Research Article

Early Detection of Disease Outbreaks: A Monitoring System for Sleman Regency

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Abstract: In early 2025, Indonesia faced a surge in infectious diseases, with 6,000 Dengue Fever and 28 deaths by January, and 889,000 tuberculosis cases by March. An outbreak or "*Kejadian Luar Biasa*" (KLB) is marked by a significant rise in illness or death within a period. However, according to the Sleman Regency Health Office, the existing Early Warning and Response System remains suboptimal in detecting such events. To improve early detection, a Disease Outbreak Monitoring System was developed using the Waterfall Method. This system features an interactive dashboard, data storage for patients and health centers, automatic KLB detection, and a feedback mechanism. Testing has demonstrated that the system improves accuracy and responsiveness, providing a promising solution for early outbreak detection and prevention.

Keywords: Epidemic Diseases, Detection, Monitoring System, Waterfall

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1. Introduction

An outbreak is a situation where an infectious disease occurs in a community, with the number of cases rising significantly beyond the usual level for a specific time and place, potentially causing widespread harm. According to the Indonesian Ministry of Health Regulation Number 1501/MENKES/PER/X/2010, an outbreak occurs when a contagious disease spreads in a community, and the number of cases increases greatly, surpassing the normal rate for that time and area, which could lead to a disaster. Indonesia's tropical climate, high population density, poor healthcare infrastructure, and low public health awareness make the country vulnerable to the spread of infectious diseases [1]. Certain conditions may indicate the potential for an outbreak before it is officially declared [2]. These conditions are known as *Kejadian Luar Biasa* (KLB).

KLB refers to a significant increase in cases of illness and/or death in a certain area over a period of time, identified based on epidemiological data [3] [4]. KLB monitoring involves several stages [5]. First, community health centers (Puskesmas) report the number of cases of each disease weekly to the Sleman Regency Health Office. The reports are manually reviewed to check for any signs of KLB. If signs are found, the Sleman Regency Health Office will ask the relevant Puskesmas to conduct an epidemiological investigation. If the investigation confirms an outbreak, the Health Office will officially declare a KLB in that area.

Dr. Novita Krisnaeni from the Sleman Regency Health Office mentioned in an interview that their current system, the Early Warning and Response System, does not fully meet their needs. The system does not provide timely warnings for cases that meet KLB criteria. There are seven KLB criteria outlined in the Indonesian Ministry of Health Regulation Number 1501/MENKES/PER/X/2010, making it difficult for the Health Office to manually check each report for KLB signs.

The need for a more efficient system led to the development of a new disease outbreak monitoring system. The system was developed using the Waterfall Method. It aims to gather patient data from each Puskesmas in Sleman Regency into one place. Once the data is entered into the system, it is automatically processed to check for signs of KLB. This system is expected to make it easier for the Sleman Regency Health Office to detect early signs of KLB and improve early warnings, allowing for faster epidemiological investigations and responses to disease outbreaks.

2. Theory

2.1 Disease Outbreaks and 'Kejadian Luar Biasa' (KLB)

A disease outbreak refers to the occurrence of cases of a particular disease in a population greater than what is normally expected in a specific time and area [6]. Kejadian Luar Biasa (KLB) or Extraordinary Events is a term used in Indonesia to describe a significant increase in disease cases that exceed normal levels, potentially leading to a public health crisis. According to the Ministry of Health Regulation No. 1501/MENKES/PER/X/2010, KLB is defined as an epidemiological situation where there is a sudden, unusual increase in the number of cases of a disease, or deaths related to a disease, within a specific time and area [7] [8]. This concept highlights the critical need for early detection and swift response to mitigate the impact on public health [9] [10].

2.2 The Role of Information Systems in Disease Monitoring

Information systems play a crucial role in managing public health data, supporting decision-making, and facilitating timely responses to disease outbreaks [11] [12]. In the context of disease outbreak monitoring, an effective information system can collect, store, process, and analyze data from various sources, such as health centers and hospitals. The system's ability to automatically detect trends and potential outbreaks, based on epidemiological criteria, enables health authorities to identify and address health threats early [13]. Such systems contribute to better management of resources, improved communication among stakeholders, and more efficient responses to emerging health issues [14] [15]. This research focuses on developing a disease outbreak monitoring system that addresses the need for early warning and quick action when signs of KLB are detected.

3. Method

3.1 Flowchart System

This research uses a quantitative method with a Waterfall approach, starting with defining the research problem, where the researcher identifies the problem to be studied and the objectives to be achieved (Figure 1). Moreover, the researcher conducts a literature review to understand existing theories and studies, as well as identify gaps that need to be filled. Following this, the researcher gathers the necessary research requirements, such as identifying variables to be measured, formulating hypotheses, and determining data collection methods. In the design phase, the researcher develops the instruments or systems to be used for data collection, such as questionnaires or other tools. Once the design is completed, the researcher begins collecting data according to the plan. After the data is collected, the researcher performs testing and validation to ensure the accuracy and consistency of the data and the effectiveness of the tools used. The validated data is then analyzed using statistical methods to identify patterns or relationships. The results of the analysis are then interpreted to determine whether the findings support the hypotheses or initial predictions. The final step is drawing conclusions, where the researcher determines whether the research objectives are met and provides recommendations for future research or practical implications based on the research findings. All these stages are carried out sequentially and carefully to ensure the research progresses effectively.

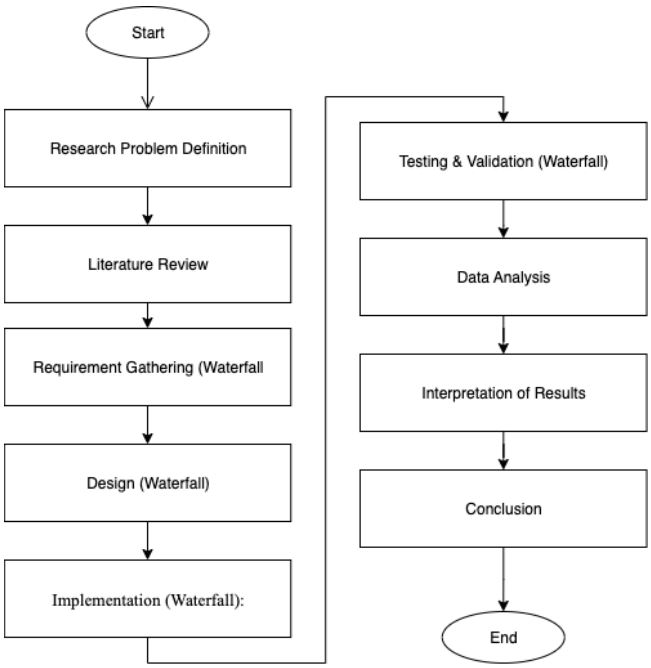

Figure 1. Research Flow

3.2 *The Waterfall Methods*

The Disease Outbreak Monitoring System uses the Software Development Life Cycle (SDLC) Waterfall Method. The Waterfall method is suitable for use in this system because all the requirements and phases can be clearly defined and completed at the beginning of the development process [16]. Since each phase is sequential and depends on the completion of the previous one, it ensures that all requirements are thoroughly understood and addressed upfront, providing a clear structure for the project [17]. This makes it easier to track progress and maintain control over each stage of development, reducing the likelihood of scope changes or unexpected issues later on [18]. These phases typically include requirements analysis, system design, implementation (coding), testing, and maintenance. Figure 2 illustrates the flow of the Waterfall method phases.

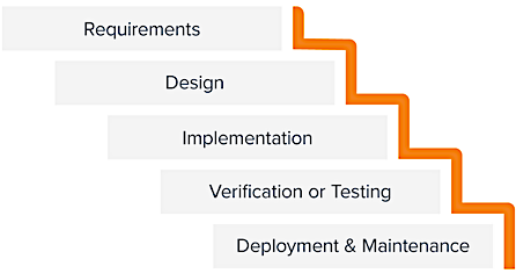

Figure 2. The Waterfall Method

I. *Requirement*: The research begins by collecting all the necessary information through various methods. The first step involves conducting a detailed requirements analysis, where data is gathered from different sources such as observations, interviews, and document reviews. The researchers meet with key stakeholders, including personnel from the Sleman Regency Health Office, to understand what information is needed and how the system should operate to support their monitoring and disease outbreak warning activities. The collected information is then carefully analyzed to identify key data points, user needs, and system functions. This detailed analysis allows the

researchers to establish the correct system requirements, which then guide the subsequent design and development process [19].

II. *Design*: The design phase ensures that every functional requirement identified during the analysis phase is represented in the system's structure, ensuring nothing is overlooked. To simplify complex ideas, the design phase involves creating visual diagrams [20]. This includes workflow diagrams, use case diagrams, database relational diagram that illustrate step-by-step how the system will operate, from input, through processing, to output.

III. *Implementation:* In this phase, developers build the system by following the detailed design and specifications created in the previous phase. This step ensures that the planned structure on paper comes to life as a functional program. Developers code functions such as managing patient data and monitoring disease outbreak warnings as outlined in the design phase. This is done to maintain consistency throughout the development process [21].

IV. *Verification or Testing*: The testing phase in this research is used to verify whether the system built during the implementation phase works correctly and meets the requirements defined earlier. Developers also conduct usability testing to understand how easy and intuitive the system is for real users, particularly the staff at the Sleman Regency Health Office. In usability testing, the system is demonstrated and presented to the end users, allowing them to provide feedback and suggest improvements [22].

V. *Deployment & Maintenance:* The deployment involves the process of installing or launching the completed software into the user or production environment so it can be used operationally [23]. Once the software is deployed and in use by the users, the maintenance phase begins [24]. This phase focuses on ongoing support, fixing any bugs or errors that may arise during use, updates to improve functionality or performance, and adjustments to keep the system running optimally and relevant to the users' needs over time.

3.3 Requirement

This phase involves conducting interviews to analyze user needs. The interview technique used is a personal interview. Personal interviews are conducted face-to-face between the interviewer and the interviewee. The purpose of the interview is to understand what data is needed so that the disease outbreak management information system in Sleman Regency, which will be developed, can function as expected [25] [26]. Based on the interview results, the general activity overview of the system is as follows: the monitoring system collects data entered by each user at every community health center (*Puskesmas*) in Sleman Regency. Then, the Admin of the Sleman Regency Health Office will monitor and manage the gathered data. The interview also outlines the functions expected to be included in the monitoring system [27]. The functional requirements describe what actions can be taken on the incoming data that support achieving the desired output. Therefore, the process is also related to organizing and managing data.

1) The responsibilities of the community health centers (*Puskesmas*) Admin include:
   - Managing patient data: create, read, update, and delete.
   - Managing KLB data: searching KLB data.
   - Managing message data: create and read.
2) The responsibilities of the Health Office Admin include:
   - Managing patient data: reading patient data.
   - Managing community health centers (*Puskesmas*) data: create, read, update, and delete.
   - Managing KLB data: searching KLB data.
   - Managing message data: create and read.

3.4 Design

Functional design is the phase where a general overview of the system to be developed is created. This design explains the benefits or objectives of the system to those outside the system. The design will be represented in the form of diagrams.

3.4.1 Workflow Diagram

A Workflow Diagram is a visual representation that shows the sequence of steps, decisions, and flow of processes within a system or project. It helps to map out how tasks or activities are carried out, from the beginning to the end, and the decisions that need to be made at each step. This diagram is useful for understanding how different elements of a system or project interact and how work moves through different stages. It simplifies complex processes, making it easier to follow and identify areas for improvement or potential bottlenecks [28].

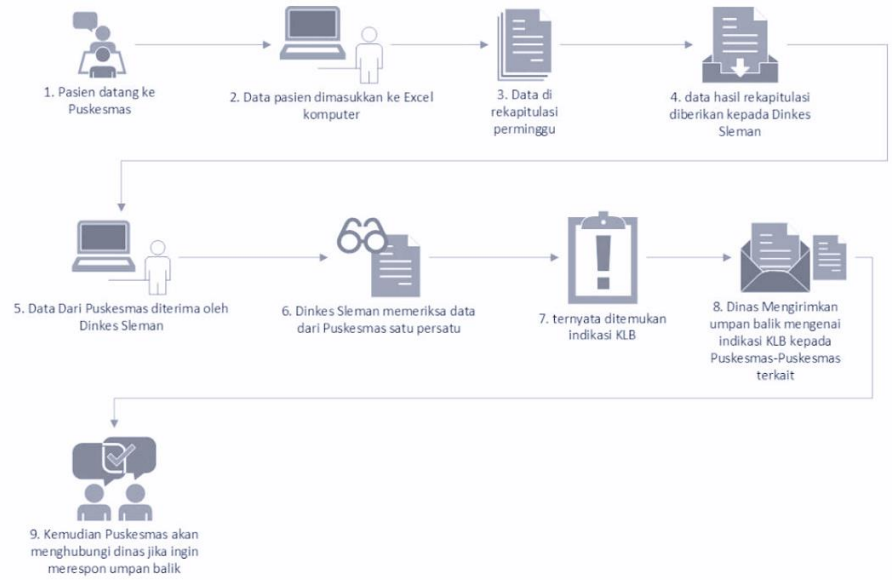

Figure 3. Workflow Diagram

Figure 3 illustrates the process of handling patient data and detecting Kejadian Luar Biasa (KLB) between *Puskesmas* and the Health Office. The process begins when a patient arrives at *Puskesmas,* and their data is entered into the system. Data from various *Puskesmas* are then collected into a centralized database for potential KLB analysis. The results of this analysis can be accessed by both the Health Office and *Puskesmas*. If KLB is detected, the system will send a notification, which is followed up by the Health Office by sending feedback to the *Puskesmas*, and the *Puskesmas* can respond to that feedback.

3.4.2 Use Case Diagram

A Use Case Diagram is a graphical visualization of interactions between the elements within a system. Use Case Diagrams are used in UML (Unified Modeling Language) as a standard notation for modeling objects and real-world systems [29].

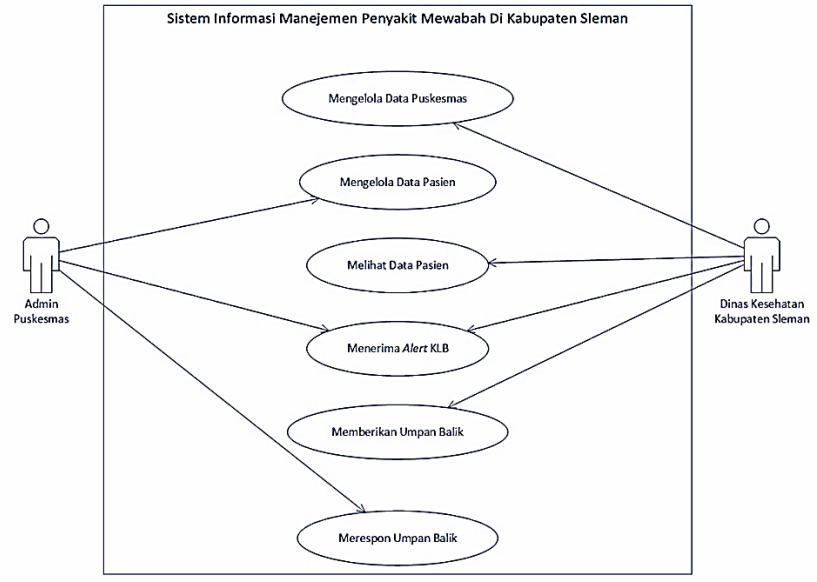

Figure 4. Use Case Diagram

Figure 4 illustrates the interaction between users (actors) and the "Disease Outbreak Monitoring System in Sleman Regency." There are two main actors: the Puskesmas Admin and the Sleman Regency Health Office. The Puskesmas Admin has functions to manage Puskesmas and patient data, receive KLB alerts, and provide and respond to feedback. Meanwhile, the Sleman Regency Health Office can view patient data, receive KLB alerts, and provide feedback regarding KLB to the Puskesmas.

3.4.3 Database Relational Diagram

A Database Relational Diagram is a database is a collection of organized data that is interconnected, allowing the data to be easily accessed, manipulated, and updated [30]. A Database Relational Diagram (Figure 5) models information and data into a set of tables with rows and columns. Each row in the relation or table represents a data entry, and each column represents a data attribute.

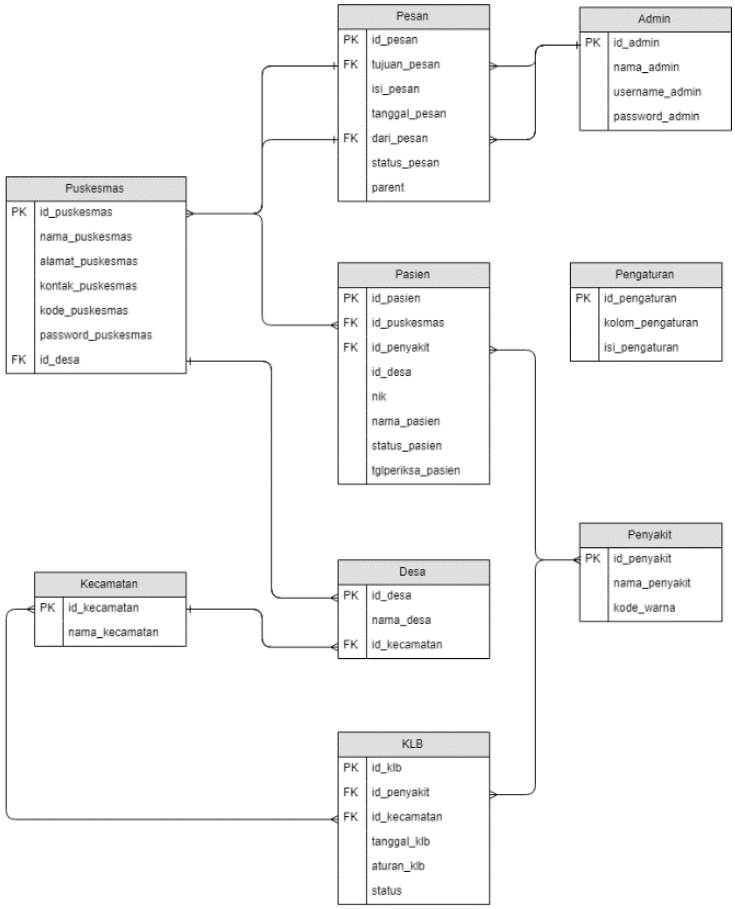

Figure 5. Database Relational Diagram

3.4.4 Implementation

In the implementation phase, the designed system will be operated to determine whether the system is functioning as expected or not. The implementation of the Disease Outbreak Monitoring System in Sleman Regency will be explained through a sequence of system usage scenarios.

4. Result and Analysis

This chapter focuses on the analysis of the implementation, testing, user verification, deployment, and maintenance stages of the Waterfall method. These stages are critical in ensuring that the system functions as intended and meets the established requirements [31]. In this chapter, we will explore how the system was implemented, the testing procedures that were carried out to ensure its accuracy and functionality, and the user verification process to confirm that it aligns with user expectations. Additionally, we will examine the deployment of the system into the operational environment and the ongoing maintenance efforts to ensure its continued effectiveness [32]. This analysis will provide a comprehensive overview of how the system evolved from design to full operation and how it is maintained to adapt to future needs.

4.1 Implementation

In the implementation phase, the designed system will be operated to determine whether the system is functioning as expected or not. The implementation of the Disease Outbreak Monitoring System in Sleman Regency is illustrated through a series of usage scenarios below.

4.1.1 Login: Before accessing the system, users will be directed to the login page. The login page shown in Figure 6 is the first page that appears before users enter the system. If the user logs in as the admin of the Sleman Regency Health Office, they will be directed to the main page shown in Figure 7.

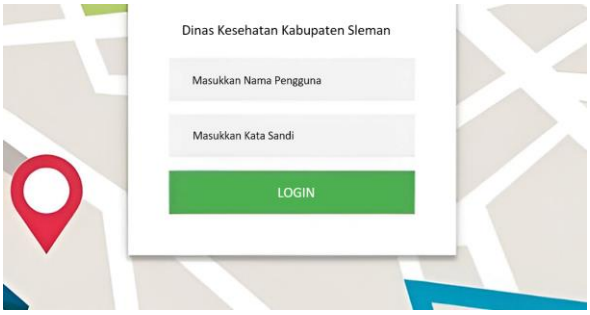

Figure 6. Login Page

The list of diseases monitored by the system to detect potential KLB can be found on the dashboard, as shown in Figure 6.

Figure 7. Main Page

4.1.2 Puskesmas Management: The Sleman Regency Health Office manages *Puskesmas* activities. The admin of the Sleman Regency Health Office can view, add, edit, and delete *Puskesmas* data.

Figure 8. *Puskesmas* Management Page

4.1.3 Patient Management: This stage is carried out by Puskesmas. The Puskesmas admin can add a new *Puskesmas* to the Puskesmas list. To add new patient data, the admin can click the "Add" button on the top right to manually input data or click the "Import Excel" button to add data by uploading an Excel file.

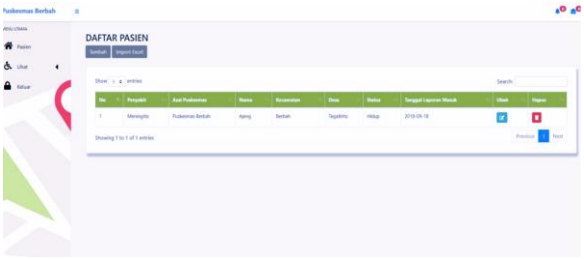

Figure 9. Patient Management Page

4.1.4 KLB Alert: The addition of patient data can now be performed. The data entered will then be automatically processed to determine if there are any indications of a potential KLB case. If an indication of KLB is found, a badge will appear on the top right of the interface.

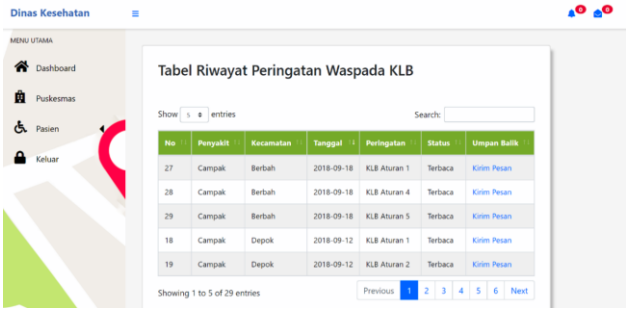

Figure 10. KLB Alert Page

4.1.5 Feedback: Provided by clicking the "Send Message" text (Figure 10), which will direct the admin to the feedback page. Figure 11 illustrates the activity of providing feedback. Figure 12 shows how to open a message and respond to the Puskesmas admin's feedback by clicking the message icon in the top right corner, which will take the user to the feedback page.

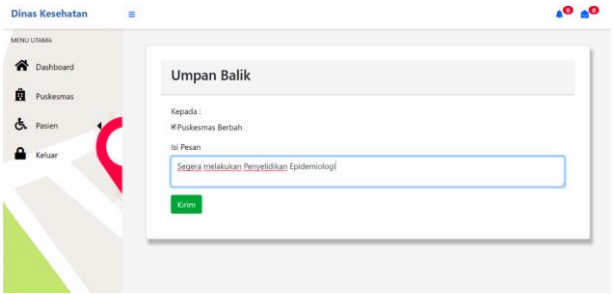

Figure 11. Feedback Page

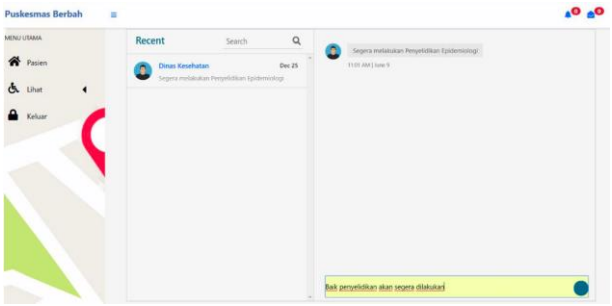

Figure 12. Message Page

4.1.6 Testing and Verification: Testing is conducted by presenting and demonstrating the system directly at the Sleman Regency Health Office. To determine the respondents for usability testing, the sampling technique used is Snowball Sampling. Snowball sampling helps identify and recruit hard-to-reach populations [33]. Table 1 presents the results from system testing.

Table 1. Testing Result

No		E	D	C	B	A	Skor
	CAPACITY						
1	The system makes the work process more effective	0	0	2	1	2	91.6
2	The system makes the work process more efficient	0	0	2	1	2	91.6
3	The system helps meet the needs of the Health Service in Sleman Regency	0	0	2	2	3	100
	USABILITY						
4	Easy to Use	0	1	1	0	2	75
5	Has a good flow to be used for obtaining necessary information	0	0	1	2	2	91.6
6	The system is Flexible	0	0	2	2	3	91.6
	LEARNING CAPACITY						
7	The system template on a mobile device	0	0	2	0	1	75
8	I can use the system template effectively	0	0	1	1	2	83.3
9	I learned how to use the system effectively	0	0	2	1	3	91.6
	SATISFACTION						
10	I am satisfied with the system	0	0	0	3	3	100
11	The system is useful in helping with my job	0	0	0	3	3	100

The data from the system testing shown in the figure indicates a highly positive user acceptance rate and highlights the system's functionality significantly. Column‘ A’ indicates that the system is very suitable for the function, and Column ‘E’ indicates that the system is not very suitable for the function. Based on the table above, a Quality of Service (QoS) analysis is conducted, focusing on key aspects such as Capacity, Usability, Learning Capacity, and User Satisfaction. This analysis aims to evaluate how effectively the system meets the needs of users in the Sleman Regency Health Office, assessing its functionality, ease of use, learning curve, and overall user satisfaction [34].

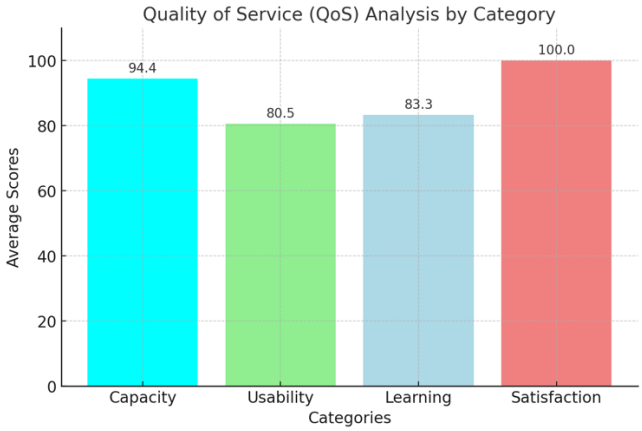

Figure 13. Quality of Service Graph

Figure 13 presents the Quality of Service (QoS) analysis based on four key categories: Capacity, Usability, Learning, and Satisfaction. The Capacity category, which evaluates the system's effectiveness in meeting the Health Office's needs, has an average score of 94.5, reflecting a high level of functionality. Usability received an average score of 80.2, indicating that while the system is largely effective, there is room for improvement in terms of ease of use. The Learning category scored 83.5 on average, suggesting that while users can quickly learn the system, there is potential to streamline the learning process further. Finally, Satisfaction achieved a perfect score of 100, highlighting that users are extremely satisfied with the system's performance and consider it essential to their work. Overall, the system performs well across all categories, with Satisfaction being its strongest feature.

4.1.7 Deployment & Maintenance

This phase includes the process of installing the system at Puskesmas and the Sleman Regency Health Office, ensuring that all core functionalities—from managing patient and Puskesmas data, sending KLB notifications, to the feedback mechanism between agencies—are operating according to the designed workflow. After the system is operational, the researchers' responsibilities include monitoring performance, fixing any bugs that arise, providing technical support to the Puskesmas Admin and Health Office staff, and making updates or adjustments to the system based on usage evaluations and dynamic needs. This ensures the system's continued effectiveness in detecting and managing disease outbreaks.

5. Conclusion

The Disease Outbreak Monitoring System has made a significant contribution to the monitoring of diseases with potential *Kejadian Luar Biasa* (KLB) in Sleman Regency. It simplifies the collection and management of data from various *Puskesmas*, streamlining the entire process. By automating notifications based on epidemiological criteria, the system enables faster early detection of potential KLB cases, facilitating a more timely response. With its user-friendly interface, the system is easy for both Health Office and *Puskesmas* staff to learn and use effectively. Usability testing shows high satisfaction, with users appreciating the system's ease of use, flexibility, and overall effectiveness in improving disease monitoring and management processes. This ensures the system's smooth integration into daily operations. Although the system meets the primary needs, some minor improvements are still needed, such as adjustments in column naming and table display. Nevertheless, the system is expected to be a reliable solution for preventing

and controlling disease outbreaks, greatly enhancing the Health Office's preparedness and response to future KLB situations.

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