Digital Innovation in Waste Management: Designing an E-Waste Prototype as a Solution to Optimize Waste Management in Gorontalo City

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Abstract— **Gorontalo City is the largest contributor of waste in Gorontalo Province. Waste production in Gorontalo City increases to 140 tonnes per day based on data from the National Waste Management Information System. One of the things that caused the waste problem in Gorontalo to become more severe is the difficulty in transporting waste due to the limited transport fleet. Furthermore, the Waste Management Reuse, Reduce, and Recycle (TPS3R) personnel in several sub-districts are no longer functioning. This article details the emergence of innovative waste management applications, providing a new paradigm for cities to become digitally connected hygiene centers. The app not only revolutionizes the way waste is perceived but also offers smart solutions to optimize waste management efficiently. With a modern and progressive approach, the app creates an interactive experience for the people of Gorontalo to manage their waste. Through smart center and route mapping features, the app empowers citizens to actively contribute to keeping the city clean. In addition, the integrated information system enables quick and informed decision-making for authorities, creating responsive and effective waste management. The research conclusion confirms that the design of E-Sampah with a focus on the centre point and route of waste collection by waste officers can provide a modern and accessible solution for the people of Gorontalo. The results of the System Usability Scale (SUS) assessment with a score of 80.5 indicate that this waste management information system received a positive response from users. This prototype is expected to change mindsets and shape behaviors that support sustainable waste management.**

Keywords *: Digital innovation, waste management, prototype design, mapping*

I.   INTRODUCTION

Garbage is waste produced by households or industry during people's daily activities [1]. Garbage is also waste produced by human activities which can have an impact on the environment [2]. Waste is one of the serious problems faced by many communities throughout the world in this century. Deputy Secretary for Mental Revolution, Cultural Advancement, and Sports Achievement Gatot revealed that SIPSN data from the Ministry of Environment and Forestry (KLHK) in 2022 shows that in 202 districts/cities throughout Indonesia, the amount of national waste stockpiles reached 21.1 million tons. Of the total waste production, 65.71% (13.9 million tons) can be managed well, while the remaining 34.29% (7.2 million tons) has not been managed well [3]. In fact, according to 2023 KLHK data published in the online media cnbcindonesia.com, Indonesia produced around 19.45 million tons of waste at the end of 2022 [4]. The amount of waste produced in Indonesia increases every year as a result of rapid population growth, urbanization, and increased consumption [5]. Rapid population growth, rapid urbanization, and significantly increased consumption patterns have led to an increase in the amount of waste produced by society, both in urban and rural areas. This problem is becoming increasingly urgent due to its negative impact on the environment, public health, and the economy.

In fact, waste has become a problem in several cities in Indonesia, such as the capital city of Jakarta, Bandung, Yogyakarta, and several other cities [4]. Likewise, in the city of Gorontalo, waste is still one of the main problems that must be resolved. Based on information published in the Gorontalo Tribune media, the volume of waste in 2021 will reach 35,197 tons [6]. This volume was obtained from several locations, namely Gorontalo City, Gorontalo Regency, Bone Bolango Regency, Gorontalo Regional Police, Bank Indonesia, Lupoyo Village, and Tenggela Housing. Gorontalo City is the largest waste contributor in Gorontalo Province. Waste production in Gorontalo City has increased to 140 tons per day based on data from the National Waste Management Information System [7]. Several things that cause the waste problem in Gorontalo to become increasingly serious are that DLH has difficulty transporting waste due to limited transport fleets. Then the staff at the Reuse, Reduce and Recycle Waste Management (TPS3R) sites in several sub-districts no longer function. Gorontalo City DLH data (2023) shows that the volume of waste entering the Talumelito landfill in the last 5 years has an average growth rate of -5% per year with the average volume of waste entering the Talumelito landfill in the last 5 years being ±69 tons/year. In 2022, the volume of waste disposed of in landfill will be 21,845 tons. Even though

in 2022 the volume of waste will decrease, the data does not contain data for November and December.

A waste management information system is an alternative solution for managing or managing the waste conditions of an area. As done by Suryani et al (2022) [8] built a Sorong Raya waste bank management information system that was integrated into the management of each division to help business and operational processes run effectively. The results of system testing show that the system built is appropriate. Then Arianto an Dedy (2018) [2] also created an Android-based waste bank information system. Baharuddin et al (2022) [9] built a circular-based waste management application, and after testing using the Usability Scale method, the application received a score of 85.75% which indicates that the usability of this application is categorized as good.

Departing from the phenomenon mentioned above, research on waste management in the city of Gorontalo is very important. With today's technological advances, implementing a waste management information system has become more possible and efficient. Technology such as smart sensors, data analysis, and mobile applications can be used to monitor and manage waste more effectively.

II. RESEARCH METHODS

1. Research Stages

Research on the design of a prototype of the waste management information system for the city of Gorontalo involves several important stages to ensure the success and effectiveness of its implementation. The following are the general stages in this research:
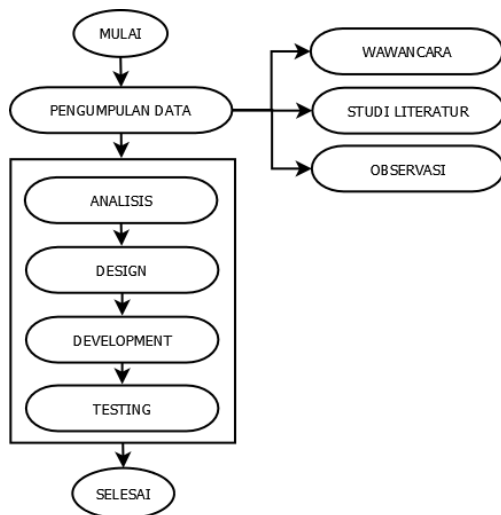

Figure 1. Research Stages

Data collection:
- **Interview:** The initial stage involves interviews with related parties at the Environmental Service, related institutions, and other stakeholders. This interview aims to gain an in-depth understanding of the waste problem in Gorontalo City and identify key needs.
- **Study of literature:** Involves an in-depth literature review regarding recent innovations in waste management and applications of information technology in similar contexts. The literature review helps us understand existing conceptual frameworks and identifies gaps that can be filled by this research.
- **Observation:** Direct observations were made in the field to understand the real situation of waste in Gorontalo City. This observation includes the waste collection process, waste distribution, and existing infrastructure.

Stakeholder Needs Analysis:
With the collected data, an analysis of stakeholder needs is carried out. This involves an in-depth understanding of the perspectives of the diverse parties involved in waste management, including local governments, communities, and the industrial sector.

Prototype Design:
Based on the results of the needs analysis, a prototype design was carried out using the Use Case method and Context Diagram. Use cases are used to detail the main functions of an application, while context diagrams help visualize the interactions between the application and its external environment.

Development of Prototype using Figma:
Figma, as a web-based design tool, was chosen for prototype development. The platform enables real-time team collaboration, making it easy to test application functionality and aesthetics.

Trials :
The author applies a data analysis method using the System Usability Scale (SUS). The score calculation procedure on the SUS follows special rules: for questions with odd numbers, the score given on the questionnaire is reduced by 1, while for questions with even numbers, the score is reduced by 5. The total scores from all questions are added up and the result is multiplied by a factor of 2.5. The range of questionnaire scores ranges from 0 to 100. The average SUS score is 68, and a score above 68 indicates a level of satisfaction.

Through these stages, this research not only seeks to develop innovative solutions for waste management in

Gorontalo City, but also ensures that each methodological step is based on a strong understanding of the local context and the needs of local communities.

III.   RESULTS AND ANALYSIS

Gorontalo City Community Perceptions Regarding Waste Conditions in Gorontalo City

Before designing a waste information system prototype. Researchers first conducted research on the perceptions of the people of Gorontalo City regarding the waste conditions in Gorontalo City.
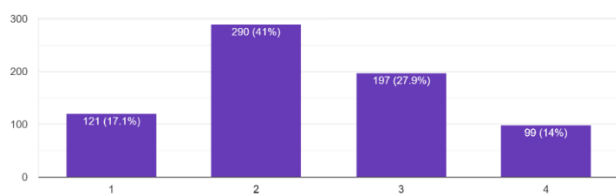
Figure 2. Gorontalo City Community Understanding of Waste Management
(Source: Researcher Observation Primary Data, 2023).

Figure 2 shows data that the majority of Gorontalotalo City residents do not understand education about the importance of good waste management. This is proven by around 700 respondents who live in Gorontalo City who filled out the questionnaire, as many as 41% or 290 people thought that they did not understand.
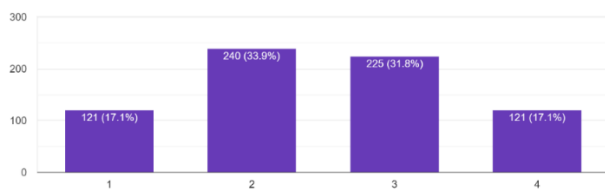

Figure 3. Gorontalo City Community Response Regarding Waste Management Practices
(Source: Primary Data Observations of Researchers, 2023)

Figure 3. Shows data regarding the perceptions of the Gorontalo City community regarding local waste management practices. The majority of people think they are not familiar with waste management practices.
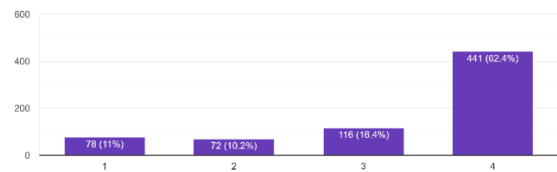

Figure 4. Gorontalo City Community Response Regarding the Importance of Waste Management
(Source: Primary Data Observations of Researchers, 2023)

The interesting thing is that even though most people do not understand waste management practices, in fact, the majority of Gorontalo City people think that good waste management is important. As seen in Figure 4.

Despite a lack of understanding and unfamiliarity with current waste management practices, the majority of people realize that good waste management is important. From this, we can conclude that there is a desire and awareness to move towards positive change.

The solution of designing an E-Waste prototype is the right step to respond to this dynamic. With technology that makes it easier to access information, interactions with the waste management process can become more transparent and actively involve the community. E-waste can be a solution that not only provides education but also empowers the community to actively participate in efforts to better waste management.

Gorontalo City E-Waste Application Prototype Construction

The solution offered based on current conditions is the need for a system that regulates or manages waste. This system regulates and informs the public regarding the main point (center point) of waste disposal at each location or residential environment. So at each residential location, there is a central waste disposal point. So every community in the environment is obliged to dispose of waste according to their center points. Next, the system regulates the waste transportation route by the fleet based on center points. This feature can also be used as a route guide using the GMAPS system by the public. This system is also equipped with a report button, residential residents have the opportunity to report to the local department if the waste at the center point has not been transported by a certain time. Through the Gorontalo City Waste Management Information System, the hope is that it can become a tool for the community and government in dealing with waste problems in Gorontalo City.

Based on the results of the researchers' needs analysis and initial research. So the next step is to design a prototype of the E-Waste application for Gorontalo City with the following design:
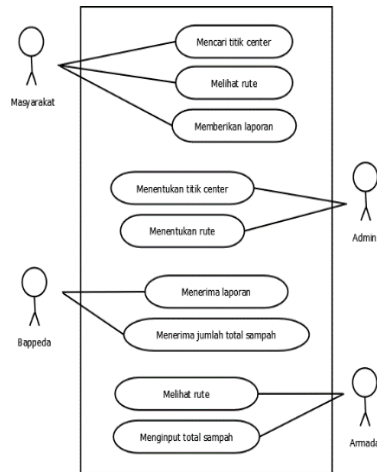

Figure 5. Waste management application prototype use case design

The use case diagram illustrates the actors involved and how they interact with the E-Waste application through certain features. In the assignment feature that will be designed, there are four main actors, namely the community, admin, fleet, and Bappeda.

Table 1. Description of the function of each actor in E-Waste

Actor	Function
Public	• Search for Center Points: The public can search for the location of the nearest center point to facilitate waste management in the surrounding area. • Viewing Routes: The public can see the routes that the waste collection fleet will take. • Providing Delay Reports: The public can provide reports if there are delays in transporting waste in their area.
Admin	• Inputting Center Point Locations: Admin can enter or manage information regarding the location of center points which are used as a reference for transporting waste. • Inputting Routes from Each Fleet: Admin has the right to enter or manage route data to be taken by each waste transport fleet.
Bappeda	• Receiving Reports from the Community: Bappeda can receive reports from the community regarding conditions or problems around the center point. • Capitulation of the Total Waste Transported: Bappeda has the right to access and calculate the total amount of waste transported every day from the reports received.
Fleet	• View Routes: Fleets can view the routes determined by the admin to find out the optimal transportation route. • Entering Total Waste: Fleets can enter information regarding the total waste transported on each route.

Each actor has their own role and function in the E-Waste application ecosystem, ensuring effective collaboration and better waste management in society. After knowing each role of each actor in the E-Waste application, the next stage is designing the appearance of the E-Waste.
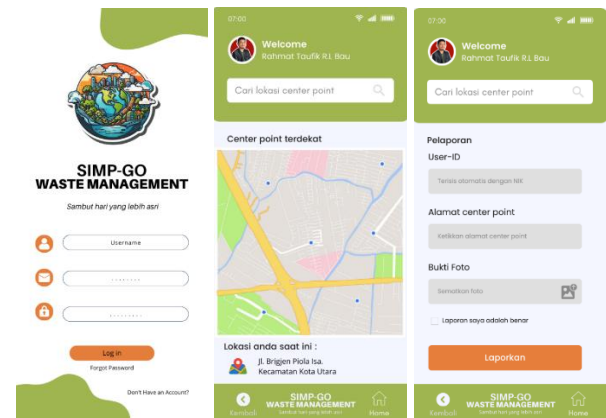

Figure 6. End-user view design (Community)

The E-Waste interface is designed to be simple yet effective to ensure an intuitive user experience. First, users are asked to log in, creating secure access before starting. After logging in, users are greeted with a clear and structured display.

The center point location service which is integrated with GMAPS makes it easy to find information on nearby center points. With a familiar map, users can clearly see the route to the center point, providing a visual experience that is easy to understand.

The report feature makes it easy to provide input. Users can quickly report delays in waste transportation in their area, contributing directly to monitoring the situation in the field.
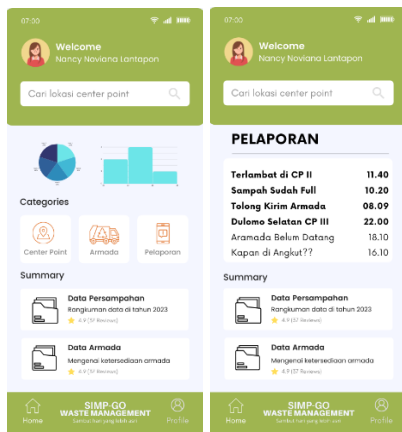
Figure 6. End-user display design (Bappeda)

After logging in, Bappeda is directed to an intuitive dashboard, providing a holistic view of reports received from the public. Simple graphs and statistics provide a quick understanding of the state of waste management in various areas of Gorontalo City.

A simple navigation menu guides Bappeda to explore the report in more detail. They can easily access incoming reports, check the details, and see trends in waste transportation delays over time.

The recapitulation feature of the amount of waste transported is presented clearly, providing a comprehensive view of waste management performance at the city level. This information can help Bappeda make better decisions to increase the efficiency and effectiveness of waste management.

Gorontalo City E-Waste Application Prototype Assessment Results

There were 10 respondents in this assessment, using random sampling of the four actors involved in this application. Here are the results:

Table 2. Respondent assessment results

Respondent	Results	Score
1	33	82.5
2	33	82.5
3	32	80
4	34	85
5	31	77.5
6	31	77.5
7	32	80
8	32	80
9	32	80
10	32	80
Total		80.5

Next, we calculated the average value of the respondents' ratings. From 10 respondents, we collected a total score of 805 and then divided it by 10, resulting in an average score of 80.5. After getting these

results, the next step is to determine the grade based on assessment, using acceptability criteria, grade scale, and adjective rating.

Determination of acceptability, grade scale, and adjective rating was carried out to assess the extent of the user's perspective on the E-Waste application prototype. There are three categories(Amini & Purwani, 2020), namely not acceptable, marginal, and acceptable. In terms of scale grade levels, there are six scales: A, B, C, D, E, and F. Adjective ratings consist of worst imaginable, poor, ok, good, excellent, and best imaginable.
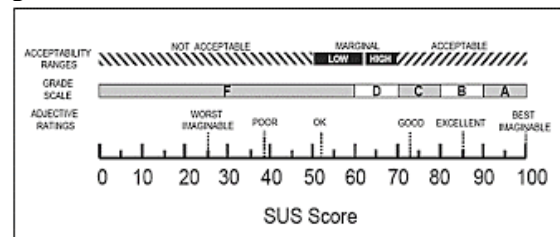

Figure 7. Grading acceptability, grade scale, and ejective rating

To determine acceptability, grade scale, and adjective rating, we compared the results of the respondents' average rating of 80.5. Therefore, based on the assessments given by respondents, the results of the assessment of the E-Waste application prototype can be described as follows:

- The level of acceptance for use is in the acceptable category.
- The scale grade level is in category B.
- The adjective rating is in the good-excellent category.

IV. CONCLUSION

By utilizing technology, E-Waste design can provide a more modern and easily accessible solution for the people of Gorontalo City. Through this prototype, it is hoped that there will be a shift in mindset and the formation of behavior that supports sustainable waste management. This is a progressive step that we can take to achieve a balance between understanding, awareness, and concrete action in keeping Gorontalo City clean towards a cleaner and more sustainable future. Research has shown that designing a waste management information system that focuses on center points and waste collection routes by waste officers can facilitate community participation. This shows that an information system that functions to regulate looting in Gorontalo City is very important for the community as shown by the SUS assessment results with a score of 80.5. This prototype is expected to change mindsets and shape behaviours that support sustainable waste management.

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