

Development of Waste Management Application using GIS

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Abstract

Waste management is a serious challenge in modern society due to rapid population growth and urbanization. The inefficiency of conventional systems such as limited coordination, infrastructure, and reporting calls for a technology-based approach. This study develops a web-based waste management application integrated with Geographic Information System (GIS) to improve waste collection, monitoring, and reporting. The development method used is prototyping, allowing iterative improvement based on user feedback. The application includes key features such as waste bin location data entry, interactive map visualization with Leaflet.js, and transaction reporting. The result showed that the app is able to provide real-time visualization of waste bin locations, display waste statistics, and improve the transparency and efficiency of waste management operations. This research contributes to the development of environmental information systems that support data-driven decision-making and environmental conservation.

Keywords: Waste management, GIS, web applications, environmental information systems, prototyping

1 Introduction

Waste management is one of the main challenges in modern society, especially with the increasing population and urbanization, which causes a surge in waste volume. With rapid population growth, industrialization, and urbanization, waste management problems are becoming more complex without a suitable management system. The inability to manage waste efficiently can cause long-term environmental impacts such as soil and water pollution and an increased spread of waste-based diseases [1]. Based on data from the World Bank, in 2022, the world produced around 2.24 billion tons of municipal solid waste, with this number projected to increase to 3.4 billion tons by 2050 [2]. According to the Ministry of Environment and Forestry (KLHK), national waste production reaches 67.8 million tons per year, of which 40% is not managed properly [3]. This uncontrolled waste accumulation triggers various problems, such as air and water pollution, the spread of disease, and ecosystem damage [4]. Additionally, waste management in developing countries tends to be reactive and unintegrated, resulting in high operational costs and low efficiency. The use of data-based and technology-based approaches is becoming increasingly crucial. Geographic Information System (GIS)-based technology has been proven to be able to support strategic decision-making in urban waste management spatially and in real-time [5]. Waste management efforts must be more efficient and integrated to minimize negative impacts.

Conventional waste management systems often face a number of obstacles, such as limited human resources, a lack of coordination between stakeholders, and limited transportation and infrastructure. These conditions result in suboptimal waste collection, transportation, and processing processes. On the other hand, advances in digital technology have opened up opportunities to overcome these challenges. Internet of Things (IoT)-based technologies, Geographic Information Systems (GIS), and web-based applications are now widely used to support various processes in resource management, including waste management [6]. A more efficient waste management system requires the use of technology to optimize the process. One solution is the development of web-based applications that can help manage waste in a more structured manner [7].

The web-based waste management application developed in this study offers an integrated solution utilizing modern technology. Key features include GIS-based waste bin location search, waste transaction management, and data visualization in the form of interactive graphs and maps. The

application also provides an intuitive interface to make it easy for users to add, update, and manage data related to waste bin locations, waste types, and transportation routes to final waste disposal sites. Furthermore, filtering and reporting features provide analytical insights that support data-driven decision-making. Previous research has demonstrated the effectiveness of web-based applications in improving waste management efficiency.

With this application, it is hoped that waste management can be more organized and efficient, and have a positive impact on the environment and society. This research not only provides a practical solution but also contributes to environmental conservation efforts and the development of more effective waste management policies.

2 Literature Review

GIS technology has been widely adopted in waste management to improve efficiency and simplify processes, such as identifying the nearest landfill, determining optimal routes, and locating strategic waste receptacles. This can reduce waste management costs and provide the best service to the public [8]. One example is the Zerowaster application, developed by (2021). This application uses mobile GIS to provide environmentally friendly location information and helps users identify waste-free areas, although this study has not explicitly demonstrated the impact of its implementation [9]. Ahmad et al. (2022) developed an IoT-based smart waste bin that is capable of transmitting real-time waste capacity data to a central system, increasing waste collection efficiency [10].

Furthermore, the implementation of a technology-based waste management system at the IIB Darmajaya has been successful in simplifying waste bank management. This system enables automated data management, generates reports, and supports waste pickup with Google Maps integration [11]. Additionally, other research has shown that GIS and web applications can provide effective spatial visualizations of waste collection routes and disposal points in smart cities [12]. The TrashOut application provides an innovative method of tackling the problem of illegal waste disposal globally. This application allows users to report illegal waste disposal locations through an interactive map, which can be accessed by government and non-governmental organizations for further action [16]. Research conducted by Zhang et al. (2020) shows that the integration of web technology with GIS, such as through the Urban Waste Management System, can improve the efficiency of urban waste management. This system utilizes Django for data management and Leaflet for interactive map visualization, which significantly helps in real-time monitoring of waste locations.

This research emphasizes the importance of spatial data-based technology to optimize resource management and reduce the negative impacts of waste in urban areas [13]. GIS and remote sensing (RS) technology have been used to optimize waste collection routes, select waste disposal sites, and analyze the composition and stability of final disposal sites. The use of this technology provides benefits in operational efficiency and environmental conservation [14]. Another study demonstrated that integrated technologies such as GIS, GPS, and RS were used to implement the Integrated Solid Waste Management (ISWM) concept for sustainable waste disposal. This study emphasized the importance of waste management with an integrated approach, including location-based waste collection, processing, and disposal [6].

3 Research Method

This research uses a software development method, namely prototyping. This method allows researchers to develop applications iteratively based on user feedback until an optimal version is achieved [15]. This study used the prototyping method as follows Figure 1.

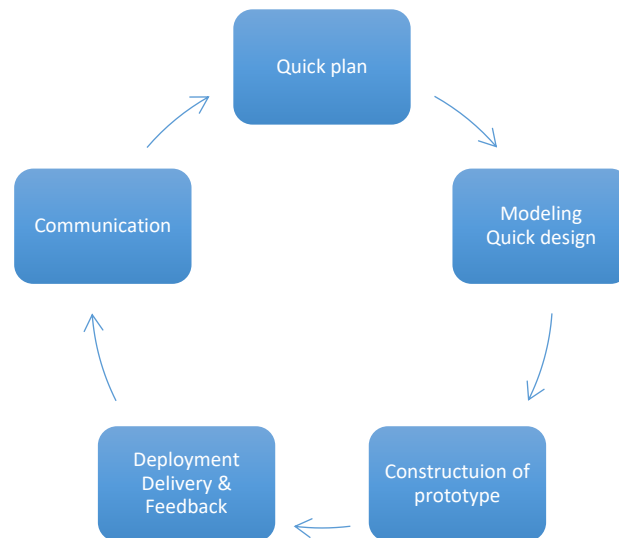


Figure 1 Prototyping method

1. **Communication**
This stage involves gathering requirements from users and other parties involved in waste management. The main activities in this stage are identifying needs, understanding the problem, and documenting the needs.
2. **Quick Plan**
This stage involves initial planning to determine the scope and priorities of development.
3. **Modeling Quick Design**
This stage produces a preliminary system design that will be visualized to users. Business processes and use case diagrams are developed, and the initial design is evaluated to ensure it meets user needs.
4. **Construction of Prototype**
Next, a prototype will be developed to be tested by users after the initial design has been completed.
5. **Development, Delivery dan Feedback**
This final stage involves testing the prototype by users and refining the system based on feedback provided by users.

4 Results and Discussion

Reffering to the stages in Figure 1, the results of this study are explained sequentially according to the prototyping process.

1. Communication

The initial phase of the project involved discussions with operators and environmental managers. The main needs identified included (a) a waste bin data management system, including location, capacity, and waste category; (b) an interactive map-based visualization feature for waste bin locations; and (c) an automated reporting system for waste transactions. This phase revealed that the main challenges in waste management were the difficulty in monitoring waste bin locations in real time and the lack of structured reports.

2. Quick Plan

The next step was to determine the main modules. Based on the needs analysis obtained from the communication phase, there were three main modules: (a) waste bin data recording, (b) interactive map visualization using Leaflet.js, and (c) waste transaction reporting. This planning ensured a focus on developing key features that have a direct impact on operational efficiency. Due to the need to monitor waste locations geographically, a web-based GIS was selected for map visualization.

3. Modeling Quick Design

At this stage, an initial system design was produced, including the use case diagram in Figure 2, which illustrates the interaction between three main actors.

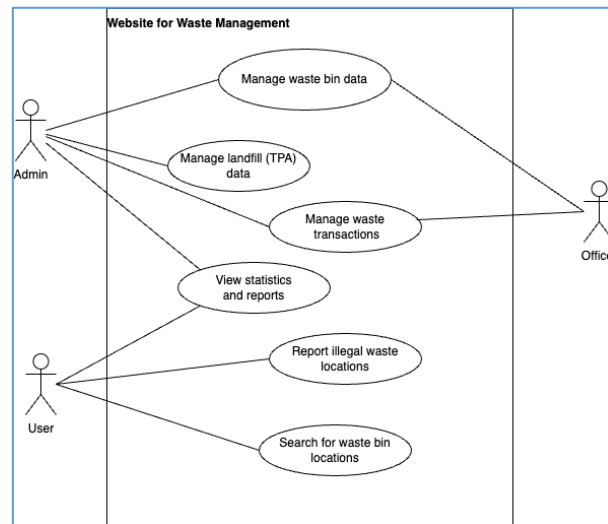


Figure 2 Use case diagram

There are three main actors in this system: Admin, Officer, and User, each with specific access rights and functions. The admin functions as the main system manager with authority over bin data, landfills, transactions, and reports. Officers have an operational role in the system, which includes managing waste transactions and accessing waste bin data. Meanwhile, users have access to features for reporting illegal waste locations, searching for waste bin locations, and visualizing statistics and reports. This use case diagram illustrates how information technology can support efficiency, transparency, and public participation in waste management.

4. Construction of Prototype

After completing the quick design modeling stage, the next stage is prototype development for the waste management website. The following is a display of the GIS-based waste management website.

a) Initial display of dashboard menu

The dashboard displays (Figure 3) information on total waste bins, total landfills, waste weight, and statistical visualizations in graphical form. The system also features CRUD (Create, Read, Update, Delete) features for categories and transactions. The following is an image of the main menu.

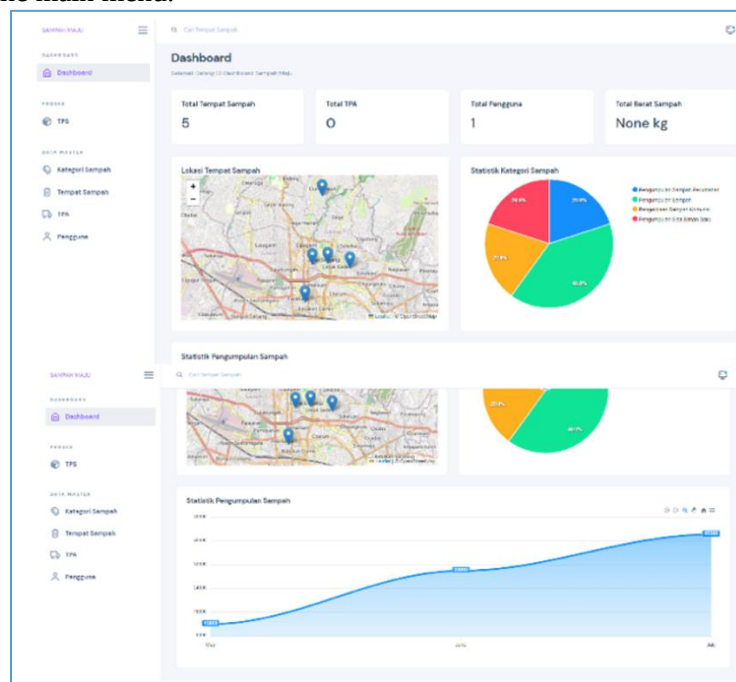


Figure 3 Initial menu display

The following is an explanation of each display.

- Total: There are four totals: the total number of waste bins on the website, the total number of landfills on the website, the total number of users on the website, and the total weight of waste collected from waste bins.
- Waste bin locations: This is a visualization of the waste bin coordinates implemented with leaflet.js.
- Waste category statistics: Statistics that calculate waste bin data based on the waste category.
- Waste collection statistics: Monthly statistics on waste collected from waste bins.

b) Waste Category Display

Waste category display (Figure 4) is a display containing features provided to manipulate data such as Input Data to add data, Update Data to change data, Delete Data to delete waste category data.

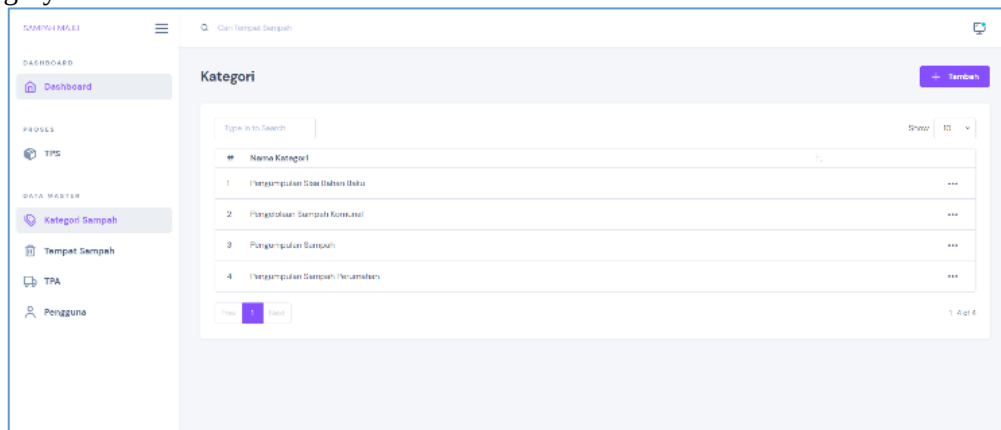


Figure 4 Waste category display

c) Waste bin display

Waste bin display in Figure 5, contains a table of data contained in the database, includes the name of the waste bin, category, and displays the latitude and longitude. Officer can add and delete data.

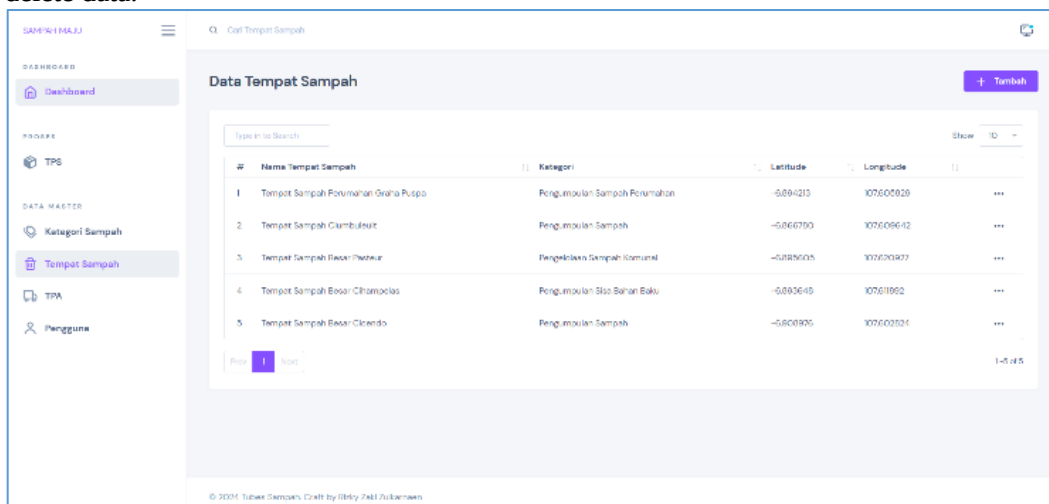


Figure 5 Waste bin display

d) Waste transaction display

Displays waste transaction in Figure 6, data in a table with codes, bins, waste weight, date, and landfill destination. Officers can update, add, and delete data.

Kode	Tempat Sampah	Berat Sampah	Tanggal	Tujuan TPA
W0000001	Tempat Sampah Ciumbureuit	3000000	15 Jun 2024	Belum Ditentukan
W0000002	Tempat Sampah Raker Cikenda	1200000	22 May 2025	Belum Ditentukan
W0000003	Tempat Sampah Diker Diker	4200000	26 Jul 2024	Belum Ditentukan

Figure 6 Waste transaction display

e) User display

Displays user data in Figure 7, in a table with columns for name, email, and role. Users can perform waste transactions tailored to their role.

#	Nama Pengguna	Email	Role
1	Super Admin	super@gmail.com	Super Admin

Figure 7 User display

5. Development, Delivery, and Feedback

In the final stage, limited testing was conducted with 15 respondents. Both quantitative and qualitative results were obtained:

a. Performance Evaluation

The application showed stable performance with an average map loading time of 2.7 seconds when displaying 100 bin data points. Transaction recording averaged 1.0 minute per entry.

b. User Satisfaction

A user satisfaction survey using a 5 point likert scale yielded the following results in Table 1. Overall satisfaction with the application was high, with an average score of 4 out 5. Among the evaluated aspects, ease of use and map visualization received the highest ratings. This suggests that the intuitive interface and real-time spatial features significantly improved user experience compared to conventional methods.

Table 1 User satisfaction

Aspect	Mean Score
Ease of use	5
Map visualization	5
Data Management	4
Reporting	3
Overall satisfaction	4

c. Qualitative Feedback

Respondents highlighted that the interactive map “reduced miscommunication between officers and managers.” Administrators noted that real-time reporting “simplified decision-making and improved transparency.” Suggestions for improvement included adding area-based filters and waste volume classification to refine monitoring.

The results demonstrate that the application successfully addressed inefficiencies of conventional methods. Transaction time was reduced by 80%, while error rates dropped by 10%. The average satisfaction score of 4.3/5 indicates that users considered the system effective and user-friendly. These findings align with previous studies [9, 10, 13] emphasizing the benefits of GIS integration for operational efficiency. Moreover, the feedback loop in the prototyping method ensured that user needs were accommodated iteratively. The integration of GIS provided significant added value by enabling real-time spatial monitoring. Compared to manual approaches, the application improved not only efficiency but also transparency, which is crucial in waste management at the community level. The findings also suggest scalability, as the system can be adopted at neighborhood units (RT/RW), campuses, or local governments.

5 Conclusion

This research successfully designed and implemented a web-based waste management application integrated with GIS. The application addressed the limitations of conventional waste management methods by enabling location-based monitoring, transaction recording, and automated reporting. The prototyping development approach ensured that the system features were closely aligned with user needs and operational realities. Initial evaluations demonstrated that the application improved efficiency by reducing transaction time, lowering error rates, and increasing user satisfaction. Practical implications of this study are significant. For government agencies, the application offers a cost-effective digital tool to enhance transparency, optimize waste collection operations, and support data-driven decision-making in environmental management. For society, the system enables broader community participation by allowing users to report waste-related issues directly, thereby fostering awareness and collective responsibility in maintaining a clean environment. In terms of future development, the system can be further enhanced by integrating IoT-based smart bins to transmit real-time waste volume data, enabling more accurate scheduling of collection routes. A notification system could be developed to alert officers about bins reaching capacity or illegal dumping reports, thereby improving responsiveness. Predictive analytics and machine learning models can also be incorporated to forecast waste generation trends, which would assist in long-term planning and policy development. Additionally, the system could be scaled and customized for broader applications in smart cities, educational institutions, and community-level waste management programs. Overall, this research not only provides a functional solution to existing waste management challenges but also lays the groundwork for more advanced and sustainable digital environmental management systems.

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