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Implementation of IoT Technology on MySmartTrash Waste Bank Application

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ABSTRACT

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The effectiveness of Waste Bank in addressing national waste management challenges is limited by inherent shortcomings. Conventional processes, which heavily rely on manual labor and record-keeping, often face logistical challenges and inefficiencies that limit the effectiveness of waste banks. This paper presents the MySmartTrash application, a solution that integrates IoT technology to enhance waste management practices through a smart waste bank system. By utilizing IoT-enabled sensors, the application allows users to monitor waste levels in real time, thereby optimizing waste collection processes and promoting effective waste segregation. This study employed IoT Design Methodology and Prototyping. Through a SWOT analysis of existing waste management applications, the research identifies strengths and opportunities for enhancing waste management systems. Usability testing also highlighted the significance of various features. This study offers insights for future research into IoT applications in environmental sustainability and waste management systems.

Keywords : *internet of things; sensor; smart waste bank; waste management.*

1. INTRODUCTION

The management of waste in Indonesia has emerged as an ongoing challenge that requires immediate and profound intervention. Various types of waste, both organic and inorganic, are often left unaddressed, leading to significant accumulation and inefficient management practices. The waste management process occurring at Temporary Disposal Sites (TPS) and Final Disposal Sites (TPA) exhibits unfavorable environmental implications due to the lack of proper segregation and distribution, contributing to adverse effects on communities residing nearby. Currently, Indonesia ranks as the top four largest producer of waste globally, particularly plastic waste, generating approximately 5.64 million tons in 2017 [1].

The collection and transportation of waste from residential areas generally happen through garbage collection services, which deposit waste at TPS for sorting and processing. Unfortunately, due to unregulated waste management practices, the burden on TPAs is escalating, exacerbated by the growing volume of waste and the limited number of TPAs. Most waste disposal methods adopted at TPAs involve practices like open dumping and landfilling, which are detrimental to the environment, risking groundwater and air pollution.

As one of the solutions to improve waste management, waste banks were introduced. The waste bank is a place used to collect garbage that has been sorted [2]. With waste banks, customers can deposit their household waste directly to the waste bank. The waste that is collected will be deposited to collectors or recycling craft makers, making the waste more useful and can be reused. The deposits can undoubtedly help the government in handling waste and improve the local economy. Waste banks also change people's perspective that waste can contain economic potential by bringing job opportunities and additional income. Although Waste Bank does improve waste management practices in some areas, Waste Bank itself has a few shortcomings on its own that hinder it from significantly impacting the national problem regarding waste. Logistical challenges and inefficiencies often limit the effectiveness of traditional waste banks. Previous studies have highlighted the problems that arise from conventional processes that depend heavily on manual record-keeping and face logistical hurdles such as potential recording errors, longer report generation times, difficulties managing growing data, and dependence on one person [3].

In this context, technological interventions have the potential to eliminate manual record-keeping and improve the efficiencies of traditional waste bank management practices through mobile applications, as mobile applications were found to be more convenient than their web or desktop counterparts [4]. Their convenience comes from the fact that mobile applications generally have a more interesting interface and varied functionality, and thus more favored by millennial generations that were used to mobile applications to do everyday tasks [5].

Many studies have explored the use of Internet of Things (IoT) technology in waste management, particularly in the context of waste banks. Previous research has developed a management information system for the Panggung Berseri waste bank, which interfaces with users via web and mobile applications. The study also highlighted the inefficacies of conventional waste management processes [6].

Budiyarto et al. [7] provided an overview of the business model for waste banks in Indonesia, highlighting the role of these systems in local waste management. Jaya and Machdum [2] focused on a waste bank in Bandung, showing how IoT can help improve waste management through a circular economy approach.

Another approach used a location-based waste collection system designed for the Enviro Andalas Waste Bank, affiliated with Andalas University [8]. The study aimed to resolve logistics challenges by creating a mobile application that would streamline communication about pick-up locations, using the waterfall method for development. Other developed mobile applications are tailored for exchanging waste for cash, granting users the ability to buy and sell between users with recycling companies through agent intermediaries collector [9]. Moreover, the application can function as a marketplace that can used by users to purchase finished recycled products such as pencil cases, flower pots, and so on.

The usability of mobile applications in waste management is also an important factor.

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Zahra et al. [4] reviewed the usability of mobile applications in various fields, offering insights that are useful for IoT-based waste management applications. Leon [5] discussed how mobile applications designed for millennials can influence the adoption of waste management systems, stressing the need for user-friendly designs.

Recent research has also explored the use of AI alongside IoT for waste detection and sorting. Aprillani et al. [10] used MobileNetV2 SSD and YOLOv8 models for waste detection in waste bank applications, showing the potential for advanced technologies to improve waste management.

Some studies have also focused on how IoT can improve financial transparency and internal control in waste bank systems. Cahyaningsih and Paramita [11] explored how IoT can enhance the quality of financial reporting in waste bank operations, while Putera et al. [12] examined the factors influencing the marketing of IT-based waste management products.

The development of MySmartTrash, a mobile application that integrates Internet of Things (IoT) technology with waste bank services, aims to create a smarter waste management solution and automate various manual labor. IoT refers to a system of interrelated computing devices, mechanical and digital machines, objects, or people that are provided with unique identifiers and can transfer data over a network without requiring human-to-human or human-to-computer interaction [13]. By utilizing sensors connected to Smart Trash cans, the MySmartTrash application provides real-time data on waste levels, enabling users to determine whether a bin is full or empty before disposal. Furthermore, MySmartTrash facilitates the buying and selling of sorted waste according to its type, enhancing waste recycling efforts in Indonesia. Through this approach, waste management can become more efficient and effective, contributing to the reduction of waste accumulation at both TPS and TPA while simultaneously fostering economic benefits for small and medium-sized enterprises (SMEs) and recycling communities.

This study explores the design and implementation of the MySmartTrash application, employing prototyping methods to ensure user needs are thoroughly assessed and met. A SWOT analysis will be utilized to evaluate existing waste management applications, allowing for strategic enhancements and innovations in the MySmartTrash system [14]. The objective of this research is to demonstrate how integrating IoT technology into waste bank applications can effectively address waste management challenges in Indonesia.

2. METHODS

The research methodology for this study on the implementation of the MySmartTrash application is divided into two main segments: data collection methods and implementation methods.

2.1. Data Collection Method

A comprehensive literature study was conducted to gather relevant data necessary for this research. Sources included books, academic journal articles, credible news reports, and other reputable resources pertinent to topics such as User Interface/User Experience (UI/UX), waste management, Internet of Things (IoT), and SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. Literature study involved reading, citing, and synthesizing information to inform the research process and underpin the foundational sections of this report. The SWOT method was chosen to avoid major pitfalls that the existing waste management application has and determine potential opportunities and threats to be considered.

2.2. Implementation Method

a. IoT Design Method

The IoT design method for the MySmartTrash application encompasses a systematic approach to developing an effective smart waste management system [15]. The process consists of multiple stages:
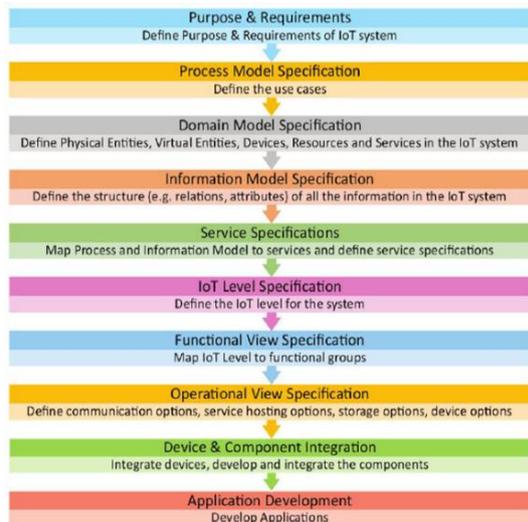
Figure 1. *IoT design method*

b.   Prototype Design Method

The prototyping approach was utilized to develop the MySmartTrash application. This approach entails several stages:
1.   Needs Analysis: Collaborating with stakeholders to gather and clarify system requirements.
2.   Prototype Design: Creating preliminary designs that focus on user experience.
3.   Prototype Evaluation: Assessing the prototype against user expectations and feedback.
4.   Refining Prototype: Incorporating user feedback into revisions to improve the prototype.
5.   Implementation and Maintenance: Final implementation of the prototype and ongoing maintenance efforts.

The prototyping method emphasizes user involvement throughout the development cycle, ensuring that the resulting application aligns closely with user needs. During the evaluation phase, card sorting method were used to determine and categorize the information that will be given to users. About twenty intern students at UIN Syarif Hidayatullah Jakarta were chosen to be participants in the card sorting evaluation.

3.   RESULTS AND DISCUSSION

3.1.   IoT Design Method

3.1.1. Purpose and Requirements

Researchers conducted a SWOT analysis on 3 (three) similar applications so as to optimize the advantages of the application. The three applications were selected based on two types of considerations
1.   The results of querying the Playstore with the query "Best Trash Collection Mobile Application". With the best user criteria.
2.   Recommendation from websites
3.   Some advantages and disadvantages of the three applications analyzed by the author

a.   Recycle!

The strengths of this application are as follows:
1.   Structured weekly recycling schedule: The application provides users with a clear and organized schedule for their recycling activities
2.   Comprehensive information on waste sorting and recyclable waste types: The application offers detailed information on how to sort different types of waste and which materials can be recycled.
3.   Information on nearby waste recycling facilities: The application provides users with information about nearby waste recycling facilities, including their location, accepted waste types, and sorting regulations.
4.   Notifications to remind users about recycling on specific days: The application sends notifications to remind users about upcoming recycling days, ensuring that they do not miss their scheduled recycling activities.
The weaknesses are as follows:
1.   No recycling history for users: Recycle! does not provide users with a history of their recycling activities, making it difficult to track their progress and identify areas for improvement.
2.   Navigation to nearby recycling facilities redirects to another application: When users attempt to navigate to nearby recycling facilities, the application redirects them to another navigation application.

3. No waste collection system is available: Recycle! requires users to visit recycling facilities to dispose of their recyclable waste physically.
4. Some information is limited to a single country: Some of the information provided in the application, such as details on recycling facilities and regulations, may be limited to a specific country.

b. Trashout

The strengths of this application are as follows:
1. International Usability: The application is designed to be usable in all countries, making it widely accessible.
2. Multiple Language Support: TrashOut offers 11 different language options, catering to a diverse user base.
3. User Reporting Feature: Users can report illegal dumping sites and update the community on waste disposal locations, fostering engagement.
4. Environmental Awareness Content: The application provides news and articles related to cleanliness initiatives worldwide.

The weaknesses are as follows:
1. Low User Engagement: The application has a relatively low number of users, which affects its primary objectives.
2. Navigational Dependencies: Users may find that navigation to waste disposal points is often directed to other applications, sometimes leading to difficulties in finding a route.
3. Limited Functional Features: Some functionalities are mainly available on the website, creating inconsistency in user experience.

c. IRecycle

The strengths of this application are as follows:
1. Extensive Waste Type Classification: Provides a detailed classification system for different types of waste, facilitating user sorting.
2. Comprehensive Recycling Center Information: The application includes thorough details about recycling centers, such as operational hours, location, and recycling policies.

3. Favorites and Sharing Features: Users can save their favorite recycling locations and share them with others, enhancing usability.

The weaknesses are as follows:
1. Geographic Limitation: The recycling center information is primarily restricted to one country, limiting its utility for international users.
2. Inefficient Location Entry: Users find the process of entering locations cumbersome and lacking efficiency, without recommendations for nearby centers.
3. More Robust Website Functions: The features available on the website often surpass those in the application, suggesting an imbalance in functionality.

3.1.2. Process Model Specification

This specification defines the system's behavior based on specific goals and requirements. It identifies the necessary statuses and attributes, defines services that modify attribute values, and presents a diagram illustrating the process flow with states and transitions triggered by events. This model ensures that the system functions as intended and meets the desired objectives.
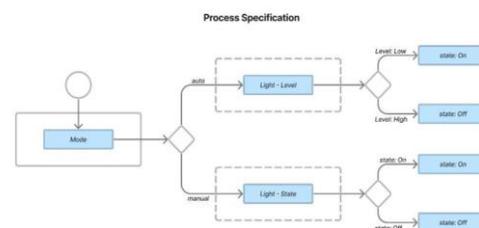

Figure 2. *Process model specification*

3.1.3. Domain Model Specification

This specification provides an abstract representation of the IoT system's domain, encompassing physical entities like the trash bin and waste, virtual entities, devices such as sensors and buzzers, resources, and services that control signals and motor status. By creating a visual representation of the system's domain, this model helps stakeholders understand the various components and their relationships, facilitating communication and collaboration during development.
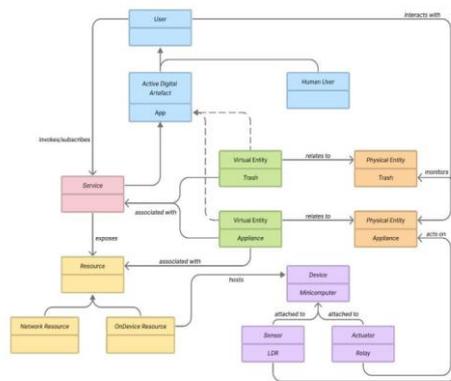
Figure 3. *Domain model specification*

3.1.4. Information Model Specifications

This specification focuses on the structure of information within the IoT system. It details the attributes and relationships of virtual entities without specifying their representation or storage. This model ensures that the system's data is organized and managed effectively, supporting efficient data processing and analysis.

3.1.5. Service Specifications

The Service Specification in the MySmartTrash system outlines the various services within the IoT ecosystem, detailing their types, inputs, outputs, and other crucial aspects. Specifically, it defines services as either controller services or threshold-based services responsible for managing waste levels. These services can modify the values of statuses or attributes and retrieve current values.

The threshold service plays a critical role in adjusting signals to high or low based on the amount of waste. On the other hand, the controller service monitors the threshold value and the motor's status (on/off), diligently updating this information in the database. This comprehensive specification ensures that the services within the MySmartTrash system function seamlessly, contributing to efficient waste management.

3.1.6. IoT Level Specifications

This specification determines the level of IoT deployment for the system, which is Level 1 for MySmartTrash, illustrated with a diagram. This model helps stakeholders understand the complexity and scope of the IoT system, guiding the implementation and integration process.
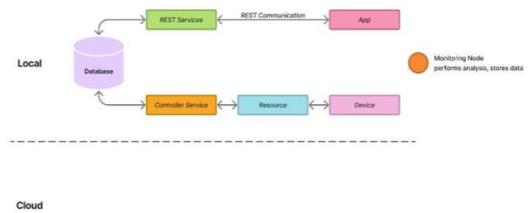

Figure 4. *IoT level specification*

3.1.7. Functional Level Specifications

The Functional View Specification defines the functions of the IoT system, categorized into various functional groups (FGs) that provide functionalities for interacting with the concepts defined in the domain model. In the MySmartTrash system, these FGs include Devices, encompassing monitoring and control devices like sensors and actuators; Communication, covering communication protocols like REST-based APIs; Services, covering device monitoring, control, data publication, and discovery; Management, for configuring and managing the IoT system; Security, covering authentication, authorization, and data security; and Application, providing user interfaces for system control, monitoring, and data access.

3.1.8. Operational View Specifications

The Operational View Specification defines the options related to the deployment and operation of the IoT system. For MySmartTrash, this includes specifications for devices used, such as the Raspberry Pi, resistors, and actuators; API Protocols, specifying the use of REST APIs; Communication Protocols, detailing protocols at different layers like Link Layer (802.11) and Network Layer (IPv4/IPv6); Services, specifying hosting and implementation details for services like Controller Service and Mode Service; Applications, specifying the web application, application server (Django), and database server (MySQL); Security, specifying authentication and authorization mechanisms; and Management, specifying management aspects for applications, database, and devices.

3.1.9. Integration of Devices and Components

The devices and components used in the MySmartTrash system are the Raspberry Pi, sensors, and actuators.

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3.1.10. Application Development

The system will be able to detect whether the trash bin is full or not. This detection utilizes sensors that will notify users through the application with a warning notification.

3.2. Display Design Method

3.2.1. Prototyping

Prototyping on MySmartTrash application is done by doing needs analysis, prototype design, prototype evaluation, refining prototype, implementation, and maintenance.

a. Needs Analysis

The foundation for the design process was laid by conducting a thorough needs analysis. This step involves analyzing existing waste management applications, identifying their strengths and weaknesses through a SWOT analysis. Based on this analysis, key needs and opportunities for improvement were identified, including:
1. Structured scheduling for recycling activities.
2. Comprehensive information on waste sorting practices.
3. Detailed information on recyclable waste types and corresponding recycling facilities.
4. Reminder notifications to prompt users about waste recycling.
5. Reporting functionalities for illegal waste disposal incidents.
6. Informative news and articles related to waste management.

b. Prototype Design

The prototype design process involved two main stages, which is wireframing and mockup development.

Wireframing involved creating sketches of the application's screens and outlining the layout and navigation flow. These wireframes served as blueprints for the application's structure and user interface. Based on key needs and analysis, two sets of wireframes were created. Six screens for user accounts, covering functionalities such as home, location tracking, waste type information, scheduling, reporting, and profile management., and profile management. Five screens for admin accounts, focusing on functionalities such as home, bin location tracking, recycle delivery management, scheduling, and profile management.
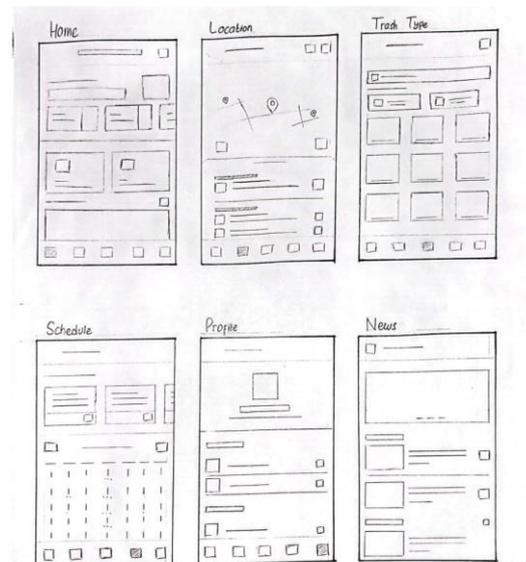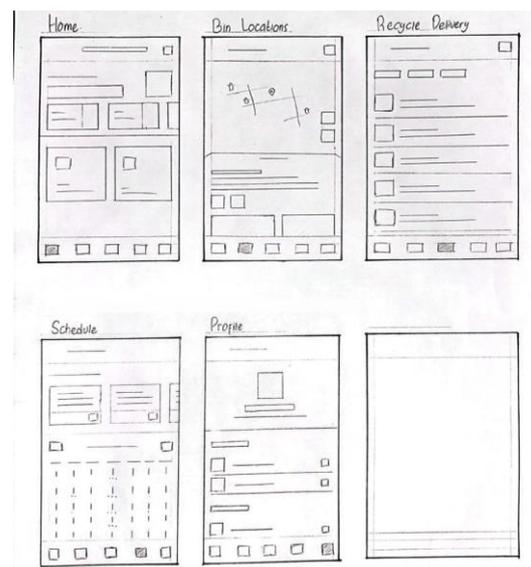

Figure 5. *User interface wireframe*

Figure 6. *Admin interface wireframe*

c. Mockup

Mockup development involved translating the wireframes into detailed visual representations using the Figma design tool. The mockups showcased the visual design of the application, including typography, color schemes, iconography, and overall aesthetics. These mockups provided a tangible representation of the final application's appearance and user interface, allowing for better visualization and evaluation of the design.
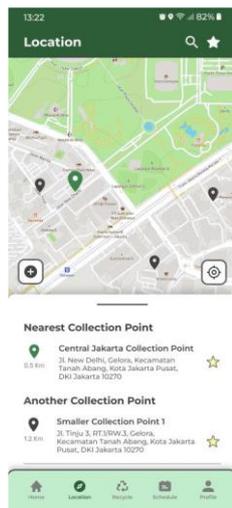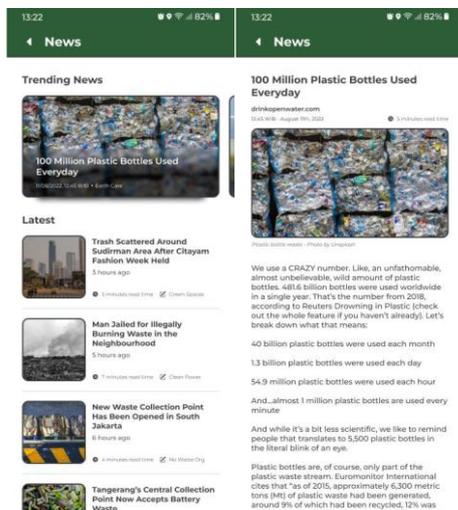
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Figure 7. *Homepage mockup*
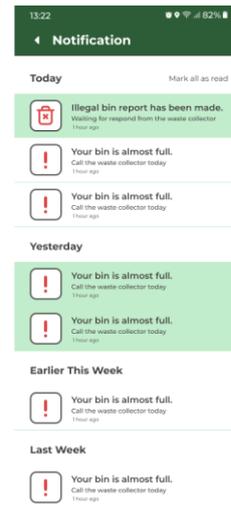

Figure 8. *Location mockup*

Figure 9. *News mockup*

Figure 10. *Notification mockup*
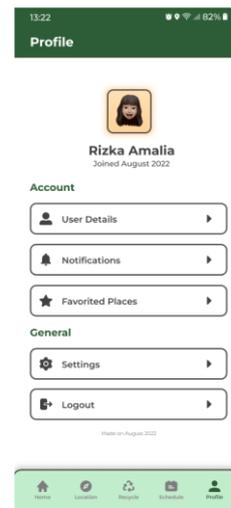
Figure 11. *Profile mockup*

Figure 12. *Recycle mockup*
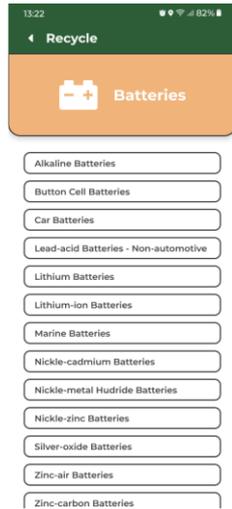
Figure 13. *Recycle batteries mockup*
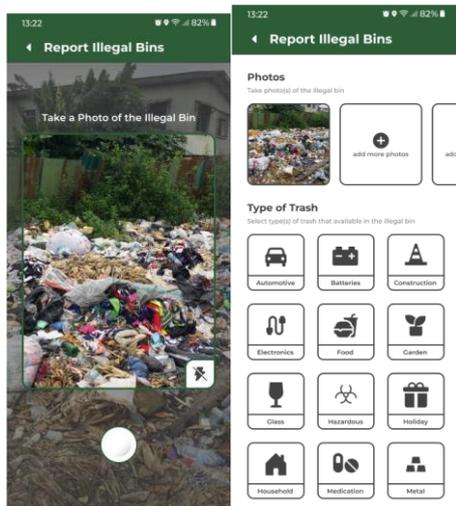

Figure 14. *Report illegal bins mockup*

Figure 15. *Schedule mockup*

3.3. Discussion

To understand how users would naturally perceive features offered by the application, an evaluation of the prototype was conducted using the card sorting method. This method involved presenting users with a set of cards representing the application's features and asking them to sort the cards into categories based on their importance and what made sense to them. The results revealed user preferences and priorities regarding the application's features, which were categorized into three levels of importance: important, moderately important, and not important.
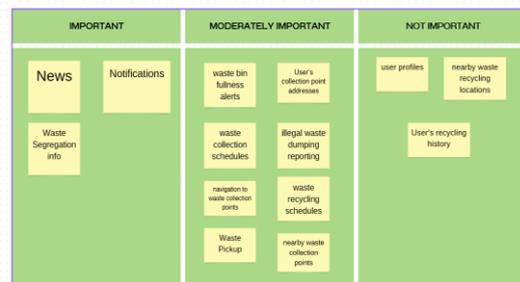

Figure 16. *Card sorting result*

Important features included the latest news, notifications, and information on waste types. This highlights the users' need for relevant information and strengthens the fact that one of the main factors influencing a person's interest in depositing waste in a waste bank is the effective dissemination of information related to waste banks [7]. Important features would likely be placed on the application's main dashboard or home screen, ensuring they are immediately visible and accessible to the user upon opening the application.

Moderately important features include waste bin fullness alerts, waste collection schedules, navigation to waste collection points, user storage of collection point addresses, illegal waste dumping reporting, information on nearby waste collection points, waste recycling schedules, and the system for waste collection by officers, demonstrating the importance of features that support waste management and recycling. Features categorized as moderately important would be designed as secondary elements in the layout.

Lastly, not important features included user profiles, information on nearby waste recycling locations, and user recycling history, suggesting that features related to personal

profiles and history were less important to users. Thus, features deemed unimportant can be deemphasized and placed within a separate menu or tab.

CONCLUSION

This research focused on the development of MySmartTrash, a waste management application prototype integrating Internet of Things (IoT) technology for enhanced monitoring and service delivery. The study employed a SWOT analysis to evaluate existing applications, identifying opportunities and challenges for MySmartTrash. System requirements were determined through a 10-step IoT design process, encompassing aspects like process flow, domain modeling, and service specifications.

The user interface was designed using a prototyping method involving wireframing and mockups, resulting in 17 distinct user screens. Evaluation of the design was conducted using card sorting, categorizing features into three levels of importance. This results in 3 features with important categories, eight features with moderately important categories, and three features with unimportant categories identified.

The study focused on the initial design and evaluation phases and did not explore the implementation of the IoT system and its integration with the application. Further evaluation besides the Card Sorting method was also needed to improve upon the prototype.

Future research could explore a more novel concept to be integrated with the application. Gamified elements (e.g., levels, badges, and challenges) could be implemented to motivate recycling habits further and attract sponsorship from local government or businesses. Meanwhile, Artificial Intelligence technology could improve the tedious manual sorting process of waste by implementing a detection algorithm for wastes that could be deposited.

This research contributes to the development of user-friendly and effective waste management applications that leverage IoT technology, promoting sustainable waste management practices and community engagement in environmental sustainability efforts.

REFERENCES

[1] E. R. K. Neo, G. C. Y. Soo, D. Z. L. Tan, K. Cady, K. T. Tong, and J. S. C. Low, "Life cycle assessment of plastic waste end-of-life for India and Indonesia," *Resour. Conserv. Recycl.*, vol. 174, p. 105774, Nov. 2021, doi: 10.1016/j.resconrec.2021.105774.

[2] R. K. Jaya and S. V. Machdum, "Indonesia Main (City-Level) Waste Bank for Waste Management toward Circular Economy: A Case Study of Bandung City," in *Effective Waste Management and Circular Economy*, CRC Press, 2022, pp. 111–124. doi: 10.1201/9781003231608-13.

[3] M. N. Utomo, S. R. Pratiwi, and F. H. Setyawan, "Improving Economic Efficiency Through Waste Recycling And Modernizing Waste Bank Management," *Int. J. Community Serv.*, vol. 4, no. 1, Art. no. 1, Feb. 2024, doi: 10.51601/ijcs.v4i1.249.

[4] F. Zahra, A. Hussain, and H. Mohd, "Usability evaluation of mobile applications; where do we stand?," in *2017 2nd International Conference On Applied Science and Technology*, Apr. 2017. doi: 10.1063/1.5005389.

[5] S. Leon, "Service mobile apps: a millennial generation perspective," *Ind. Manag. Amp Data Syst.*, vol. 118, no. 9, pp. 1837–1860, Aug. 2018, doi: 10.1108/IMDS-10-2017-0479.

[6] V. Julianto, H. S. Utomo, and Herpendi, "Design and Build Information System for Waste Bank Management Case Study in Serious Waste Bank (BSPB)," *J. RESTI Rekayasa Sist. Dan Teknol. Inf.*, vol. 3, no. 3, Art. no. 3, Dec. 2019, doi: 10.29207/resti.v3i3.1133.

[7] A. Budiyarto, B. Clarke, and K. Ross, "Overview of waste bank application in Indonesian regencies," *Waste Manag. Res.*, vol. 43, no. 3, 2024, doi: 10.1177/0734242X241242697.

[8] H. Kamil, F. Akbar, and M. Andriani, "Design of Location-Based Waste Collecting on Enviro Andalas Waste Bank," *JOIV Int. J. Inform. Vis.*, vol. 3, no. 1, pp. 35–40, Jan. 2019, doi: 10.30630/joiv.3.1.212.

[9]   K. W. Indrawan *et al.*, "Digital Marketplace Design & Development for Creative Recycle Product," in *2023 IEEE 9th Information Technology International Seminar (ITIS)*, Oct. 2023, pp. 1–6. doi: 10.1109/ITIS59651.2023.10419958.

[10]   S. Aprillani, F. Y. Baqir, I. N. Zaini, S. N. Hertiana, and S. Sussi, "Advanced Waste Detection: Mobilenetv2 SSD and Yolov8 for Waste Bank Mobile Application," in *2024 IEEE International Conference on Control & Automation, Electronics, Robotics, Internet of Things, and Artificial Intelligence (CERIA)*, Oct. 2024, pp. 1–5. doi: 10.1109/CERIA64726.2024.10914827.

[11]   C. Cahyaningsih and V. T. Paramita, "Waste Bank Application: Internal Control System and the Quality of Financial Statements," in *2023 International Conference on Digital Business and Technology Management (ICONDBTM)*, Aug. 2023, pp. 1–5. doi: 10.1109/ICONDBTM59210.2023.10326757.

[12]   A. S. Putera, I. Aknuranda, and D. Priharsari, "A Systematic Literature Review on Factors Influencing Waste Management IT-Based Products Marketing," in *2021 International Conference on Information Management and Technology (ICIMTech)*, Aug. 2021, pp. 55–60. doi: 10.1109/ICIMTech53080.2021.9535070.

[13]   V. Lesch, M. Züfle, A. Bauer, L. Iffländer, C. Krupitzer, and S. Kounev, "A literature review of IoT and CPS—What they are, and what they are not," *J. Syst. Softw.*, vol. 200, p. 111631, June 2023, doi: 10.1016/j.jss.2023.111631.

[14]   C. A. Lauff, D. Kotys-Schwartz, and M. E. Rentschler, "What is a Prototype? What are the Roles of Prototypes in Companies?," *J. Mech. Des.*, vol. 140, no. 061102, Mar. 2018, doi: 10.1115/1.4039340.

[15]   A. Bahga and V. Madisetti, *Internet of Things: A Hands-On Approach*. VPT, 2014.