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Application of the design thinking method in the development of the Zero Left application for waste management

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Abstract:
According to data from the Coordinating Ministry for Human Development and Culture, an estimated 7.2 million tons of waste remained unmanaged in 2023, with the figure projected to rise to 11 million tons by 2024. Furthermore, the National Waste Management Information System (SIPSN) under the Ministry of Environment and Forestry (KLHK) reported that as of July 24, 2024, the cumulative volume of national waste had reached 31.9 million tons, based on input from 290 regencies and municipalities across Indonesia. Among the most prevalent waste types are plastic and food waste. Despite the growing volume, public awareness regarding proper waste management practices remains insufficient. In response to this issue, the present study proposes the design of an integrated waste management application, developed using the design thinking methodology. Evaluation of the application through the System Usability Scale (SUS) revealed a high usability score of 91.5 out of 100, as assessed by 19 respondents. The application, named Zero Left, is grounded in Jakob Nielsen's Usability Heuristics for User Interface Design and includes features such as recycling services, waste transportation, landfill navigation, and a points-and-rewards system. It is expected that Zero Left will encourage greater public participation in fostering a cleaner and healthier environment.

Introduction

The waste issue in Indonesia has grown more concerning as the annual amount of generated waste continues to increase. Data from the Coordinating Ministry for Human Development and Cultural Affairs (Kemenko PMK) shows that 7.2 million tons of waste were left untreated in 2023, and this number surged to 11.3 million tons the following year (Pristiandaru, 2024). According to the Ministry of Environment and Forestry's National Waste Management Information System (SIPSN), data from 290 cities and regencies as of July 24, 2024, indicated that Indonesia produced 31.9 million tons of waste nationally. Of this amount, 63.3% (or 20.5 million tons) was successfully processed, while the remaining 35.67% (11.3 million tons) was not handled properly, leading to excessive waste buildup and environmental pollution (Ratnasariningsih et al., 2024). The emergence of this issue is inherently connected to the consumer-oriented behavior prevalent among the public.

Given the significant volume of improperly managed waste, active community involvement is essential in mitigating its growth (Girsang & Situmeang, 2023). Community participation awareness is a key determinant in assessing environmental quality, particularly in waste management. When public consciousness regarding environmental preservation is low, the likelihood of ecological degradation and harm increases significantly (Agustin et al., 2022). Community concern plays a vital role in the household waste management process, as it directly supports governmental efforts in addressing environmental challenges.

Among the various types of waste, plastic and food waste are the most prominent. Plastic, being a man-made inorganic material, consists of chemical elements that can be highly detrimental to environmental health (Alfirahmi et al., 2023). Plastics, which are derived from petrochemical substances, have been shown in scientific studies to contain compounds that are harmful to human health. When plastics are left to decompose, incinerated, or improperly disposed of, they break down into toxic elements. Over time, these substances contaminate the soil, water, and air, eventually being absorbed by flora and fauna. This can lead to serious health issues such as congenital disorders, hormonal disruptions, and even cancer. Moreover, if plastic waste reaches rivers or oceans, it can severely disrupt and damage aquatic ecosystems. (Majida et al., 2023).

Improperly managed food waste undergoes decomposition, releasing methane gas a potent greenhouse gas that significantly accelerates climate change (Wiranata et al., n.d.). Food waste has emerged as a growing global concern due to its detrimental effects on the environment. The combination of increasing population and shifting lifestyles has led to a surge in food waste generation, contributing to soil and water contamination, greenhouse gas emissions, and the depletion of valuable resources (Zuhra & Angkasari, 2023). Food waste contributes approximately 6% to 8% of the total greenhouse gas emissions generated by human activities. (Aalfakihuddin et al., 2022). Decomposing food waste emits methane, a greenhouse gas that is approximately twenty times more powerful than carbon dioxide. With rising food consumption globally, this environmental threat is expected to escalate in the near future. As a result, it is essential to implement strategies that enhance public awareness regarding the ongoing and large-scale waste crisis.

The swift advancement of technology over the years has significantly facilitated information dissemination, improved communication, and enabled the creation of advanced optimization tools (Al-Faruq et al., 2022). Integrated technology offers potential solutions for addressing waste management challenges. One such approach involves utilizing applications as a platform. In developing these applications, a well-designed User Interface (UI) and User Experience (UX) are essential to ensure user convenience and seamless interaction with the product or service (Haryuda et al., 2021). Consequently, the development of waste management applications represents a relevant and practical innovation for addressing this issue.

The design of the *Zero Left* application is intended to address existing waste related issues by enhancing public awareness of proper waste management, with a strong emphasis on meeting user needs (Putra and Ma 2024). One of the key concepts implemented in this design is gamification through a reward system, which serves as the *Zero Left* application's unique selling proposition compared to its competitors. The development process adopts the **design thinking** methodology, while data is collected through surveys and observations, indirectly referencing competitor applications. To evaluate the application's effectiveness, the **System Usability Scale (SUS)** is employed at the final stage of the design thinking process.

Method

This study employs the design thinking approach as introduced by Tim Brown (2008). The method involves an iterative process consisting of several stages that aim to understand users, identify their problems, and explore potential solutions allowing the researcher to frame the issue from a specific perspective. Through this process, design thinking facilitates idea generation and the development of innovative solutions via hypothesis testing and prototyping (Nasution & Nusa, 2021).

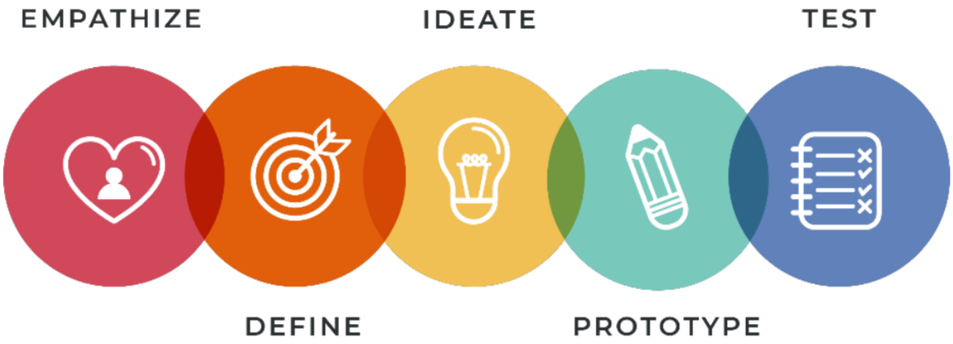


Figure 1. Stages of Design Thinking Method

Figure 1 illustrates the five phases of the design thinking process: empathize, define, ideate, prototype, and test. Each phase builds upon the previous one, forming a structured progression. Nevertheless, due to the flexible nature of design thinking, these stages are not strictly linear and may be revisited or rearranged depending on the needs of the design process.

Stages of Design Thinking Research Method

Empathize

The Empathize phase is intended to develop a deep understanding of users by exploring their needs, preferences, and behaviors. During this initial stage, researchers gather data directly through methods such as field observations and surveys to establish a comprehensive view of the user experience.

Define

In the **Define** phase, researchers interpret and analyze data collected during the Empathize stage to articulate the core problems experienced by users. By identifying patterns and trends from observations and survey results, they can classify the most relevant issues and establish a solid basis for developing more focused and effective solutions.

Ideate

The **Ideate** phase involves generating creative ideas as responses to the problems identified in the previous stages. Methods such as brainstorming are employed to explore a wide range of potential solutions. From these ideas, researchers select the most promising and user relevant options to guide the prioritization of the design and development process.

Prototype

The **Prototype** phase focuses on developing an early version or visual model of the proposed solution. In this stage, researchers utilize methods such as user flows, wireframes, and mockups to construct a prototype that can be tested. These prototypes function as tools to validate ideas and reduce the likelihood of failure prior to full-scale development. Evaluation is conducted through observation and analysis to identify the prototype's effectiveness and limitations before it is released to a broader audience.

Test

In the Test phase, the prototype is evaluated directly by users to determine its functionality and overall quality. A total of 19 prospective users participated in this stage, and feedback was gathered through survey instruments. To assess system usability, the System Usability Scale (SUS) method was applied a standardized questionnaire designed to evaluate ease of use from the user's perspective.

The SUS results serve as a reference point for refining the system's performance and enhancing user comfort.

Results and Discussion

The following section presents the outcomes derived from implementing the Design Thinking methodology in the development of the Zero Left application. This approach facilitated the identification of core issues, the formulation of effective solutions, and the stimulation of user-centered innovation. By employing the Design Thinking framework, the author was able to gain a comprehensive understanding of user needs, preferences, and challenges. Each stage of the process was conducted thoroughly to ensure that the Zero Left application delivers solutions that are both relevant and impactful for its users.

Implementation of Design Thinking

Empathize

At this stage, the author independently collected data using observation and survey methods, the latter conducted via Google Forms distributed to the target audience. The main objective of this activity was to gain an in-depth understanding of audience needs, allowing the author to accurately identify their problems and expectations.

The observational research involved analyzing similar existing applications to identify research gaps. The first application reviewed was BankSampah.id, a nationwide integrated waste management platform. Its strengths include broad regional reach and features such as waste transaction records, location-based bin information, and educational content. However, its weaknesses include an unappealing interface and recycling features that are not uniformly accessible across all regions.

The second application studied was Simba, developed by the Indonesian Ministry of Environment and Forestry (KLHK) for national waste management. Its advantages lie in government support and access to reliable data, while its drawbacks include limited functionality, minimal interactivity, and an overly simplistic interface design.

The third application examined, Pemol, facilitates the collection of both organic and non-organic waste, allowing users to request waste pickups through the app. Its key strengths include scheduled waste collection and a strong emphasis on recycling. However, the application is limited by its narrow geographic coverage and the lack of a navigation feature to guide users to nearby disposal sites.

From the comparative analysis above, the author identifies a clear research gap. The Zero Left application is designed to provide a comprehensive solution to waste-related issues, specifically addressing both food and plastic waste. This direction is validated by a preliminary survey conducted with 50 respondents, where 42% were individuals aged 21–25, mostly students, representing a highly productive demographic. Furthermore, 63% of respondents expressed interest in participating in recycling efforts, citing their awareness of its positive environmental impact. Zero Left integrates features such as recycling and waste pickup services, navigational support to locate the nearest landfill, and tools to simplify the waste processing experience. Through this application, users gain not only practical benefits in managing waste but also contribute positively to environmental sustainability and the broader community.

Define

At this stage, the author maps the results of observation and survey data to focus on the core problems and goals of this design. Plastic waste and food *waste* are the most dominant types of waste. Plastic waste is difficult to decompose, polluting the soil and the sea. Meanwhile, food waste that is not managed properly will decompose and produce 10% of the world's greenhouse gas emissions. The community needs innovative solutions that can encourage them to care more about the environment by knowing good and correct waste management.

The use of digital technology can be one of the effective ways to increase awareness, facilitate, and motivate the community in waste management. Therefore, an application is needed that can help the community understand, sort, and recycle waste effectively. And the design of the Zero Left application is a step in describing these problems.

Ideate

The next stage is Ideate, where researchers generate ideas and solutions based on user problems identified in the previous stage. The Zero Left application aims to help the community manage waste better and there are several interesting features as follows: first, recycling, This feature provides recycling services for organic waste and non-organic waste. Users can use this feature to be able to separate and submit their waste for recycling. Both of these features offer garbage pick-up services. Users can make an appointment for their garbage pickup, making it easier to dispose of their garbage responsibly. Third, navigation, this feature helps users find the nearest dump. This makes it very easy for users who want to dispose of garbage quickly and easily. For the four points/rewards, users who participate in the recycling and waste transportation process will get points or rewards. These points can be redeemed for various attractive prizes, such as balances, new products, or shopping discount vouchers that can be donated to those in need.

Prototype

The prototyping phase constitutes a critical stage within the design thinking methodology applied in this study. At this juncture, a preliminary model or prototype is constructed to represent the conceptual framework established in the earlier phase. This approach facilitates the refinement and empirical evaluation of proposed solutions prior to their full-scale implementation. Accordingly, a series of methodical steps must be undertaken to ensure the effectiveness of the prototyping process:

1. Userflow

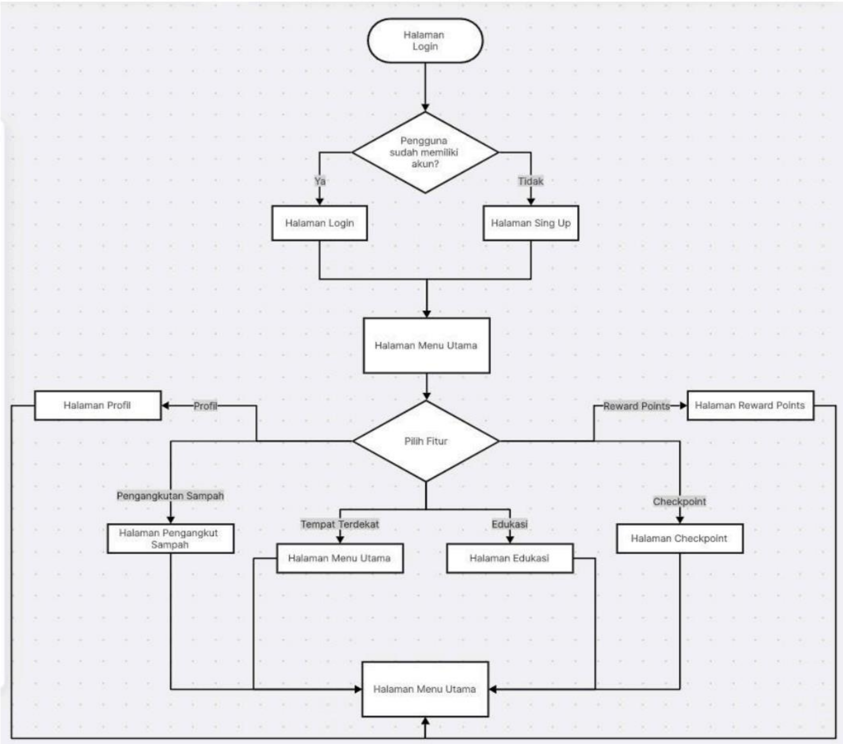


Figure 2. User Flow (Source: personal documentation)

At this stage, the researcher developed a user flow diagram to depict the sequential interactions users undertake when navigating the Zero Left application. This diagram is intended to offer a comprehensive and structured visualization of user behavior, thereby enhancing user comprehension and ease of navigation throughout the application's features. Through this representation, users are expected to follow the application flow intuitively, ultimately improving their overall experience. Furthermore, the user flow diagram enables the researcher to systematically map user interactions and identify potential usability issues. The complete user flow is presented in Figure 2.

2. UserPersona

In this phase, a user persona was developed to serve as a representative profile of the target user for the proposed application. This persona functions as a reference point to better understand user needs, behaviors, and expectations throughout the design process. The constructed user persona is illustrated in Figure 3.

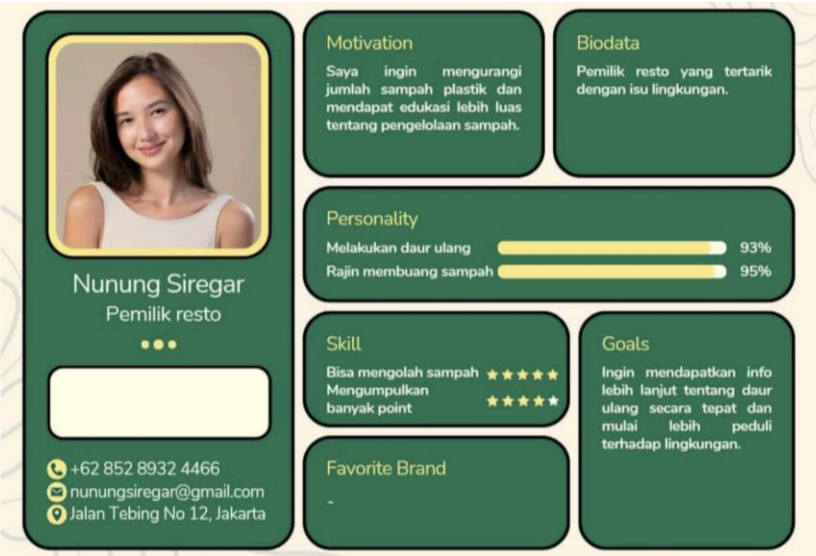
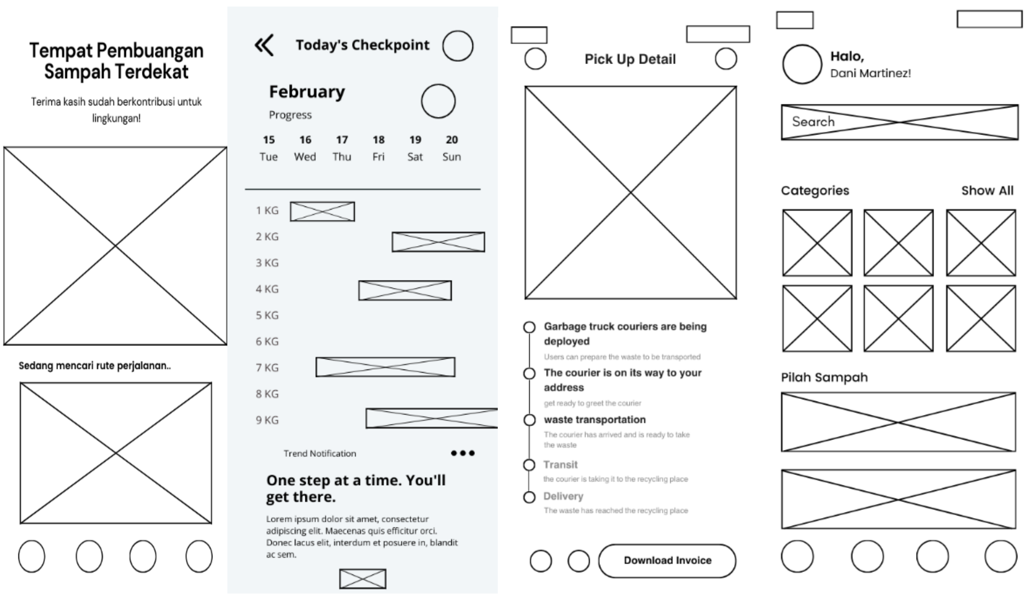


Figure 3. User Persona (Source: personal documentation)

3. Wireframe



Gambar 4. Beberapa tampilan wireframe low fidelity (Sumber: dokumentasi pribadi)

At this stage, the author developed an initial sketch of the Zero Left application's user interface, presented as a low-fidelity wireframe (see Figure 4). This preliminary design focuses primarily on layout and functionality rather than detailed visual aesthetics. Wireframes serve to validate the structural composition of the interface, ensuring alignment with user requirements before incorporating advanced visual components. Key interface elements such as buttons, navigation menus, and other functional components are outlined to provide a clear representation of the application's foundational design.

4. Mockup / Final Prototype

In this phase, a more refined and comprehensive prototype of the Zero Left application interface was developed. The primary objective of this prototype is to evaluate and visually represent the conceptual ideas formulated in earlier stages. During the mockup creation process, meticulous attention was given to visual elements such as color schemes, typography, and the proportionality of interface components. The interface design adopts a minimalist approach, incorporating visual elements like icons, navigation bars, and cards, aligned with Jakob Nielsen's usability heuristics to enhance user comprehension and interaction. The color palette is categorized into primary and secondary tones. The primary colors consist predominantly of dark green complemented by white, while the secondary colors include variations of greenish white and greenish gray. The complete mockup can be seen in Figure 5.

Figure 5. Some mockup/final prototype images (Source: personal documentation)

Following the prototyping phase, a comprehensive UI/UX design for the Zero Left application was successfully developed through the integration of user flow diagrams, wireframes, and mockups. At this stage, the design was subjected to an evaluative process involving end users, with the aim of gathering constructive feedback and suggestions to enhance the overall quality of the application interface. The evaluation was conducted by distributing questionnaires, enabling the researcher to assess the extent to which the interface aligns with user needs and expectations.

5. Compatibility with Jakob Nielsen's Usability Heuristics for User Interface Design Theory

This theoretical framework emphasizes that heuristic evaluation involves assessing user needs and identifying which elements of the user interface are effective or problematic. The goal is to inform design decisions that enhance usability by distinguishing between beneficial and detrimental interface components. (Indrayan Septiandi et al., 2024). The Usability Heuristics for User Interface Design framework enables the identification of critical usability issues that are often overlooked by other evaluation methods. This approach is recognized for its efficiency, as it can reveal a greater number of usability problems at a relatively low cost. Additionally, heuristic evaluation offers practical advantages, including its intuitive nature, minimal need for complex planning, and the ability to be conducted without requiring specialized training in usability (Girdayanto et al., 2022). The following is a description of the application of theory to planning:

a. Visibility of System Status
The Zero Left application demonstrates adherence to this principle through interactive functionalities, such as waste drop-off navigation and scheduled pick-up features. These allow users to monitor the current status of their actions—such as whether a pick-up is scheduled or underway by providing real-time feedback, which contributes to a greater sense of user awareness and system transparency.

b. Match Between System and the Real World
The application utilizes terminology familiar to users, including recycling, transport, and reward, which mirror real-world household waste management activities such as sorting, transferring, and exchanging points. The language employed is contextually grounded in everyday usage, ensuring better user comprehension.

c. User Control and Freedom
Features like customizable pick-up scheduling empower users to define their preferred times for service, reflecting the principle of user autonomy. This flexibility reduces feelings of restriction and enhances user satisfaction by supporting individualized control over interactions.

d. Consistency and Standards
Visual elements within the application are consistently aligned with usability heuristics, as seen in the uniform application of environmental colors (predominantly green) and standardized UI components such as buttons, icons, and navigational structures. This consistency supports user learning and reduces cognitive load across different screens.

e. Error Prevention
Error prevention is addressed through a clearly structured design process that includes user flows, wireframes, and mockups. These elements guide users through predefined, intuitive pathways, thereby reducing the likelihood of confusion or incorrect actions from the outset.

f. Recognition Rather Than Recall
The user interface is designed with simplicity and familiarity in mind, incorporating recognizable icons such as trash bins and transport trucks. This visual approach reduces reliance on memory and facilitates immediate recognition of core functions, improving usability for both new and returning users.

g. Flexibility and Efficiency of Use
Zero Left incorporates a point-and-reward system adaptable to various user behaviors. For frequent users, this system increases motivation and efficiency by offering incentives for continued engagement. For newcomers, the interface remains accessible and easy to navigate.

h. Aesthetic and Minimalist Design
The interface adopts a clean and focused design, dominated by green and white tones. The restrained use of visual elements avoids unnecessary clutter, allowing users to concentrate on key actions such as selecting waste types or disposal locations without distraction.

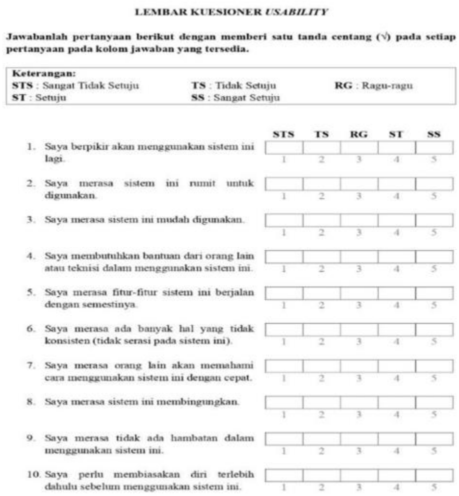
i. Help Users Recognize, Diagnose, and Recover from Errors
Although not explicitly described, this principle is reflected in the application's iterative development process, which includes System Usability Scale (SUS) testing and direct user evaluations. These methods provide valuable feedback that helps identify usability issues and enables continuous refinement of the interface.

j. Help and Documentation

Although the user documentation is not explicitly explained, the prototype developed through wireframe and mockup stages shows that the application was designed with the user's information needs in mind. If further developed, help and documentation features can certainly be added so that users can easily access the guide if they experience confusion.

6. Test

System Usability Scale (SUS) is a widely used tool to evaluate the usability or usability of survey-based systems. SUS is simple, reliable, and has been proven to provide a quick evaluation of the user experience with various types of products, both software and hardware (Kurniawan et al., 2022). System Usability Scale (SUS) is a tool used to measure the usability of a system, product, or service. This is a rating scale that is often used to evaluate the extent to which users can easily use the system or product, how effective they are in achieving their goals, and user satisfaction with the user experience (Hiu & Erlyana, 2024). Users are asked to provide a rating based on a Likert scale consisting of five answer choices, Each question item uses a five-point scale, where respondents rate each statement from 1 to 5. To get the overall SUS score, add up the scores of each question and multiply it by 2.5. The final score of the SUS will be in the range of 0 to 100, where the higher the score obtained indicates the better level of usability of the system or product. The statement in the SUS includes aspects such as simplicity of use, ease of learning, user trust in the system, and the user's desire to use the system in the future. The SUS score is calculated based on statements answered by the user and can provide an overview of the overall user satisfaction with the system being evaluated. By using SUS, developers or researchers can gain valuable insights into the user experience and identify areas of improvement needed to improve the usability of the system (Ansori et al., 2023).



LEMBAR KUESIONER *USABILITY*

Jawabanlah pertanyaan berikut dengan memberi satu tanda centang (√) pada setiap pertanyaan pada kolom jawaban yang tersedia.

Keterangan:
STS : Sangat Tidak Setuju **TS** : Tidak Setuju **RG** : Ragu-ragu
ST : Setuju **SS** : Sangat Setuju

	STS	TS	RG	ST	SS
1. Saya berpikir akan menggunakan sistem ini lagi.	1	2	3	4	5
2. Saya merasa sistem ini rumit untuk digunakan.	1	2	3	4	5
3. Saya merasa sistem ini mudah digunakan.	1	2	3	4	5
4. Saya membutuhkan bantuan dari orang lain atau teknisi dalam menggunakan sistem ini.	1	2	3	4	5
5. Saya merasa fitur-fitur sistem ini berjalan dengan semestinya.	1	2	3	4	5
6. Saya merasa ada banyak hal yang tidak konsisten (tidak serasi pada sistem ini).	1	2	3	4	5
7. Saya merasa orang lain akan memahami cara menggunakan sistem ini dengan cepat.	1	2	3	4	5
8. Saya merasa sistem ini membingungkan.	1	2	3	4	5
9. Saya merasa tidak ada hambatan dalam menggunakan sistem ini.	1	2	3	4	5
10. Saya perlu membiasakan diri terlebih dahulu sebelum menggunakan sistem ini.	1	2	3	4	5

Figure 6. Usability Questionnaire Sheet (Source: Soni Ansori Journal)

The method of calculating the SUS Score, which is the sum multiplied by 2.5, will produce the SUS Score, the next step is to calculate the SUS Final Score with the following formula:

$$\bar{x} = \frac{\sum x}{n}$$

Keterangan :
$\bar{x}$: Nilai Rata-rata
$\sum X$: Jumlah Skor
n : Total Responden

Figure 7. Final calculation formula for SUS score (Source: Soni Ansori Journal)

Table 1. SUS calculation

user	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUM	X 2,5	FINAL
User 1	4	2	4	3	5	1	5	2	5	4	35	87,5	
User 2	5	2	5	2	5	1	4	1	4	4	33	82,5	
User 3	5	2	4	2	4	2	5	1	5	3	33	82,5	
User 4	5	5	5	5	5	5	5	5	5	5	50	125	
User 5	4	2	4	4	4	4	3	2	4	4	35	87,5	
User 6	4	2	4	1	4	2	4	1	5	1	28	70	
User 7	4	4	4	4	3	4	4	4	3	5	39	97,5	
User 8	5	5	5	5	5	5	5	5	5	5	50	125	
User 9	4	3	3	4	4	3	4	3	4	4	36	90	
User 10	4	2	5	2	5	3	4	1	4	4	34	85	
User 11	5	1	5	1	4	2	4	2	4	2	30	75	
User 12	4	2	4	2	4	3	4	2	4	4	33	82,5	
User 13	4	2	4	5	4	2	4	2	4	2	33	82,5	
User 14	4	5	4	5	3	4	3	4	4	4	40	100	
User 15	5	4	5	1	5	2	5	1	5	5	38	95	
User 16	4	3	5	2	4	1	5	1	4	4	33	82,5	
User 17	4	4	5	4	4	5	5	5	5	4	45	112,5	
User 18	4	2	4	2	4	2	3	2	4	4	31	77,5	
User 19	4	4	4	2	5	2	4	2	4	5	36	90	
											692	1730	1730:19=91,05

Based on the results of testing the Zero Left application UI/UX prototype to 19 respondents, it was found that the final score of the System Usability Scale (SUS) reached 91.5/100. These results indicate that users have a positive perception of the usability of this application prototype.

Conclusion

Based on the findings of research that has been carried out by testing prototypes through the SUS (System Usability Scale*)* technique in the design of the Zero Left application, this application received a score of 91.5/100, which can be seen in table 1. This is of course supported by the stages in the design thinking research method, which include empathize, define, ideate, prototype, and test. The Zero Left application is here as a digital solution that helps the community in sorting, recycling, and managing waste more effectively. With features such as recycling services, garbage transportation, landfill navigation, and points and reward systems, Zero Left is expected to increase community participation in efforts to maintain a cleaner and healthier environment.

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