



Development of an integrated waste management information system to support sustainable development

Lanto Ningrayati Amali, Indhitya R. Padiku, Aprilia M. Hunta

Information Systems Study Program, Faculty of Engineering, Universitas Negeri Gorontalo, Indonesia

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ABSTRACT. The issue of waste in Indonesia is still a severe problem that has not been resolved, and Indonesia is included among the top 10 countries as the most significant waste producer. These problems include people throwing their consumption waste in the open or even burning it, the lack of systematization of integrated waste management to provide information on waste collection and transportation, which causes environmental pollution and hurts public health, and the lack of effective monitoring and reporting in waste management. This hampers practical evaluation, planning, and decision-making efforts in waste handling and in conducting a waste retribution or payment system by the community. This research aims to develop a web-based integrated waste management information system to support sustainable development. The system development method used is the prototype model through the stages of communication, quick planning, modeling, quick design, prototype construction, deployment delivery, and feedback. The result of this research is the availability of data and information on waste management effectively and efficiently; this system can perform adequate data collection and documentation in registering all units affiliated with waste management to record waste payment transactions. In addition, this system can assist in managing and supervising the entire waste management process efficiently.

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Corresponding Author:

Aprilia M. Hunta,

Universitas Negeri Gorontalo,

Jl. Prof. Dr. Ing. B. J. Habibie, Gorontalo, Indonesia.

Email: aprilia_s1sisfo2018@mahasiswa.ung.ac.id

INTRODUCTION

The rapid increase in population in Indonesia also increases the rate of increase in waste. According to Ardiantoro and Rohmah (2019), waste is a consequence of human activity. Along with the rise in population and economic growth, waste management for most cities still causes problems that are difficult to control. According to Law Number 18/2008, waste management is a systematic, comprehensive, and sustainable activity that includes reducing and handling waste. Waste Management (2021) states that waste management is an activity that manages waste from the beginning to disposal, including collection, transportation, treatment, and disposal, accompanied by monitoring and regulation of waste management.

According to Rofifah and Tarlani (2023), waste management can be referred to as an 'entry point' to achieve sustainable development targets, as it is a multi-sectoral issue that impacts various aspects of society and the economy. Waste management is linked to health, climate change, poverty reduction, food and resource security, and sustainable production and consumption (Wang et al., 2021; Wilson & Velis, 2015; UNEP, 2015; Sari et al., 2022). However, waste management can also be considered a 'system bottleneck' with several factors affecting it, such as population distribution and density, socioeconomic and physical environment characteristics, attitudes, behaviors, and culture in the

community (Khoiriyah, 2021; Sukma et al., 2022; Rapii, 2021). Based on Law Number 18 of 2008, managed waste consists of household waste, similar to household and specific waste. Waste that is not managed correctly will cause several negative impacts. Therefore, sustainable waste management is needed to achieve various targets and sustainable development.

Waste management is a strategic issue of sustainable development related to the development process in districts/cities in Indonesia. In the Regulation of the Minister of Home Affairs Number 33 of 2010 concerning Waste Management Guidelines article 3, there are points Local governments in reducing waste are carried out by limiting waste generation, recycling waste, and reusing waste. Waste management in Pohuwato Regency, a regency in Gorontalo Province, has been handled by the Waste Division under the Pohuwato Regency Environmental Service Office. The service area of this office covers 13 sub-districts, two urban villages, and 79 villages with a total population of 22,567 people in 2021. The service area in waste management in this region, with data on waste generation in 2021, is the daily waste generation of 58.27/ton and an annual waste generation of 21,379.07/ton (Dinas Lingkungan Hidup Kabupaten Pohuwato, 2021).

The environmental office of Pohuwato Regency has a vital role in creating a clean environment. Good waste management is needed to make a clean and healthy environment, while the waste management problem in Pohuwato Regency does not yet have a long-term solution. This waste management problem cannot be considered optimal because public awareness and participation are still lacking. Therefore, the problem is how the suitable concept can be applied in Pohuwato Regency to maximize community participation in waste management. Another problem is the lack of systematization of waste management and the absence of an integrated system to provide information on waste collection and transportation, which causes environmental pollution and hurts public health.

The problems in monitoring and reporting and the absence of an effective information system in waste management also make it difficult for the Pohuwato District Environment Office to accurately and comprehensively monitor the amount and type of waste generated. This hampers practical evaluation, planning, and decision-making efforts in waste management and conducting a waste payment system that is still carried out manually. Therefore, developing a policy tool in integrated waste management that synergizes with each other using modern technology is necessary. Information systems currently have an essential role in various government agencies, one of which is for waste management systems to make it easier, more accurate, and faster to store data automatically (Sinduningrum et al., 2021). This system must include data collection, waste retribution/payment monitoring, waste transportation, and easy reporting to make better decisions.

According to Waliyansyah and Novita (2021) and Lase et al. (2020), web-based integrated waste management information systems can produce fast, precise, and accurate web-based data information with an integrated approach method and accelerate the process of data management and information delivery effectively and efficiently. According to Badadhe and Dahiwal (2019), the need for web-based waste management applications is increasing daily due to the increasing population and lack of maintenance in waste disposal. The existence of this system can provide many benefits, including increased efficiency, reduced costs, and improved environmental sustainability (Babu et al., 2023). The environmental agency can use this system to monitor waste collection status, measure officer performance, and reduce manual processes in monitoring and reporting. Based on these problems, this research aims to develop a web-based integrated waste management information system to support sustainable development.

METHOD

This research is in Pohuwato Regency, specifically the Environmental Service, Pohuwato Regency. The method used in this research is the Prototyping model system development method. This model

is a software development model that uses an approach to create designs quickly and gradually so that they can be immediately evaluated by potential users/clients (Pressman, 2012). With this prototyping model, developers and clients can interact with each other during the process of creating a system prototype. Which consists of several stages, as can be seen in Figure 1.

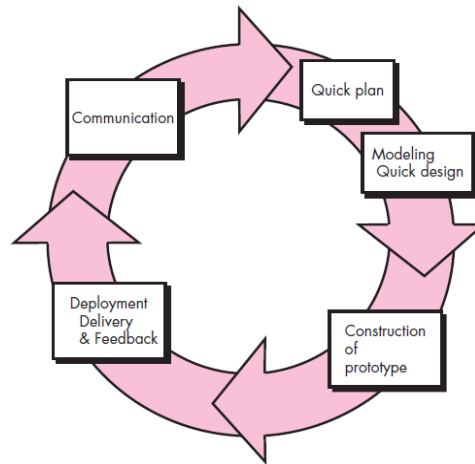


Figure 1. Prototype model (Pressman, 2012)

The stages of the prototype model are described as follows:

1. Communication

It starts with communication with the Pohuwato Regency Environmental Service as a stakeholder to determine the overall purpose of the software, identify any requirements or needs related to the system, outline areas that require further definition, and look at ongoing business processes. Direct interviews with the Head of the field and the Head of the Subdivision of Waste Management, Hazardous Waste, and Capacity Building were carried out at this stage.

2. Quick Plan

When the goals and functions are well-defined, this stage will produce data related to the user's wishes when making the application. This stage is carried out by collecting information from respondents to identify needs and determine the overall software for the application to be designed and conducting literature studies related to similar research. Furthermore, the collection of needs is made in the form of a system design design with system modeling to the design of the system interface. This stage helps provide an overview of what can be seen by the user. This quick design includes context diagrams, external entities, level diagrams, and database design.

3. Modelling Quick Design

Make a general design by making a temporary design centered on user presentation. This stage uses the results of the previous stage, namely the quick design stage, in making a system that has been agreed upon by the developer, the Environmental Service, and other stakeholders according to their wishes and needs.

4. Construction of Prototype

Prototype development is based on the previous stages. This stage was carried out by conducting meetings and limited FGDs with the Pohuwato District Environmental Service, especially in the fields of Management, Waste, Hazardous Waste, and Capacity Building. Stakeholders can provide suggestions and input on deficiencies in the system design. The results of this meeting were evaluated, and improvements were made to the system that had been made before so that the system could match the wishes and needs of users.

5. Deployment Delivery and Feedback

The stage where the prototype has been completed and the user will be seen checking the prototype that has been built, as well as submitting suggestions and shortcomings to the prototype. Then, an evaluation is carried out based on the suggestions given by the user.

RESULTS AND DISCUSSIONS

This research produces a web-based integrated waste management information system at the Pohuwato Regency Environmental Service. This web-based integrated waste management information system has benefits and conveniences in managing data and information and explaining how to use it for users. The application runs well according to user needs by providing information on waste reports, transportation routes, retribution/payment data, etc.

Communication

The communication stage is the process of collecting data based on system requirements analysis, divided into two parts, namely functional and non-functional requirements analysis.

Functional Needs

The web-based integrated waste management information system has four user entities: Village Admin, P3B3K Field Admin (Management, Waste, B3, and Capacity Building), Waste Collection Officers, and the Community. Each user has the following functional requirements:

- a. The Village Admin enters the data of the people who are (Customers) and the waste retribution/payment data.
- b. The P3B3K Field Office Admin enters Village data, waste type data, vehicle data, transportation schedule data, achievement data, waste retribution reports, and achievement data reports.
- c. Officers/drivers can receive information on waste transportation schedules according to the predetermined route.
- d. Customers (community) can perform the waste retribution/payment process on waste transportation according to the route in the village.

Non-functional needs

At this stage, non-functional requirements are included in the system requirements specification. Requirements specifications involve hardware/hardware analysis, software/software analysis, and user/user analysis. The hardware and software requirements needed to implement a web-based integrated waste management information system are sufficient to implement the application to be built. The users include Village Admins, P3B3K Field Admins (Management, Waste, B3, and Capacity Building), Waste Transport Officers / Drivers, and the Community.

User Characteristics

Users of this system are divided into two categories: administrators and ordinary users. This grouping is done based on each user's access rights and responsibilities to the system. The difference between administrators and ordinary users lies in the access rights to the system. Administrators have the authority to manipulate data, while general users can only view information the system presents.

Quick Design Planning

At this stage, it is the beginning of the design and visualization of the system to be designed. The design of the information system includes a Data Flow Diagram (DFD) consisting of an external entity, context diagram, data flow diagram, database design, and relationships between tables. As is known in waste management at the Pohuwato Regency Environmental Service, the current system is still not integrated with the application system. Based on the analysis of the old system, a new system

can be proposed to simplify and speed up the process of managing, processing, and providing information to be more effective and efficient, as shown in Figure 2. Figure 3 explains the Context Diagram to describe the flow of processes in the designed system. In this system, four entities play a role in the designed system: Village, P3B3K, Officers / Drivers, and Customers. The level 0 data flow diagram, as in Figure 4, consists of 3 system flows that describe the general system flow, namely the data input required by the system, the transactions that occur after data input is carried out, and the output of processed data in the system.

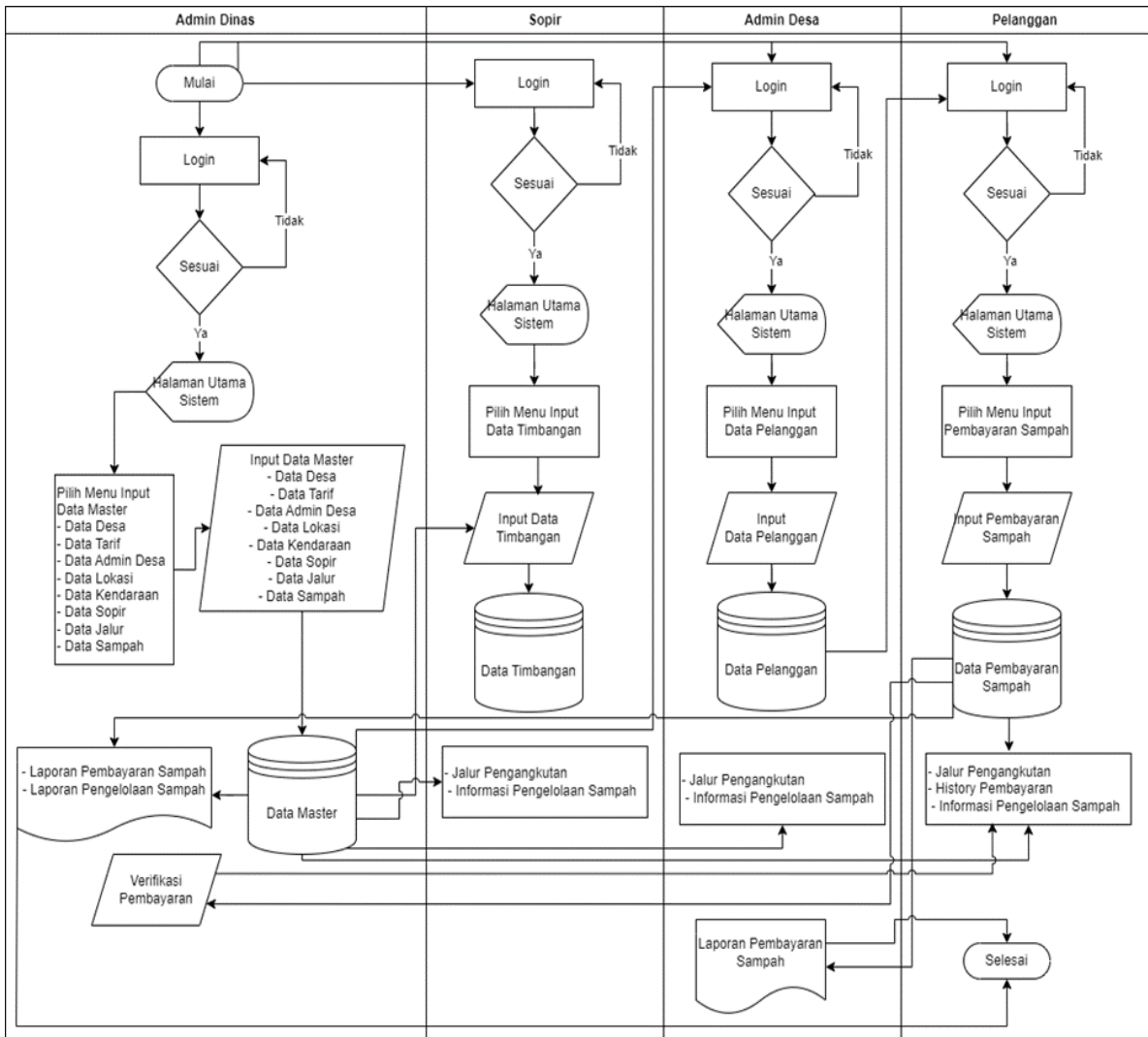


Figure 2. Flowchart system

The database planning and design process was developed as a Relational Data Model. Database table relations are relations that occur in a table with others that function to organize the operation of a database, as described in Figure 5.

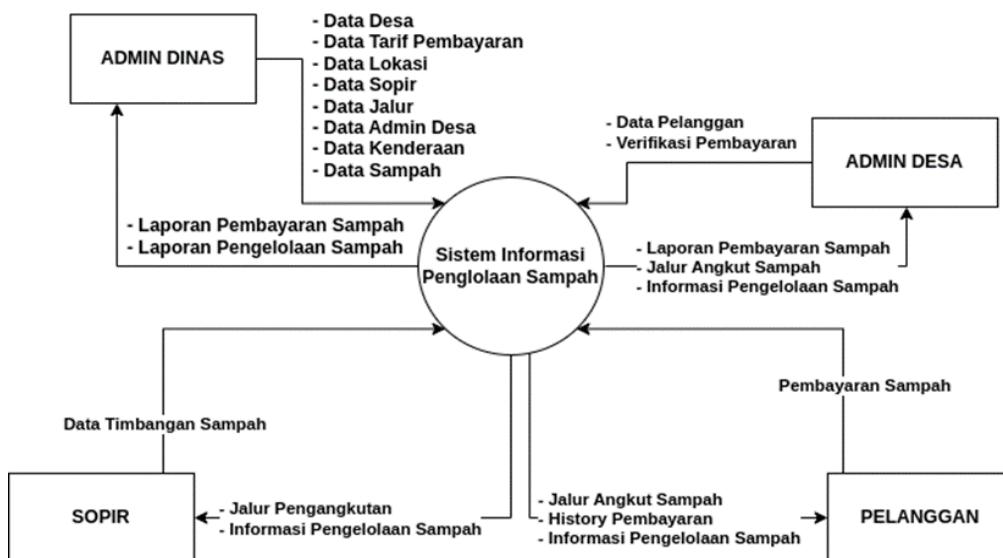


Figure 3. Information system context diagram

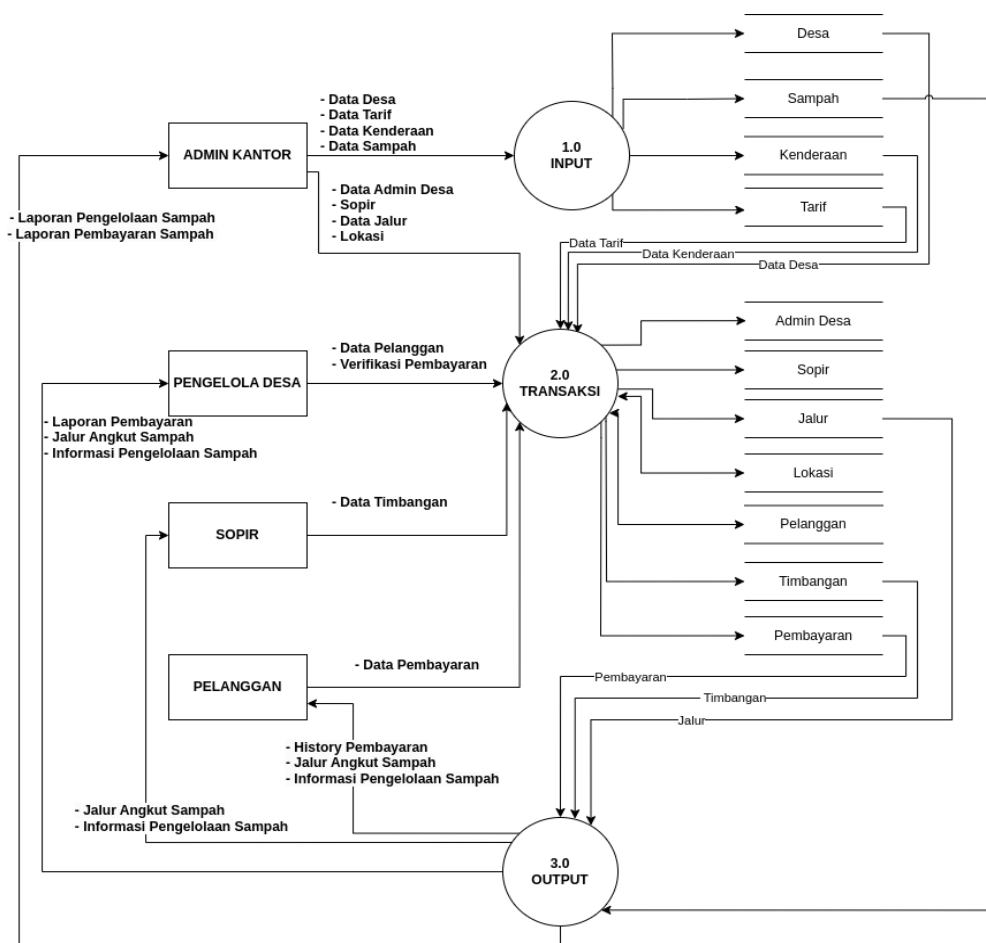


Figure 4. Level 0 data flow diagram

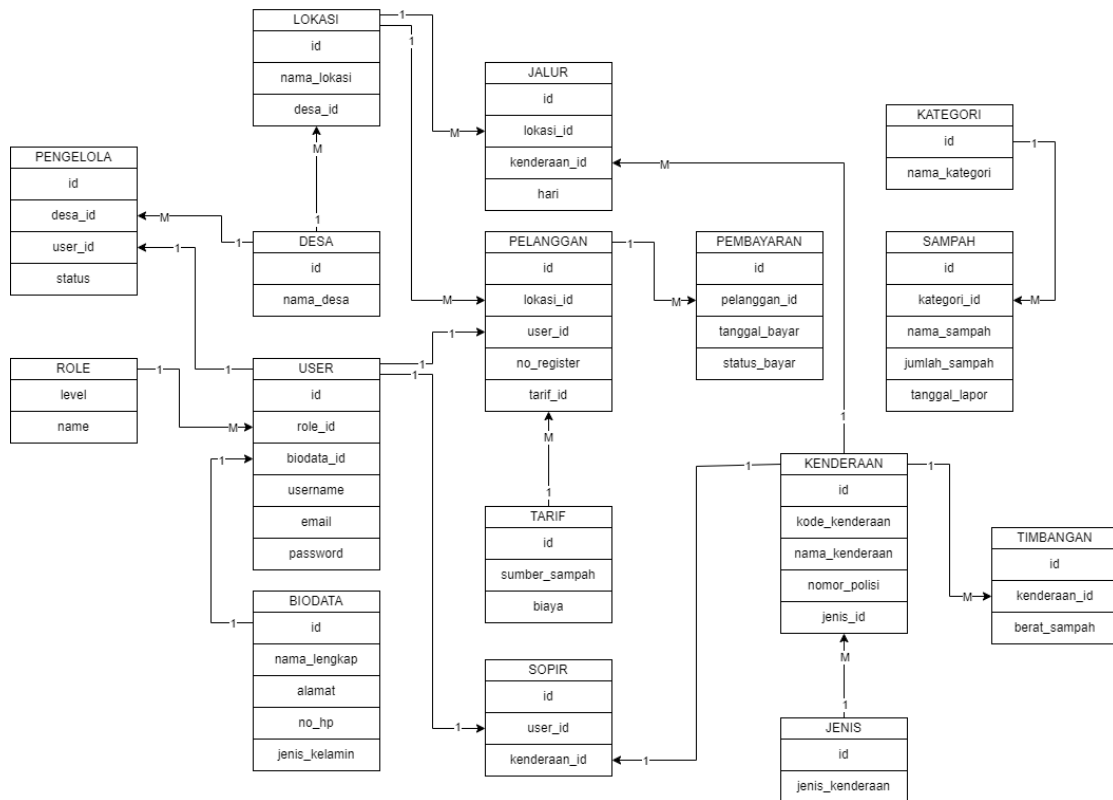


Figure 5. Database design

Modeling Quick Desain

General design by making a temporary design centered on presentation to users using the Prototype interface application, Figma. This design serves to provide convenience to users when operating the system. This design is divided into the home and administrator interface pages. Example Figure 6 shows the waste data page display to provide users with an informative and easy-to-use interface that displays waste-related data, such as the amount of waste collected, the type of waste, and the location of waste collection.

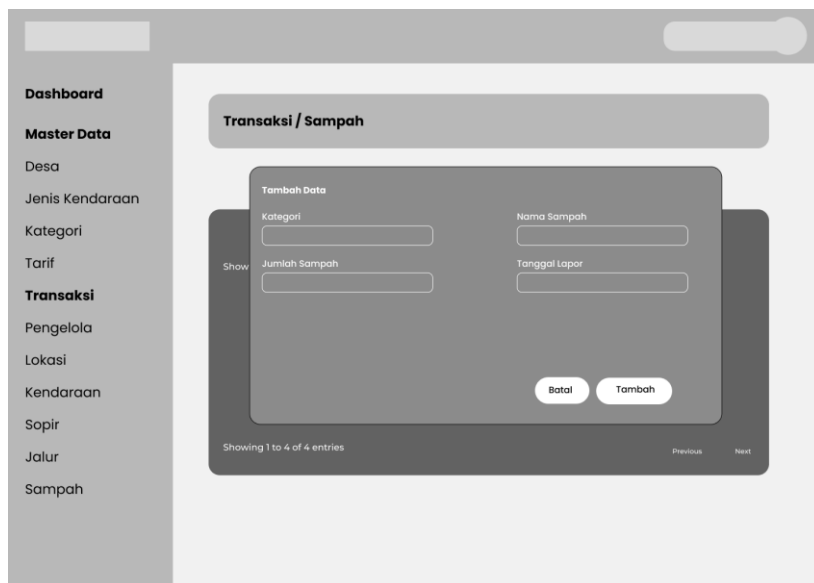


Figure 6. Junk data page design

Construction of Prototype

At this stage, the quick design that has been made before will be made as a prototype in the PHP (Hypertext Preprocessor) programming language and MySQL as a database processor so that the desired results can be seen. Figure 7 shows the appearance of the main page as the initial display of the first-time access.



Figure 7. Main page display

Figure 8. displays a page addressed to the public as a service line page display; this display contains information on the type of vehicle that matches the schedule with the day of operation on the service line. Figure 9 shows the page where you can view the waste retribution/payment report.

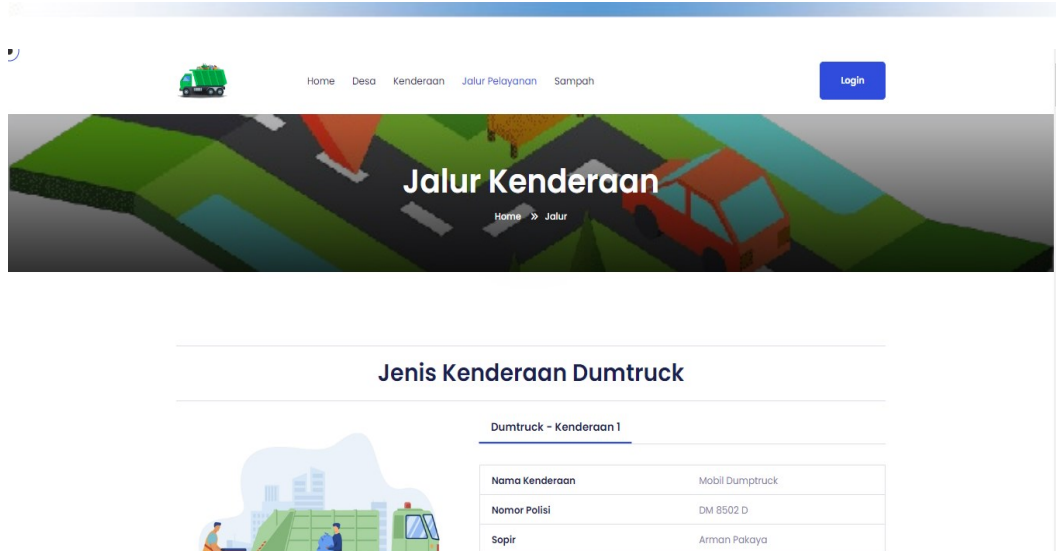


Figure 8. Service path page view

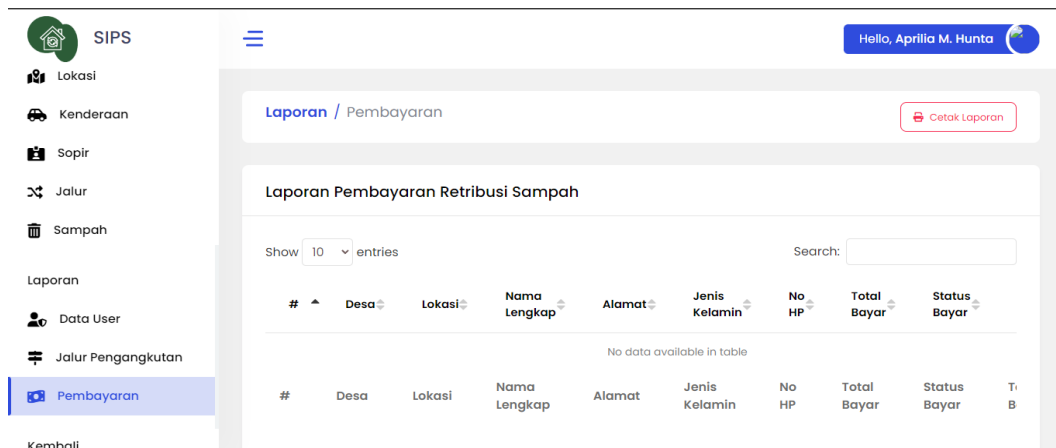


Figure 9. Garbage levy report

Deployment Delivery and Feedback

This stage of system testing is carried out to discover errors that occur in the system so that it can be seen whether the system that has been built is functioning correctly. Tests were carried out using black-and-white testing methods. Table 1 shows black box testing on the garbage rates page for white box testing by testing the source code on the system created.

Table 1. Blackbox junk rates page

Test Results Cases			
Input Data	Expected results	Observation	Conclusion
Select a button Add Waste Rates	Display the Add form Garbage Rates	Display formAdd Garbage Rates	Appropriate
Enter Garbage Tariff Data	Data successfully saved and View data messages Successfully saved	Stored data and Data saved successfully appears	Appropriate
Select the edit button Garbage Rates	Display waste rate edit form	Show form edit trash rate	Appropriate

Test Results Cases			
Input Data	Expected results	Observation	Conclusion
Changing data Village	The data was successfully changed and displayed a data message Successfully modified	Data changed, and a message appears that the data was successfully changed.	Appropriate
Select the remove button Garbage Rates	The data was successfully deleted and display data successfully deleted	Data deleted, and the data message appears successfully deleted	Appropriate

Figure 10 shows the flowgraph of the waste data deposit, which results from testing for a method called waste data deposit. This method displays the waste data deposit page by filtering based on access rights.

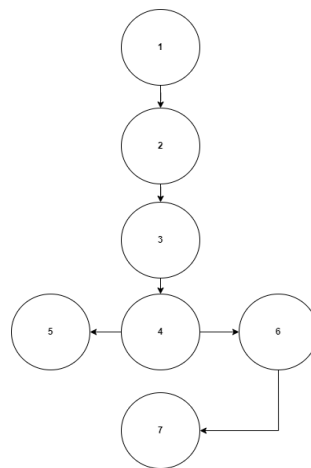


Figure 10. Data deposit flowgraph

Cyclomatic Complexity is used to measure a quantitative measure of the logical complexity of a program. The results of this measurement can determine whether a program is simple or complex based on the logic applied to the program. After entering the formula $V(G) = \text{Edge (line)} - \text{Nodes (point)} + 2 = (6 - 7) + 2 = 1$, the results show that the algorithm logic of the location method works as expected. The number 1 from the cyclomatic complexity calculation results shows the number of independent paths from the path testing base, which shows the number of tests that must be run to ensure all statements in the program are executed once.

The system evaluation with the System Usability Scale (SUS) Score approach, carried out on 15 respondents, showed a value of 80, which was classified as a system in very good qualification with a grade of B. The evaluation was used as a benchmark to measure the product's usability. It also shows a global product assessment from the aspects of effectiveness, efficiency, and satisfaction subjectively felt by users, as well as the success rate of the assessment, namely with grade ranking of SUS scores and percentile ranking of SUS scores.

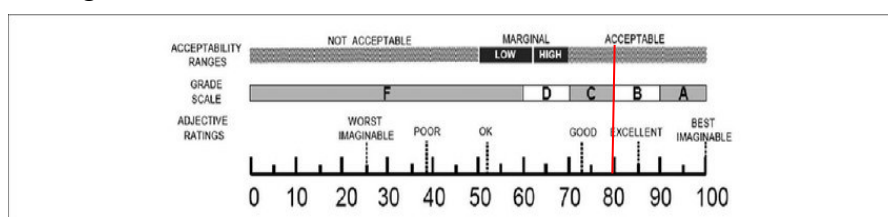


Figure 11. Grade ranking of SUS scores

Figure 11 is the Grade ranking of SUS scores. According to Bangor et al. (2009), it is the determination of acceptability, grade scale, and adjective rating to see the extent of the user's perspective on a Web-based integrated waste management information system. From the assessment given by the respondents, the assessment results of the web-based integrated waste management information system are the level of user acceptance in the acceptable category, the level of scale grade in the B category, and the objective rating in the Excellent category. It can be concluded that this information system can be used easily by users.

CONCLUSION

The web-based integrated waste management information system at the Pohuwato Regency Environmental Service. Developed offers an effective solution for monitoring and reporting information on waste reports, transportation routes, and retribution/payment data. It was based on system testing using three tests: black box testing, white box testing, and user acceptance testing. In black box testing, the percentage reached 100%, and 0% failed; in white box testing, no error detection was obtained in the program code, while the complexity in the program code was 1, and in user acceptance, test testing resulted in a percentage of 80%. User acceptance tests are used to measure the usefulness of the product made. This information system has benefits and conveniences in managing and using user data. The system testing results show that this system is feasible to use.

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