2
2	Registration Module	2	2	2
3	Outpatient Module	2	2	2
4	Pharmacy Module	3	3	3
5	Medical Records Module	2	2	2
6	BPJS Module	3	3	3
7	Cashier Module	3	3	3
8	Management Module	3	3	3
9	Admin Module	1	1	1
	Total	21	21	21

Furthermore, the second test using User Acceptance Testing (UAT) was conducted with the participation of 10 end users, consisting of management, staff/admin at the registration counter, and doctors from a hospital in Kolaka Regency. The UAT testing involved 10 respondents who provided feedback on the system's functionality and performance, with results visible in Table 3.

Table 3. User Approval Range

No	Question	Strongly Agree (SA)	Agree (A)	Disagree (D)	Strongly Disagree (SD)
1	Is the layout and design of the display elements easy to understand and intuitive?	5	3	2	0
2	Is the system easy to use (user friendly)?	2	8	0	0
3	Does the system meet all the functional requirements that were set beforehand?	2	6	2	0
4	Does this application make it easier to perform common or routine tasks for users?	4	4	2	0
5	Does the system run smoothly and stably when used?	7	2	1	0
	Total	20	23	7	0

The total respondent answers in Table 2 were calculated using equation (1) below:

Equation (1):

$$\text{Score} = \text{Weight} \times \text{Total Weight} \text{ \textit{Score} = \textit{Weight} \times \textit{Total Weight}}$$

$$\text{Weight} \times \text{Score} = \text{Weight} \times \text{Total Weight}$$

$$\text{Strongly Agree} = 4 \times 20 = 80 \text{ \textit{Strongly Agree} = 4 \times 20 = 80}$$

$$\text{Agree} = 3 \times 23 = 69 \text{ \textit{Agree} = 3 \times 23 = 69}$$

$$\text{Disagree} = 2 \times 7 = 14 \text{ \textit{Disagree} = 2 \times 7 = 14}$$

$$\text{Strongly Disagree} = 1 \times 0 = 0 \text{ \textit{Strongly Disagree} = 1 \times 0 = 0}$$

$$\text{Total Score} = 163 \text{ \textit{Total Score} = 163}$$

Next, the value X is calculated using equation (2):

Equation (2):

$$X = \frac{\text{Highest Score} \times (\text{Number of Questions} \times \text{Number of Respondents})}{(\text{Number of Questions} \times \text{Number of Respondents})}$$

$$X = \frac{\text{Highest Score} \times (\text{Number of Questions} \times \text{Number of Respondents})}{(\text{Number of Questions} \times \text{Number of Respondents})}$$

$$X = 4 \times (5 \times 10) \text{ \textit{X} = 4 \times (5 \times 10)}$$

$$X = 200 \text{ \textit{X} = 200}$$

Finally, the UAT percentage is calculated using equation (3):

Equation (3):

$$\text{UAT Percentage} = \frac{\text{Total Score}}{\text{Highest Score}} \times 100\%$$

$$\text{UAT Percentage} = \frac{163}{200} \times 100\% = 81.5\%$$

$$\text{UAT Percentage} = 200 \times 163 \times 100\% = 81.5\%$$

The UAT result of 81.5% indicates that the cloud-based medical record information system in this study has met user needs and expectations, is easy to use, not confusing, and aligned with the desired objectives. Users are satisfied with the performance, functionality, and interface of the tested application. This UAT result overall provides an overview of the feasibility of this cloud-based medical record information system in meeting user needs and the extent to which the system can be accepted by users. Moreover, the UAT result of 81.5% can be used as a basis for deciding that this system is ready for use.

IV. Conclusion

In this study, the development of a cloud-based medical record information system was conducted to improve the efficiency and reliability of medical data management in a hospital environment. The system's implementation involved testing using white-box and User Acceptance Testing (UAT) methods. The white-box testing results with a cyclomatic complexity value of 27, a region value of 27, and an independent path value of 27, indicate that the system is running well without errors. Meanwhile, the UAT results show an approval rate of 81.5%, which indicates a good rating in the user assessment of the developed system. The main integrated pages in the system, such as doctor data, diagnosis, inpatient, and main doctor menu pages, provide easy and structured access for users to manage patient data, disease diagnosis, inpatient information, and doctor information efficiently. Thus, the development of this medical record information system is expected to contribute significantly to improving the quality of healthcare services in hospitals, enhancing medical data management, and providing a more structured approach to patient care processes.

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