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Design and Evaluation of a User-Centered Mobile Application for Community-Based Waste Management

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A B S T R A C T S

It is very hard to keep an eye on garbage at the village level when there is no clear information about when sorted waste will be picked up and when sales will happen, and when there is no method for documenting waste data. This lack can cause garbage to build up in places where it shouldn't and make it harder to manage waste properly. To fix these problems, Badan Usaha Milik Kalurahan requirements a mobile application that is easy to use and makes waste management tasks easier. BUMKALs are very important for helping communities grow and providing important services, like waste management. This study is all about making a waste management software, with a big focus on User Interface and User Experience principles. The design process uses a User-Centered Design method, which makes sure that users are included in every step. This method makes sure that the final application fits their demands and wants very well. In Caturharjo Village, which is in the Pandak Subdistrict of Bantul Regency, the local BUMKAL has taken the lead in starting community-based garbage management. But they still have problems with keeping track of data in a systematic way and having good ways to communicate. We used the User Experience Questionnaire to find out how users felt about the design of the application and how satisfied they were with it. The evaluation results show that the mobile application had mostly good feedback on all UEQ aspects, such as how clear, beautiful, and useful it was. All of the ratings were over the positive benchmark, which is really impressive. This shows that users were very happy with the application that was made, which means it may be successfully implemented and used.

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1. INTRODUCTION

The problem of managing solid waste in Bantul Regency is getting worse since people keep making more and more rubbish every day. New data shows that the area makes almost 400 tons of waste per day, yet the current infrastructure can barely handle 100 tons. As a result, almost 300 tons of rubbish go uncollected every day, which is bad for the environment and the economy. The waste management rate reached 62% in 2020 because more people signed up for residential waste service. However, the regional waste processing facility has long been over its technical capacity, making the issue much worse.

The Bantul Regency Government started the "Bantul Clean from Waste 2025" strategic program in response to this growing concern. The goal of the program is to create a waste management system that is more integrated

and based on the community. A Village-Owned Enterprise-based waste management model is a major technique that gives local businesses the freedom to run waste operations in their own neighborhoods. The local administration of Caturharjo Village, along with BUMKAL Caturharjo, started a BUMKAL-based Integrated Waste Management Laboratory as part of this project. This strategy combines collecting inorganic garbage by sorting it and selling it with treating organic waste through a home-based integrated farming system that includes both animal and crop production.

Even with these efforts, there are still some problems. A early survey of 20 people living in Caturharjo Village found that 61.9% of them used scheduled waste pickup services, but 38.1% still burned, buried, or dumped their waste illegally. Additionally, 65% of participants said they had problems with irregular service, such as pickup schedules that changed, costs that changed, and the inability to process sorted recyclable material. Adding to the difficulty, there isn't much data on how much waste households make, which makes it hard to establish policies and operations based on statistics. This proof shows that the Waste Management Laboratory alone has not yet adequately met the requirements of the community.

Even though digital technology has a significant amount of potential, the use of this technology in the management of waste in urban and peri-urban areas in Indonesia is still relatively limited[1]. When it comes to decentralized waste management systems, mobile applications present a potentially fruitful path for improving transparency, efficiency, and citizen engagement[2]. These solutions can make the system far more responsive and accountable by adding features like real-time pickup scheduling, logging of recyclable garbage, member registration, and built-in digital payments.

The principles of user interface and user experience need to be carefully considered in order to carry out an effective design of waste management systems[3]. According to the findings of research, the success of applications that provide public services is significantly impacted by the amount of user satisfaction, efficiency, and intuitiveness that they possess[4]. In recent years, the User-Centered Design (UCD) methodology has evolved as a powerful framework that can guarantee that applications are adapted to the specific requirements and preferences of the consumers they are intended for[5]. Among various design methodologies, UCD stands out as particularly suitable for addressing community-level waste management challenges due to its iterative, participatory, and context-aware nature. Unlike System-Centered Design, which prioritizes system logic and constraints, or Technology-Driven Design, which may focus on available digital capabilities without thoroughly assessing user realities, UCD ensures that the needs, limitations, and behaviors of end users are the driving force behind the design process. This approach is crucial in rural or semi-urban contexts like Caturharjo Village, where users may have varying degrees of digital literacy[6], irregular service expectations, and diverse waste management habits. UCD facilitates continuous feedback from real users, allowing the development team to tailor the interface, features, and workflows to actual community practices and preferences. Moreover, UCD's emphasis on usability, learnability, and emotional satisfaction directly supports higher rates of adoption, engagement, and long-term sustainability—key factors for the success of technology-mediated environmental initiatives.

Several studies show that technology solutions alone are not enough for good waste management systems. Local institutions and community-based programs are important for long-term waste management at the village level[7]. The implementation of digital waste management application has the potential to reduce overflow and improve decision-making procedures[8]. Also, community-driven smartphone applications can help people learn more about separating their waste[9] and make it easier for people to make money from recyclable goods. However, if appropriate attention is not paid to the usability of the digital solutions and the requirements of the users, it is possible that they would not acquire widespread adoption. The incorporation of behavioral insights and nudges into the design of the application has been shown to further promote the behaviors that are sought in terms of waste management[10].

This project aims to create and evaluate a mobile-based waste management application utilizing the User-Centered Design method, specifically for the requirements of Caturharjo Village in Bantul Regency. This study's main research questions are:

- How can the UI/UX of a waste management application for the community be made to fit the requirements and demographics of the people who live in Caturharjo?
- How do users feel about and react to the application's ease of use, efficacy, and overall satisfaction, which were all created using UCD principles?

The research intends to provide both a practical solution to local waste management problems and an academic reference for UI/UX development in public-facing environmental technologies by answering these concerns

2. RESEARCH METHODOLOGY

This research uses the UCD method to build a mobile-based waste management software that meets the demands of the people in Caturharjo Village, Bantul Regency. The UCD process shown in Fig. 1 was done in four main steps, as suggested by ISO 9241-210: (1) understanding and specifying the context of use, (2) specifying user and organizational requirements, (3) producing design solutions, and (4) evaluating the design against user requirements. The following is a detailed description of each phase:

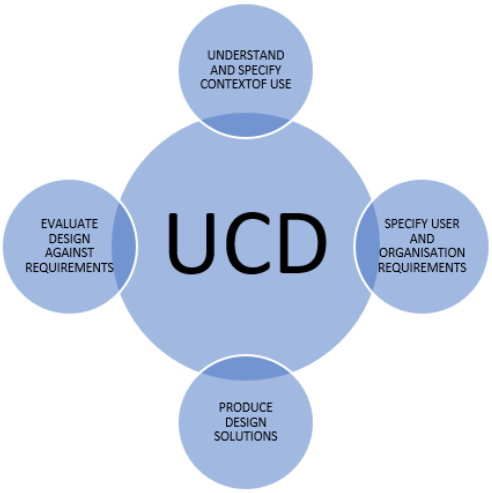

FIG 1. UCD Processes

2.1 Understand and Specify the Context of Use

In the first step, the research team wanted to learn everything they could about the users, their goals, the surroundings, and the situation in which the system would be utilized. This meant figuring out who the main users were, which in this case were people who lived in Caturharjo Village and staff members who worked for BUMKAL and the Waste Management Laboratory.

A survey was sent out to people in the area to find out about their waste management habits, how happy they are with the services they already use, and the problems they have getting to those services. The answers were looked at to find patterns in how people use the service and problems with how things are done now, especially when it comes to scheduling waste pickup, getting information, and recycling. These results were used as the real-world basis for putting the design process in context

2.2 Specify User and Organisational Requirements

The second step after the contextual analysis was to get and write down detailed user and organizational requirements. This was possible by using both questionnaire analysis and in-depth interviews with stakeholders such household representatives, community leaders, and BUMKAL staff.

We did a user requirements analysis to turn the insights into functional and non-functional requirements that could be used to build the application. For instance, customers said they needed a clear schedule for picking up waste, a way to keep track of sorted recyclables, and a way to pay or get rewards. These requirements were written down and grouped into feature groups to help with the design process.

2.3 Information Requirements Analysis and Sitemap Development

Using the information gathered in the preceding steps, an analysis of the application's information requirements was done to figure out what kinds of data and interaction flows it needs to enable. Then, the information was utilized to make a sitemap, which is a structured outline of the application's pages and how they work.

The sitemap gave an overview of the application's structure, including the main menu, submenus (such "Schedule Pickup," "Waste Records," "Sell Recyclables," and "Account Management"), and how each interface component was connected to the others. This structure was used as a guide for the next stages of design.

2.4 Produce Design Solutions

The goal of this phase was to come up with and improve design ideas using visual and interactive objects. During this phase, two significant deliverables were made:

- Low-fidelity wireframe:
  For visualizing the initial layout of the user interface for the application, a collection of low-fidelity wireframes was generated. These low-fidelity wireframes were a simple prototype that helped make sure that the design principles matched what users wanted and that the navigation flows, interface grouping, and content placement were all correct.
- High-fidelity prototype:
  A high-fidelity prototype of the mobile application was produced with the help of Figma in order to replicate realistic user flows and interactions. The graphic design, clickable interface elements, and user interaction paths were all part of this prototype. It was meant to give customers a hands-on experience with the planned application so that they could give more accurate input during the review process.

2.5 Evaluate Design Against Requirements

During the final step, a predetermined evaluation of the application prototype was carried out to check that it satisfied the user requirements that were defined. The User Experience Questionnaire (UEQ) was used for the evaluation. This is a typical tool for measuring how people feel about the usability and user experience of a product.

Ten people from the Caturharjo community were invited to a live demonstration session where they could use the high-fidelity prototype. After that, they took the UEQ, which looks at six important areas:

- Attractiveness : Do users enjoy the application overall?
- Perspicuity : Is the application easy to understand and learn?

- Efficiency : Can users perform tasks with minimal effort?
- Dependability : Do users feel in control of the interaction?
- Stimulation : Is the application engaging and motivating to use?
- Novelty : Is the design innovative and aligned with user interests?

The findings of this review provide quantifiable proof of how easy and useful the application was thought to be, as well as ideas for how to make it even better.

3. RESULTS AND DISCUSSION

3.1. Understand and Specify Context of Use

A structured questionnaire was given to the people of Caturharjo Village, Bantul Regency, to find out what real-life challenges they had with local garbage management. There were 20 people who answered this first step. The purpose of the questionnaire was to find out what problems people have when they use waste management services supplied by the village-owned business (BUMKAL).

Following an examination of the data that was gathered, a number of significant problems were discovered:

- Users had trouble signing up for waste collection services, especially when it came to accessibility and consistency.
- People thought that the method for billing and paying for waste pickup was unclear and not very effective.
- Even if the sorted recyclable rubbish had value, residents couldn't sell it.
- There was a lack of classified sorting at the level of the waste collector (pengepul), which made it difficult to implement recycling techniques that were successful.

These results were very important for figuring out what users wanted and the situation in which the app would be used, which is in line with the first step of the User-Centered Design (UCD) technique.

3.2. Specify User and Organizational Requirement

The following step included transforming the problems that users were experiencing into features that could be implemented in the application. Based on the results of the last survey, a more specific list of user requirements was developed and called "requirements" for the system. The functional specifications of the Waste Management Laboratory application were based on these requirements:

- Scheduling waste pickups: Users need to know exactly when their waste will be picked up.
- Pickup status and details: Users need to be able to see real-time updates and explanations of the progress of their collection.
- Information on billing and payment: The system should clearly show how much each service costs.
- Sorted waste sales feature: a part that lets people keep track of and sell things that can be recycled.
- Details of the sale: Users should be able to see the status and value of recyclable products that have been sold.

These functional requirements were built into the system architecture and had a direct impact on how the application was designed.

3.3. Product Design Solution

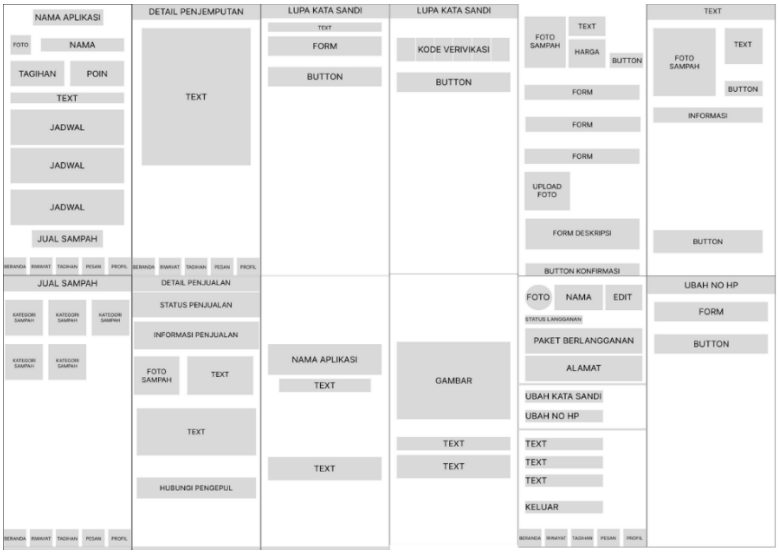

FIG 2. Low-fidelity wireframes

A series of low-fidelity wireframes was made at the beginning of the design process to depict the basic structure and layout of the application. This is represented in Fig. 2. The low-fidelity wireframes were a guide for further development because they showed where content should go, how navigation should flow, and how interfaces should be grouped.

The low-fidelity wireframe was followed by the production of a high-fidelity prototype using the Figma software. This version added visual elements such color schemes, typography, icons, and layout improvements. The prototype followed a design philosophy based on simplicity, employing a dark green color scheme to show themes of the environment and sustainability. This step made sure that both the looks and the functions met what users expected and what they said in earlier stages.

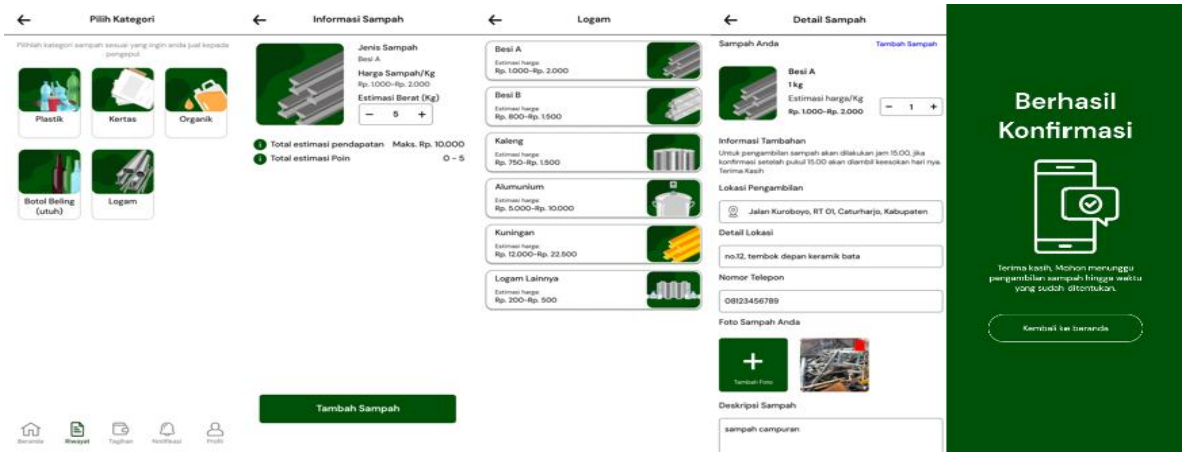

FIG 3. High Fidelity Prototype

3.4. Evaluate Design Against Requirement

An online questionnaire that was based on the User Experience Questionnaire (UEQ) framework was issued through Google Forms in order to collect data for the purpose of evaluating the usability and quality of the interface. There were 54 people who filled out the evaluation. Participants used the prototype and then rated their experiences on six UEQ dimensions: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty. After that, the data were examined statistically to find out what users thought and to see if the prototype matched the functional and emotional requirements that had been determined in the previous UCD phases. Table 1 shows the average and range of scores for the UEQ scales.

Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty are the six key aspects that were involved in the evaluation of the user experience that was carried out with the use of the UEQ. Table X shows that all of the mean values are over the +1.5 level, which UEQ standards say indicates a strong favorable appraisal. Below is a full explanation of each dimension:

- The Attractiveness dimension shows how users feel about the product as a whole. A mean score of 1.880 shows that users were highly happy and satisfied with the application, which is a very good sign. The minimal variance shows that the respondents had a similar view.
- The Perspicuity dimension shows how simple it is for consumers to learn about and utilize the software. The score shows that most users thought the system was easy to learn and understand. The slightly higher variance, on the other hand, suggests that there are little variances in how easy it is to use, which could be due to users' different backgrounds or levels of digital literacy.
- The results of the Efficiency score indicate that users were able to successfully execute tasks with a minimum of effort. This dimension got a high score and a low variance, which means that everyone was happy with how quickly the application responded to requests and how well it helped with tasks.
- Dependability measures how much users feel in charge and able to predict what will happen when they use the system. A high mean score and low variation mean that users felt safe and sure about using the application, and that the system worked as it should.
- The Stimulation dimension reflects the characteristics of the system that motivate and appeal to the emotions. The high score means that the software was fun to use and made people want to keep using it. Even if the variance is a little higher, it is still within an acceptable range, which means that emotional engagement is somewhat variable.
- Novelty looks at how creative and new the application is. The mean score is still in the positive area, but the biggest variance across all categories shows that users have very different opinions. This could be because people have different expectations or have used comparable apps before.

TABLE 1. Mean and variance results of UEQ scales

UEQ Scale	Mean	Variance
Daya tarik	1,880	0,85
Kejelasan	1,731	1,17
Efisiensi	1,741	0,87
Ketepatan	1,750	0,77
Stimulasi	1,801	0,88
Kebaruan	1,630	1,79

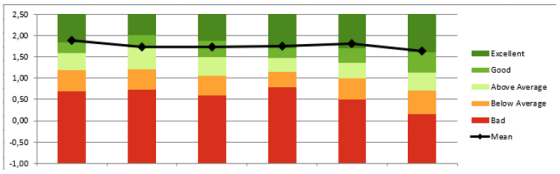

FIG 4. UEO Dimension benchmark

TABLE 2. Effect Size Analysis (Cohen's d) for Each UEQ Dimension Compared to International Benchmark

Dimension	User Score	Benchmark Score	Cohen's d	Interpretation
Stimulation	1.801	1.05	0.751	Medium-to-large effect
Attractiveness	1.880	1.20	0.680	Medium effect
Novelty	1.630	0.95	0.680	Medium effect
Perspicuity	1.731	1.15	0.581	Medium effect
Dependability	1.750	1.25	0.500	Medium effect
Efficiency	1.741	1.35	0.391	Small-to-medium effect

The evaluation results show that the application we made gives users a very good experience in all the areas we looked at. Attractiveness and Stimulation were the two areas where the system did the best, showing that it can produce a positive and encouraging encounter. The dimension of Novelty, on the other hand, showed a lot of variation, which means that design components that are meant to make the application stand out need to be improved even more. These results give us useful information for future versions and show how important it is to keep innovation consistent without making it harder to use.

The UEQ findings showed that users had a very good view of the Waste Management Laboratory application in all six areas that were examined. The average score on the Attractiveness scale was 1.880, which means that users thought the interface was pretty, nice, and fun to use. The Novelty dimension got a score of 1.630, which means that users thought the design included new and original parts.

The application worked really well for tasks that needed to be done. The Efficiency dimension got a score of 1.741, which shows that respondents thought the system could help them finish tasks quickly and easily. The Stimulation score was also high, at 1.801, which means that users found the application interesting and motivating. The Dependability score of 1.750 shows that people have a lot of faith in how predictable and reliable the system is. The last score, 1.731, for Perspicuity, shows that users thought the application was easy to use and understand.

A statistical comparison was carried out with the help of Cohen's d, which is a typical metric for quantifying effect size. This was done to evaluate the accuracy of these results in respect to standardized usability benchmarks. The effect sizes for each UEQ dimension are shown in Table 1. They were obtained by comparing them to international benchmark scores from the UEQ data source. According to Cohen's (1988) rules, the meaning is as follows:

- $d \geq 0.2$ indicates a small effect,
- $d \geq 0.5$ indicates a medium effect, and
- $d \geq 0.8$ indicates a large effect.

The application that was produced outperforms conventional expectations across all six dimensions of user experience, according to the outcome of a comparison analysis between user evaluation ratings and international UEQ benchmarks. As a result, this demonstrates that the system offers a high level of use, efficiency, and emotional involvement.

The Stimulation dimension had the highest user score (M = 1.801), which was much higher than the international standard (M = 1.05). This means that the application not only works well, but it also keeps users interested and motivated during interactions. The Cohen's d for this dimension is 0.751, which means that the effect size is medium to big. This means that the performance of the application in the benchmark dataset is very different from the average.

In the same way, Attractiveness (M = 1.880) and Novelty (M = 1.630) both had Cohen's d values of 0.680, which means they had medium impact sizes. These results show that people think the application looks good and is somewhat new compared to other systems. The Novelty score has a significant variation of 1.79, which means that people's answers were different. However, the mean score is still substantially above the standard, which supports the idea that it is creative.

The Perspicuity and Dependability dimensions have impact values of 0.581 and 0.500, which means that they are better than international standards by a significant amount. These scores show that users thought the

application was straightforward to use and understand, and they also felt like they had control over it and could trust it.

Lastly, the Efficiency score (M = 1.741) gave a Cohen's d of 0.391, which is a small-to-medium impact size. Even while the gain isn't as big as in other areas, it's still a favorable change from the benchmark and shows that the application can help people do tasks quickly

4. CONCLUSIONS

The UCD method was effectively used in this project to make a mobile application for managing waste in Caturharjo Village, Bantul Regency. The study found real-world problems and turned them into clear system requirements through a disciplined and iterative design process that included end-users. These included the requirement to plan when waste would be picked up, make sure transactions were clear, and handle recyclable waste in a way that was quick and easy.

The design process, which included low- and high-fidelity prototyping, was in line with principles of usability and an awareness of the consumers' context. We used the standard UEQ to evaluate the final prototype's usability. The findings were very good across all six dimensions: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty.

All the mean scores were over the +1.5 criterion, which means that users had a very good experience. More comparisons with foreign UEQ standards showed that the application not only met but well exceeded typical performance levels. The Stimulation dimension had the biggest effect size (Cohen's d = 0.751), which shows how well the application can encourage and engage users. Also, Attractiveness and Novelty both had modest impact sizes (d = 0.680), which added to the application's visual appeal and perceived newness.

The results show that the UCD strategy works to solve localized waste management problems through digital innovation. Users expressed excellent levels of satisfaction and usage, which suggests that it might be successfully implemented and adopted at the village level. Still, the Novelty dimension has a rather significant variance, which shows that design aspects need to be constantly improved to meet the requirements and expectations of different users.

To sum up, getting input from the community at every stage of the design process has been key to making a digital tool that works well, is fun to use, and fits the situation. This tool not only helps BUMKAL reach its operational goals, but it also helps with larger initiatives to make garbage management in rural Indonesia more sustainable and community driven.

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