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UI/UX Design and Usability Evaluation of a High-Fidelity Prototype for an Android-Based Waste Management Application Using Design Thinking and the System Usability Scale

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Abstract: *Community-based waste management increasingly relies on mobile applications, whose success depends heavily on the quality of the User Interface (UI) and User Experience (UX). This study designed and evaluated the UI/UX of a high-fidelity prototype of the Resikel Android application for the Batam City context using the Design Thinking methodology (Empathize, Define, Ideate, Prototype, Test). The contribution is context-specific rather than methodological: it presents a user-centered interface design and its perceived-usability evaluation for a community-based waste-management prototype situated in Batam. Usability was measured through unmoderated, cross-sectional testing on the Maze platform involving 100 respondents, followed by the System Usability Scale (SUS). Task-based metrics (success rate, completion time, and misclicks) were recorded, and the mean SUS score was 78.2 (SD = 6.70), indicating a good level of perceived usability within the Acceptable range. Because the artifact evaluated is a prototype rather than a functioning Android application, technical feasibility, performance, accessibility, and real-world task completion were not established. The findings provide an empirical usability reference for the future development of community-based waste-management applications and should be interpreted within the stated design and sampling limitations.*

Keywords: *Design Thinking, System Usability Scale, UI/UX, high-fidelity prototype, waste management application.*

1. Introduction

Indonesia continues to face challenges in urban waste management because the increasing volume of waste is not matched by adequate processing capacity, particularly in areas with rapid population growth [1], [2]. Beyond infrastructure, the success of waste management depends heavily on community participation [3], [4]. Digital technology has therefore emerged as an alternative for increasing public engagement in waste management.

Batam City exemplifies these challenges. With a population exceeding 1.2 million, the city generates approximately 1,159 tons of municipal waste each day [5]. Rapid population growth simultaneously represents a resource for collaborative waste management when supported by appropriate digital services [6], [7]. There is thus a need for a mobile application that enables residents to access waste-collection services, locate recycling collection points, and obtain waste-management information efficiently [8].

The Resikel application was developed as a community-based waste-management platform providing waste pickup scheduling, recycling collection-point maps, community forums, and a reward-point calculation system. A point-based incentive is expected to encourage participation [7]. However, successful adoption depends not only on feature completeness but also on UI/UX quality [9]. A poorly designed interface reduces usability and hinders adoption; prior research shows usability and UX quality are important predictors of continued mobile-app use [9], [10].

Among UI/UX design approaches, Design Thinking emphasizes understanding user needs through the iterative stages of Empathize, Define, Ideate, Prototype, and Test [11], [12]. Its iterative, empathy-oriented nature enables refinement of solutions based on feedback [13]. To evaluate the design outcome, the System Usability Scale (SUS) was employed because it is a simple, reliable, and standardized instrument for measuring perceived usability [14].

Building on this, the present study integrates Design Thinking and SUS to design and evaluate the UI/UX of a high-fidelity Resikel prototype for the Batam City context. Accordingly, the study addresses the following research questions:

- **RQ1**. How can a user-centered UI/UX design for the Resikel prototype be derived from community waste-management needs using the Design Thinking process?
- **RQ2**. What level of task performance (success rate, completion time, and misclicks) do users achieve on the prototype during unmoderated task-based testing?
- **RQ3**. What level of perceived usability, as measured by SUS, does the prototype achieve among the sampled respondents?
- The study is explicitly bounded to a high-fidelity prototype rather than a deployed Android application; therefore, no baseline design, controlled before–after comparison, or long-term adoption claim is made.

2. Literature Review

The adoption of mobile technologies has encouraged applications supporting sustainable waste management [15], enabling users to access collection services, recycling information, and awareness programs. Their success depends on UI/UX quality, which influences satisfaction and long-term adoption [16]. Point-redemption incentives can further boost participation in sustainable waste management [17].

Design Thinking is a user-centered methodology comprising the iterative stages of Empathize, Define, Ideate, Prototype, and Test [12], [18]. It enables developers to identify user needs, formulate solutions, and refine prototypes based on user feedback, and has been applied across information systems where usability is a critical success factor [12], [13]. The System Usability Scale (SUS), developed by Brooke, is a standardized ten-item, five-point Likert instrument producing a 0–100 score, with scores above 68 generally indicating above-average usability [14]. Its simplicity, reliability, and interpretability make it one of the most widely used usability-evaluation methods for mobile applications.

Table 1. Synthesis of representative studies on Design-Thinking-based UI/UX with usability evaluation.

Study	Domain	Prototype status	Sample size	Task protocol	Usability metric	Iteration evidence	Limitation
Aulia et al. (2024) [11]	Waste mgmt.	Prototype	20	Guerrilla usability test	Usability + task efficiency	Not user-validated	Long-term participation not evaluated
Saraswati et al. (2024) [19]	Waste mgmt.	Prototype	30	SUS	SUS	Design only	No implementation evaluation
Maukar (2024) [20]	Waste mgmt.	Prototype	30	SUS	SUS = 80.29	Not reported	Long-term adoption not studied

Study	Domain	Prototype status	Sample size	Task protocol	Usability metric	Iteration evidence	Limitation
Rifa'i et al. (2025) [14]	English learning	Prototype	10	SUS	SUS = 86.5	Not reported	Different domain
Santoso (2025) [16]	Healthcare tracking	Prototype	4	SUS	SUS = 85	Not reported	Non-environmental domain
This study	Waste mgmt. (Batam)	High-fidelity prototype	100	Unmoderated Maze tasks + SUS	Task metrics + SUS	Internal refinement only	Prototype, single session, no baseline

Synthesizing these studies shows that most prior work reports aggregate usability scores for prototypes, rarely documents user-validated design iteration, and seldom evaluates community-based waste-management applications in the Batam context with a comparably sized respondent pool. The present study addresses this specific gap while acknowledging that it, too, evaluates a prototype in a single testing session.

3. Methods

A. Data Description

The study used qualitative data (to identify user needs as the basis for the Design Thinking process) and quantitative data (SUS responses and Maze task metrics collected after respondents interacted with the high-fidelity prototype).

B. Research Location and Ethics

The study was conducted in Batam City, Indonesia, involving residents who were active Android users aged 18–50 years. Prototype evaluation was conducted online using the Maze platform from 18–22 June 2024. A Figma prototype link was distributed via WhatsApp to 102 respondents, of whom 100 independently completed all tasks and the SUS questionnaire. Two respondents did not complete the evaluation due to internet connection issues.

C. Research Tools and Evaluation Instrument

The Resikel UI/UX was built in Figma as a high-fidelity prototype of eleven interface screens. Task scenarios were distributed and logged through Maze. After completing the tasks, respondents completed the ten-item SUS, chosen for being standardized, simple, and reliable, producing a 0–100 score [14].

D. Research Method

The UI/UX was designed through the five iterative Design Thinking stages, summarized below and detailed in the Results.

1) Empathize

User needs and challenges were identified through two discussion sessions with the Pelita Hijau Nusantara team, involving the community chairperson, one operational staff member, and two volunteers. The discussions, each lasting approximately 90 minutes, focused on the existing waste management workflow, challenges faced by residents, and the features most needed in the application. To complement these discussions, direct observations of waste weighing and record-keeping activities were conducted at the partner site to provide additional contextual insights.

2) Define

Findings were translated into problem statements and mapped to design requirements (Table 2).

3) Ideate

Seven design alternatives were generated and evaluated against two criteria-alignment with user needs and implementation feasibility-using a decision matrix (Table 3). Each alternative was scored on a scale of 1 (very low) to 5 (very high) for both criteria, resulting in a maximum total score of 10. Five alternatives demonstrated strong alignment with user needs (score $\geq$ 4) and moderate to high implementation feasibility (score $\geq$ 4) and were therefore selected for further development. Two alternatives, namely e-commerce integration and waste-auction service, received low scores and were excluded because of limited alignment with the core objectives and low implementation feasibility. The five selected alternatives were subsequently developed into the final application features: waste pickup scheduling, community forum, collector map, reward-point estimation, and transaction management. This process ensured transparent selection and traceability from evaluated design alternatives to the final prototype.

4) Prototype

Selected concepts were realized as low- then high-fidelity Figma prototypes.

5) Test

Respondents independently completed predefined Maze task scenarios and then the SUS.

E. Data Analysis and Evaluation

SUS scores were computed using the standard procedure: for odd items (1, 3, 5, 7, 9) subtract 1 from the rating; for even items (2, 4, 6, 8, 10) subtract the rating from 5; sum all adjusted values and multiply by 2.5, yielding a 0–100 score. The mean, minimum, maximum, and standard deviation were reported. Data-quality checks removed incomplete submissions and retained only respondents who completed all task scenarios. Maze task logs provided success rate, completion time, and misclick/drop-off counts per scenario. Because only aggregate SUS statistics were retained, item-level distributions, internal-consistency reliability (e.g., Cronbach's alpha), and a confidence interval for the mean could not be computed; this is stated as a limitation and recommended for future work.

4. Result and Discussion

A. Empathize

User needs were identified through two discussion sessions with the Pelita Hijau Nusantara team, involving the community chairperson, one operational staff member, and two volunteers who regularly assist residents with waste sorting. The discussions explored the existing waste management workflow, challenges encountered by residents, and the application features considered most important. To complement these findings, direct observation of waste weighing and recording activities at the partner site was conducted to provide contextual insights into the current waste management process.

B. Define

Table 2. Problem definition based on Empathize findings.

Empathize finding	Problem statement	Proposed solution
Residents do not know the pickup schedule	Unclear schedules reduce participation	Pickup scheduling with notifications
Collector information is scattered	Difficulty selling recyclable waste	Interactive collector map with pricing
No interaction among residents	Lack of social support lowers motivation	Community discussion forum

Empathize finding	Problem statement	Proposed solution
Reward estimation is unavailable	Low transparency of incentive calculation	Reward estimation calculator

The problem formulation established a clear relationship between user needs and the proposed system functionality, ensuring that the interface design remained user-centered throughout the development process.

C. Ideate

Seven alternatives were scored against alignment with user needs and implementation feasibility. Five (e.g., e-commerce integration, waste-auction services, and customer-service chatbot) were excluded for high technical complexity and limited contribution to core objectives; the remaining alternatives were consolidated into the five final features.

Table 3. Decision matrix for design-alternative selection.

No.	Design alternative	Alignment (1–5)	Feasibility (1–5)	Decision
1	Waste pickup scheduling	5	5	Selected
2	Community forum	5	4	Selected
3	Collector map	5	4	Selected
4	Reward-point estimation	4	4	Selected
5	Transaction management	4	4	Selected
6	E-commerce integration	2	1	Excluded
7	Waste-auction service	1	1	Excluded

The selected concepts were translated into an information architecture (sitemap and user flows) as the basis for prototyping.

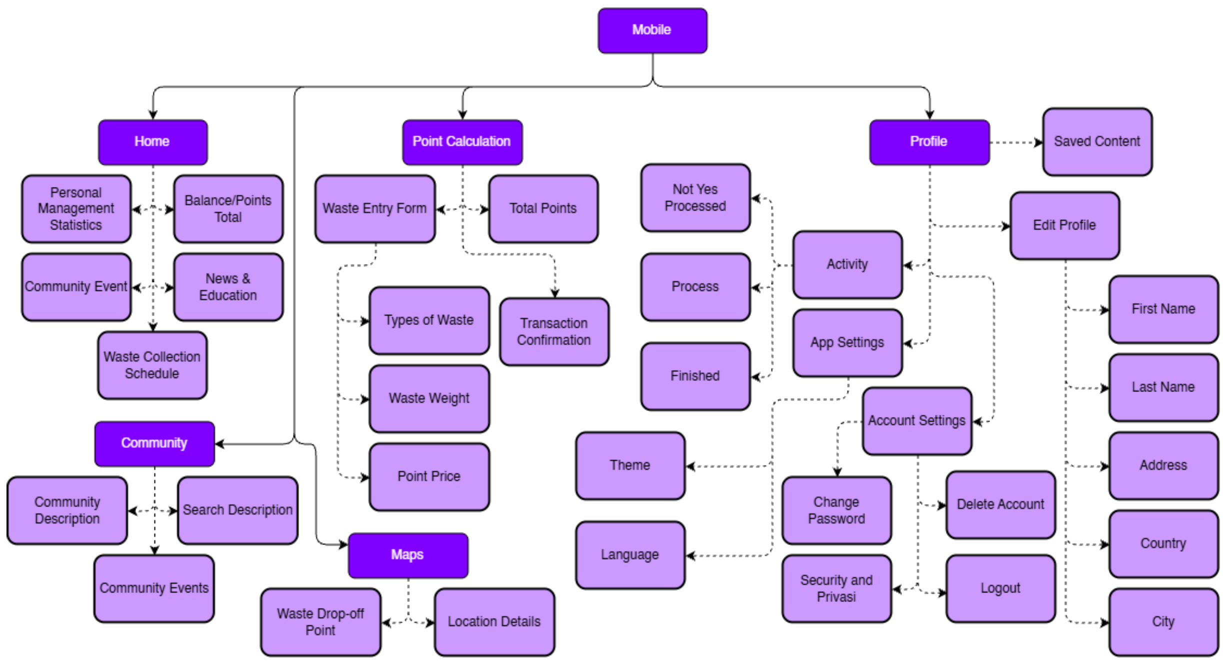

Figure 1. Sitemap of the Resikel Application.

Figure 2. User Flow of the Resikel Application.

The developed user flows provide a clear interaction sequence for each feature and serve as the basis for interface prototyping.

D. Prototype Stage

A low-fidelity prototype in Figma first validated the information structure and navigation across the core interfaces (login, sign-up, homepage, reward calculation, pickup scheduling, collector map, community forum, profile, and password management), focusing on layout and interaction flow without detailed visuals. The high-fidelity prototype (eleven screens) then added color, typography, icons, and illustrations. One internal design refinement was performed based on internal (designer) evaluation, not user feedback: the initially equal emphasis on the Pickup and Self-Delivery options was revised to give Pickup a stronger visual hierarchy, with additional adjustments to spacing, typography, and alignment.

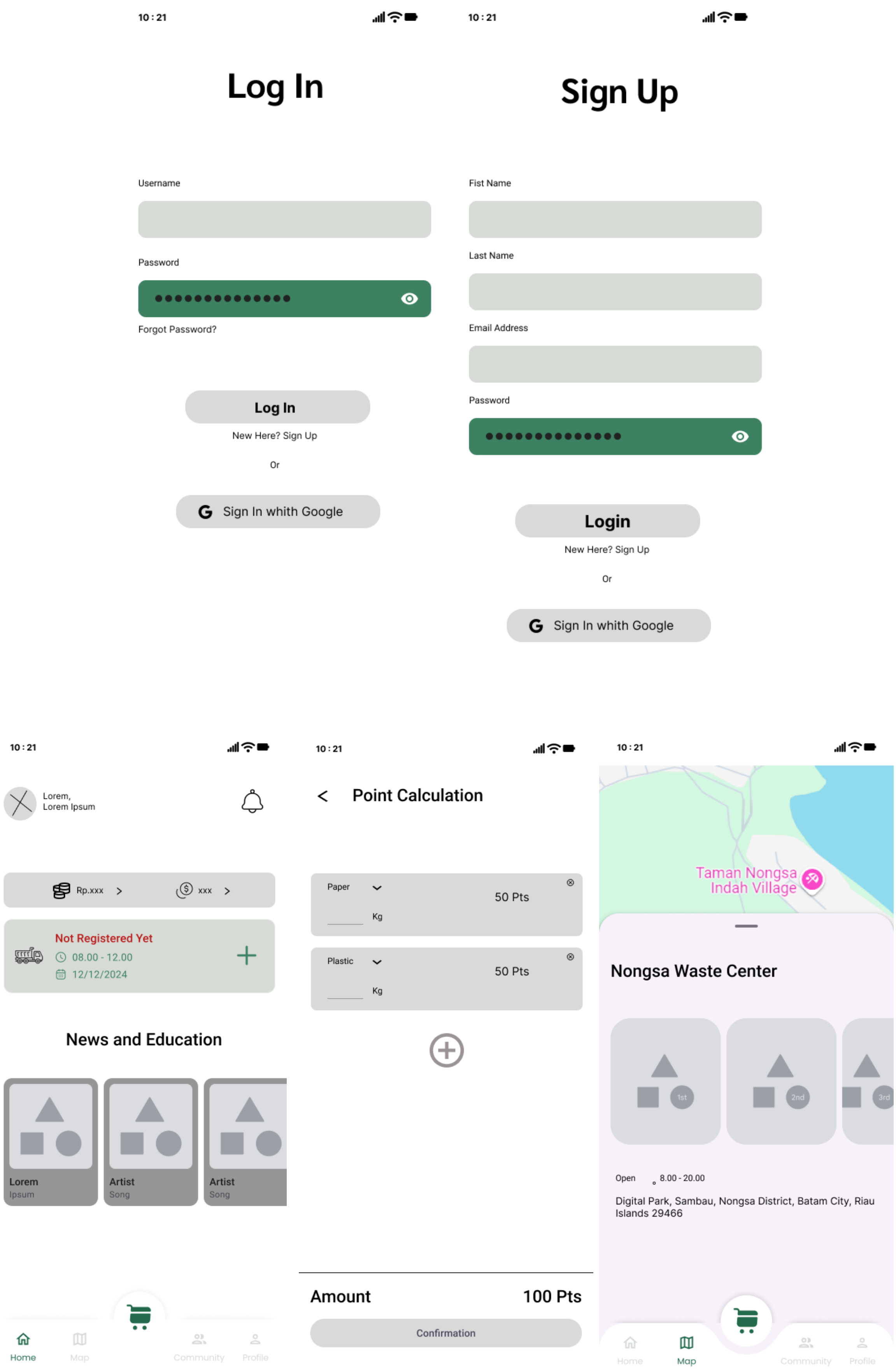

Figure 3. High-Fidelity Prototype.

E. Respondent Characteristics

The usability evaluation involved 100 respondents who successfully completed all assigned tasks using the Maze platform. The demographic characteristics and prior experience of the respondents are presented in Table 4.

Table 4. Respondent Characteristics

Characteristic	Category	Number	Percentage
Age	≤ 20 years old	11	11%
	21–30 years old	44	44%
	31–40 years old	39	39%
	41–50 years old	6	6%
Occupation	Entrepreneur	29	29%
	Private Sector Employee	21	21%
	Civil Servant	16	16%
	University Student	16	16%
	Student	15	15%
	Others (freelance, services)	3	3%
Experience with digital waste bank applications	Have used before	66	66%
	Have never used before	34	34%

F. Task-Based Usability (Maze)

The 100 respondents completed the predefined task scenarios on Maze. Table 5 summarizes task-level performance.

Table 5. Maze task-based usability results (n = 100).

Task scenario	Success rate (%)	Avg. completion time (s)	Misclicks	Drop-offs
Register & login	96	28	0.3	4%
Schedule a pickup	93	44	1.0	7%
Reward calculation	87	76	2.4	13%
Find collector on map	91	53	1.5	9%
Post in community forum	95	35	0.7	5%

Across scenarios, the reward calculation task showed the weakest performance. Specifically, 13 of 100 respondents (13%) experienced difficulty on the reward-calculation task, operationally defined as failure to complete the task (drop-off) or deviating from the expected path in Maze log. They expected an automatic real-time calculation rather than manual confirmation, indicating a target for future automated reward calculation.

G. SUS Results

The average SUS score obtained from all respondents was 78.2, with the highest score reaching 100 and the lowest score 67.5.

Table 6. Summary of SUS Results

Statistic	Value
Average Score	78.2
Highest Score	100
Lowest Score	67.5
Standard Deviation	6.70

The mean SUS score of 78.2 (SD = 6.70) falls within the Good adjective rating and the Acceptable range, exceeding the commonly cited benchmark of 68 [21], [22]. SUS measures perceived usability only; the result should not be interpreted as evidence of operational effectiveness, technical performance, or long-term adoption. As noted in Section 3.E (Data Analysis and Evaluation), item-level reliability and a confidence interval could not be computed from the retained aggregate data and are recommended for future evaluations.

H. Discussion

The Design Thinking process supported a user-centered interface in which needs from the Empathize stage were translated into interface solutions and evaluated through task-based and SUS testing. The SUS score of 78.2 indicates good perceived usability; differences from prior studies may reflect variation in application complexity, functional scope, and respondent characteristics. Resikel integrates five modules within a single platform, which can affect perceived complexity. Task analysis identified reward calculation as the primary usability challenge, motivating automated calculation in future development. Limitations include evaluation of a high-fidelity prototype rather than a functioning application (so performance, response time, and operational errors were not assessed); a single, unmoderated, cross-sectional testing session; a respondent pool generally familiar with smartphones; and the absence of a baseline design or controlled before–after comparison. These bound the generalizability of the findings, particularly for older or less digitally experienced users.

5. Conclusions

This study designed a user-centered UI/UX for a high-fidelity Resikel Android prototype and evaluated its perceived usability using SUS within the Design Thinking framework. The process produced an eleven-screen prototype supporting authentication, waste pickup scheduling, reward estimation, collector-location services, and community interaction. Task-based testing and a mean SUS score of 78.2 (SD = 6.70) among 100 respondents indicate a good level of perceived usability within the Acceptable range for the sampled respondents. The evidence supports favorable perceived usability for one prototype under an unmoderated, single-session, non-probability sampling protocol; it does not establish that the interface is optimized or ready for deployment, and no baseline comparison or implemented Android system was evaluated.

Future work should implement the prototype as a functioning Android application and re-evaluate it in real-world scenarios with more diverse users, including older and less digitally experienced groups, and should report item-level SUS reliability and confidence intervals. Camera-based waste recognition using computer vision is suggested cautiously as a future enhancement, since it was not examined in this study.

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