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DEVELOPMENT OF SMARTPHONE WASTE MANAGEMENT PLATFORM USING DESIGN THINKING APPROACH TO SUPPORT IMPLEMENTATION OF EXTENDED PRODUCER RESPONSIBILITY (EPR) IN INDONESIA'S SMARTPHONE INDUSTRY

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ABSTRACT

Indonesia generated approximately 1.9 million tons of electronic waste (e-waste) in 2021, growing at an annual rate of 39%. By 2030, e-waste generation is projected to reach 4.4 million tons. A study by the National Development Planning Agency (Bappenas) revealed that only 17.4% of e-waste was recycled in 2021, highlighting the inefficiency of Indonesia's current e-waste management system. Smartphones are the most frequently disposed of e-waste, with an average lifespan of 3.42 years—shorter than most electronic devices. By 2028, over 40 million discarded smartphones are expected to significantly contribute to e-waste. To address this, the Indonesian government introduced a circular economy roadmap through Regulation No. 75 of 2019, mandating Extended Producer Responsibility (EPR). However, its implementation has been suboptimal, hindered by limited collaboration among stakeholders. Effective smartphone waste management requires awareness, clear procedures, secure data handling, and practices that maximize economic value. This study involves key stakeholders—consumers, producers, waste managers, and government representatives—to co-design solutions using a design thinking approach. The research delivers a smartphone waste management prototype, comprising a service blueprint and a high-fidelity platform, to support value exchange and improve EPR implementation in the smartphone industry.

Keywords: ***Design Thinking, Circular Economy, Smartphone Electronic Waste, Extended Producer Responsibility (EPR), Platform***

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INTRODUCTION

This research aims to design a solution for smartphone waste management in Indonesia using a design thinking approach based on circular economy principles. Electronic waste, particularly smartphone waste, is rapidly increasing along with technological advancements that drive the use of new products and shorten the lifespan of old products. With projections of electronic waste in Indonesia reaching 12,187 tons per day by 2030, the urgent challenge of managing this waste must be addressed to prevent further environmental damage (Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, 2023).

Smartphone waste rapid growth is largely influenced by the obsolescence of the product due to ongoing technological innovations. Smartphone global usage and circulation is predicted to reach 4.45 billion units worldwide in 2022 (Gartner, 2021). In 2022, over 62 million tons of electronic waste were produced globally, but only 22.3% was collected and recycled. In Indonesia, the e-waste recycling rate remains far below the global average, at just 17.4%, indicating a significant imbalance between the amount of waste generated and the existing waste management capacity (The Global E-waste Monitor, 2024).

Notable among the challenges in managing electronic waste in Indonesia is the lack of effective coordination and collaboration among key stakeholders. This problem includes a lack of consumer awareness (Raharjo et al., 2021), the absence of producer responsibility and Extended Producer Responsibility (EPR) for electronic equipment in Indonesia (Wilyani et al., 2018), and limited parties with adequate infrastructure for e-waste management (Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, 2023). These issues lead to inefficient and disorganized e-waste management, hindering efforts to reduce environmental impacts (Direktorat Industri Elektronika dan Telematika Kementerian Perindustrian Republik Indonesia, 2021).The circular economy approach offers a transformative solution to tackle these pressing challenges. It emphasizes waste reduction, reuse, and recycling of raw materials to maximize the efficiency of limited resources (Holuszko, et al, 2021). In the context of smartphone waste, this approach can significantly extend product lifespans and reduce the reliance on new materials. The key pillar of circular economy is the collaboration among all stakeholders in the product lifecycle, including consumers, producers, and waste management companies. Moreover, it aligns with policies such as Extended Producer Responsibility (EPR), which requires producers to take accountability for the waste generated by their products. A good EPR implementation could solve overall electronic waste management, however, EPR has yet to be effectively implemented in Indonesia, hindering the full potential of this approach in addressing the growing e-waste problem (Wilyani et al., 2018).

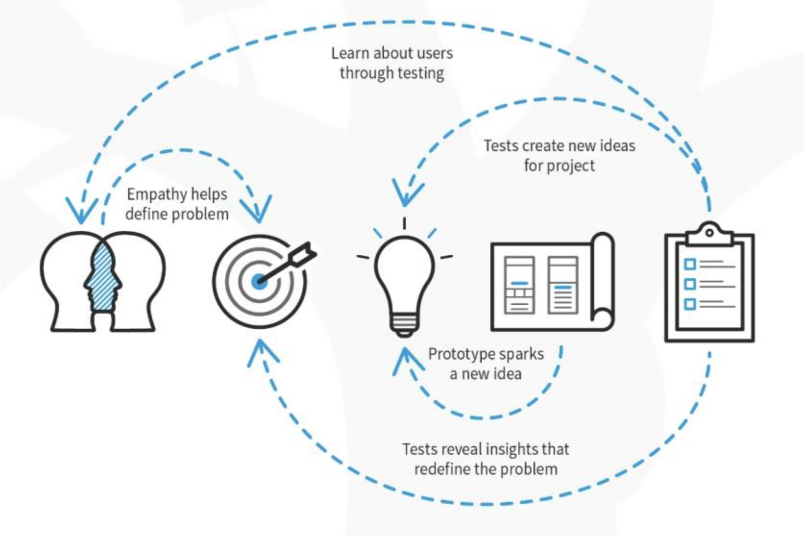
This research aims to deliver practical benefits for smartphone waste management in Indonesia by providing integrated solutions that improve recycling efficiency and enable the reuse of recycled materials in smartphone production. This approach reduces reliance on finite natural resources, minimizes environmental pollution, and extends product lifespans. Additionally, the findings may serve as a foundation for developing waste management models applicable to other technology sectors, advancing the adoption of circular economy principles across industries. By promoting stakeholder collaboration and sustainable practices, the research seeks to enhance the electronic recycling rate, create economic value from waste materials, and mitigate the environmental impact of smartphone waste in Indonesia. Ultimately, it offers both theoretical and practical contributions to e-waste management and circular economy implementation.

LITERATURE REVIEW

This research adopts a design thinking approach, which has proven effective in creating stakeholder-focused solutions. Design thinking offers a framework that enables stakeholders to collaborate in formulating innovative solutions that address the needs and challenges of each party. The phases of design thinking—empathize, define, ideate, prototype, and test—provide a holistic approach to understanding the problem and designing inclusive solutions that are acceptable to all stakeholders (Interaction Design Foundation, 2024). Moreover, the study conducted by Baldassarre et al. (2021) explores responsible design thinking as a framework for advancing sustainability in the context of circular economy implementation. Through the design thinking approach, this research aims to create more creative and inclusive solutions for smartphone waste management.

Design thinking is a systematic approach to problem-solving and creating innovative solutions by focusing on a deep understanding of users and the problem context. The stages of design thinking are iterative. The results from the test stage often lead to new insights about users and the problem, which then trigger a revisit to the empathize, define, or ideate stages. This process repeats until the solution effectively meets user needs and solves the problem. The goal of these design thinking stages is to create innovative solutions that are user-centered and relevant to the users' needs.

Figure 1. Design Thinking Stages (Interaction Design Foundation, 2024)



As part of the research objective, the research output is to develop a technology-based platform that enables stakeholders to collaborate more effectively. Through this platform, consumers can easily return their old devices for recycling, producers can monitor and manage the waste generated, and collectors and waste management companies can carry out recycling processes more efficiently. Stronger integration between these parties will increase transparency, reduce costs, and improve the effectiveness of waste management processes, platform approach supports a circular economy that connects the e-waste management ecosystem for reuse, repair, refine, or recycle activities (MIT Management Sloan School, 2023).

Platform-based business models are well-suited to support the circular economy due to their ability to connect various stakeholders in a mutually beneficial ecosystem, including consumers, producers, collectors, and waste managers. Platforms provide a means for interaction and collaboration among these parties, enabling the exchange of information, resources, and sustainable products. In the circular economy, the primary goal is to maximize the value of existing resources and minimize waste, which aligns with the platform's role in creating a network of users who can contribute to one another. For example, a platform can facilitate recycling programs by connecting consumers who wish to recycle their devices with recycling service providers, promoting active participation and awareness of sustainability. By utilizing data from user interactions, platforms can also enhance efficiency and foster innovation in recycling processes and product maintenance, thereby supporting the overall goals of the circular economy (Geissdoerfer et al., 2018; Ranta et al., 2018).

Digital platform supports the circular economy by enhancing resource efficiency and sustainability by facilitating circular business models and promote sustainable practices among businesses and consumers (Sloth et al., 2024). Digital platforms can overcome existing barriers in the circular economy; however, specific requirements such as platform management, regulatory compliance, and handling externalities must be addressed to ensure successful implementation (Berg et al., 2018)

METHODS

Respondent Selection

The research involved the relevant stakeholders throughout smartphone waste management including producers, consumers, waste management companies, and government representatives. The purposive sampling method is used to select the stakeholder representative to identify the roles and responsibilities of each party in the implementation of Extended Producer Responsibility (EPR) and to ensure that the feedback collected reflects the real conditions and challenges at field.

The interviews were conducted in a semi-structured format, allowing flexibility for the interviewer to adjust the conversation based on the responses from the informants. This approach enabled a more open exploration of emerging topics, resulting in richer and more contextual data. Thus, the interviews are expected to provide valuable information for designing more targeted solutions in managing smartphone e-waste in Indonesia. The respondents involved in the design thinking stages of empathize, define, ideate, prototype, and testing stages.

Table 1. Design Thinking Respondent Selection Criteria

Stakeholders	Selection Criteria
Consumers	Selected 10 smartphone consumers selected with following criterias: - 18-45 years old, located in provincial capitals or large cities from different geographical locations in Indonesia, non-homogeneous profession - Have purchased a smartphone in the last 2-3 years and non-first-time smartphone user - Openness to new technologies with education of a minimum bachelor's degree background
Producer	Selected a smartphone company with the following criterias: - Significant business in Indonesia, represented by top five market share size - Have a recycling program or sustainability policy related to environmental management and historical experience of smartphone waste management
Smartphone Waste Collector and Management Company	Selected a waste collector and management company with the following criteria: - Have permits to manage smartphone waste - Have a smartphone waste processing facility that meets environmental standards and serve a wide geographic area or focus on a specific region with

Stakeholders	Selection Criteria
	high waste on a regional or global scale to gain perspective on a broader smartphone waste management model
Government Representative	Involved Direktorat Industri Elektronika dan Telematika (IET) Kementerian Perindustrian Republik Indonesia: - Direktorat IET supervised Smartphone Industry to comply with related industrial regulation including management of environmentally friendly products. - Related to smartphone waste, Direktorat IET released a Regulation of the Minister of Industry No. 35/M-IND/PER/8/2009 concerning Guidelines for the Management of Electronic Products Containing Hazardous and Toxic Materials (B3).

Data Collection

Data collection is conducted through various methods, including moderate participatory observation, in-depth interviews, documentation, and data triangulation along with design thinking stages. Observations are made directly on the smartphone waste lifecycle process, covering stages from waste collection to processing. The researcher participates in several activities and discussion related to electronic waste management to gain a deeper understanding of the field practices, challenges, and stakeholder behaviors. In qualitative research, data collection is carried out in natural settings (natural conditions), primary data sources, and data collection techniques are more on participant observation, in-depth interviews and documentation (Sugiyono, 2013).

Interviews are conducted in two forms of structured and semi-structured, to gather rich and in-depth data. Structured interviews are used to obtain factual data, such as the amount of waste generated, waste management policies, and targets set by producers and the government. Semi-structured interviews aim to explore the views, experiences, challenges, and innovative ideas of stakeholders involved. As part of data collection, the documentation is collected including official reports and policies, supports the interview findings. To enhance data reliability, the research uses prolonged observation and member checks, and analyzes data using Miles and Huberman's approach—data reduction, presentation, and conclusion drawing. Throughout the design thinking stages of empathize, define, ideate, prototype, and test, there are several data collection activities performed. The data collection method aligned with the tools and methods used in each design thinking stages as follows:

Table 2. Data Collection Process within Design Thinking Phases

Phases	Tools and Method	Data Collection Methods
Empathize	Stakeholder mapping for stakeholder validation	Participant observation and documentation collection based on discussion activities, regulation documents and previous research data collection
	Empathy Map for stakeholder feedback collection	Structured interview with pre-defined questions and semi-structured interview with follow up questions based on the structured interview feedback
Define	Affinity diagram for feedback grouping	Structured interview with pre-defined questions and semi-structured interview with follow up questions based on the structured interview feedback
Ideate	SCAMPER for idea exploration	Semi-structured interview through discussion and brainstorming sessions, involved each group of stakeholders
	Idea Selection	Structured interview with pre-defined idea selection parameter feedback collection, involved each group of stakeholders
Prototype Test	Feedback Capture Grid	Semi-structured interview through discussion and brainstorming sessions, involved each group of stakeholders

Measurement

In measuring the research impact, final prototype test plays a critical role in this research. Prototype test is executed by validating the platform functionality and usability through iterative testing processes. This stage ensures relevant stakeholders feedback is gathered, helping refine the prototype and making adjustments to improve both the user experience and the overall platform's ability to facilitate value exchange effectively.

Using a Feedback Capture Grid tool, feedback will be systematically collected from stakeholders in the form of positive comments, concerns, and questions. The measurement process involves four iterative steps ensures that the platform evolves according to user needs and promotes greater stakeholder integration:

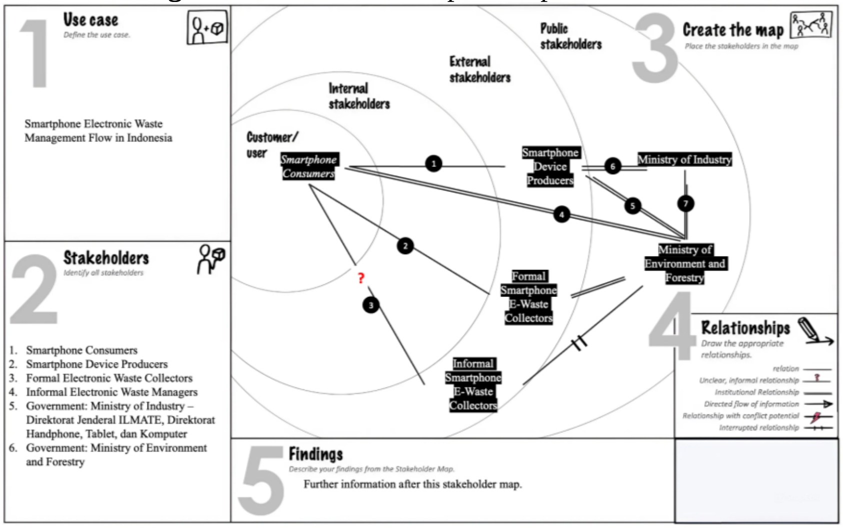
1. Asking stakeholders to interact with the platform prototype,
2. Collecting their feedback through structured questions,
3. Categorizing feedback into actionable insights (e.g., usability issues or suggestions for improvement),
4. Revising the prototype based on the feedback.

RESULTS

Empathize Phase

The empathize phase in this study focuses on understanding the needs, behaviors, and challenges faced by stakeholders within the smartphone waste management ecosystem. The process begins with identifying and finalizing the stakeholders involved throughout the smartphone waste management lifecycle, followed by the development of a stakeholder map. Stakeholder map serves as a tool to validate the roles of various parties in the ecosystem. As part of stakeholder analysis, the stakeholder map helps identify key interests, potential barriers and enablers, and the influence structure within the system (Michael Lewrick et al., 2020).

Figure 2. Stakeholder Map in Empathize Phase



The stakeholder map provides information about the characteristics of each interest group and the relationships between them, and helps in effective communication with all stakeholders. The explanation of stakeholder map results as follows:

Table 3. Explanation of Stakeholder Map

Relationship in Stakeholder Map	Type of Relationship	Description
Consumer - Producer	Relation	The basic relationship between providers and users of products/services
Consumer – Smartphone E-Waster Formal Collectors	Formal Relation	The basic relationship that occurs because of the consumer's need to dispose of smartphone waste and the role of managers certified by the government.
Consumer – Smartphone E-Waster Informal Collectors	Unclear, Informal Relation	The relationship generally does not have a legal basis or formal contract. Consumers interact directly with informal collectors to dispose of or sell used devices.
Consumer - Ministry of Environment and Forestry	Institutional Relation	The relationship is formal because KLHK has the responsibility to protect the environment through policies,

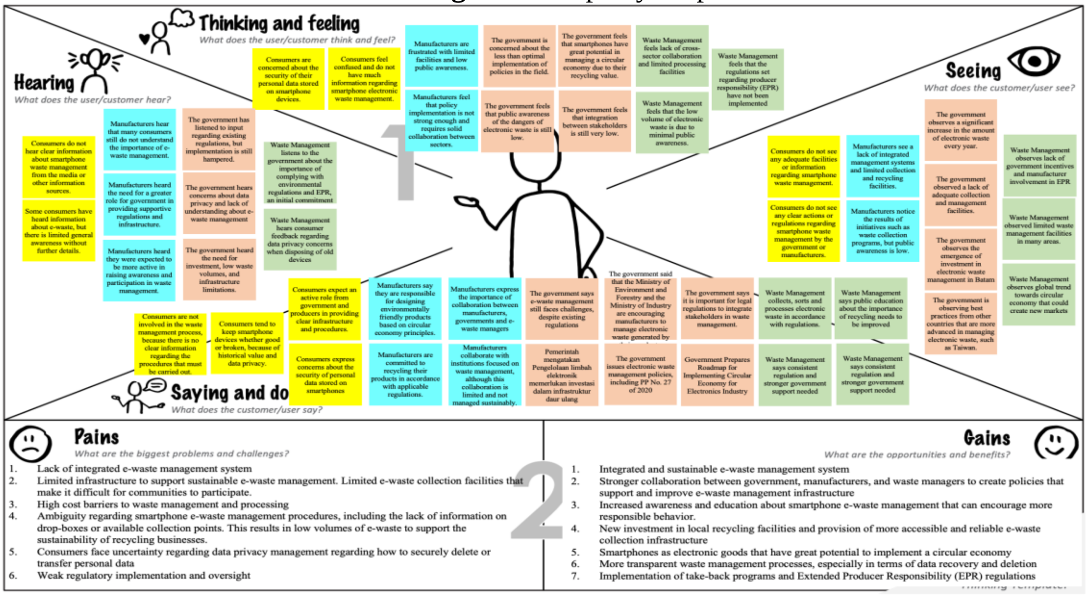
Relationship in Stakeholder Map	Type of Relationship	Description
		regulations, and supervision that affect consumers.
Smartphone Producer - Ministry of Environment and Forestry	Institutional Relation	This relationship is formal and regulated by environmental regulations set by the Ministry of Environment. Manufacturers must comply with policies related to production, waste management, and corporate responsibility.
Smartphone Manufacturer - Ministry of Industry	Institutional Relation	This relationship is formal and regulated by industry regulations. The Ministry of Industry establishes policies related to production standards, industrial development, and technological innovation that must be adhered to by producers
Smartphone Manufacturer - Ministry of Environment and Forestry	Institutional Relation	The relationship between the Ministry of Industry and the Ministry of Environment and Forestry is formal, with each ministry having a specific role in setting industrial policies and regulations as well as environmental protection.

Through the stakeholder map, researchers then conducted exploratory interviews to gain an in-depth understanding of smartphone waste management. Exploratory interviews are suitable for questioning previously made assumptions and directing the development of solutions that are truly relevant to stakeholder needs. Exploratory interviews were conducted involving various stakeholders including consumers, smartphone manufacturers, formal and informal smartphone waste collectors and managers, and government representatives. This approach aims to explore the needs, challenges, and potential solutions relevant to addressing the complex and less integrated smartphone waste management problem. Respondents in this exploratory interview were purposively selected based on their level of involvement in the smartphone waste management ecosystem, including consumers, producers, collectors, waste managers, and government representatives. This selection was based on their relevance and potential contribution to a more comprehensive understanding of the challenges and opportunities in smartphone waste management.

The final outcome of empathy phase is development of empathy map with main objective to group and analyze information obtained. Collected interview information mapped into predetermined categories, such as feelings, views, statements, and actions. In developing empathy map, researchers filtered and grouped the collected informations based on the main themes identified. Thus, researcher can find behavioral patterns and problems faced by users, as well as potential needs that need to be accommodated in the solutions to be developed. This also allows researchers to focus more on real problems faced by users, not just assumptions.

The empathy map helps the design team to dig up complete information about user behavior by mapping the various elements that influence them. This mapping includes what is felt, seen, said, and done by users, as well as the problems they face. By doing this mapping, the team can get a clearer picture and minimize assumptions in designing solutions. In the context of this research, the empathy map is utilized to comprehend the needs and challenges faced by various stakeholders in smartphone waste management, including consumers, collectors, and waste managers. The outcomes of this phase are expected to provide a solid foundation for developing effective solutions that are genuinely aligned with user needs.

Figure 3. Empathy Map Result



In addition to identifying challenges, the empathy map also reveals several opportunities to improve smartphone waste management in the future. These include addressing key issues such as strengthening waste management systems, enhancing stakeholder collaboration, raising consumer awareness through outreach programs, and encouraging investment in waste management facilities. Smartphones, as electronic devices, hold significant potential for applying circular economy principles. With modular designs, upgradable components, and recyclable materials, they can serve as examples of sustainable products that help conserve natural resources.

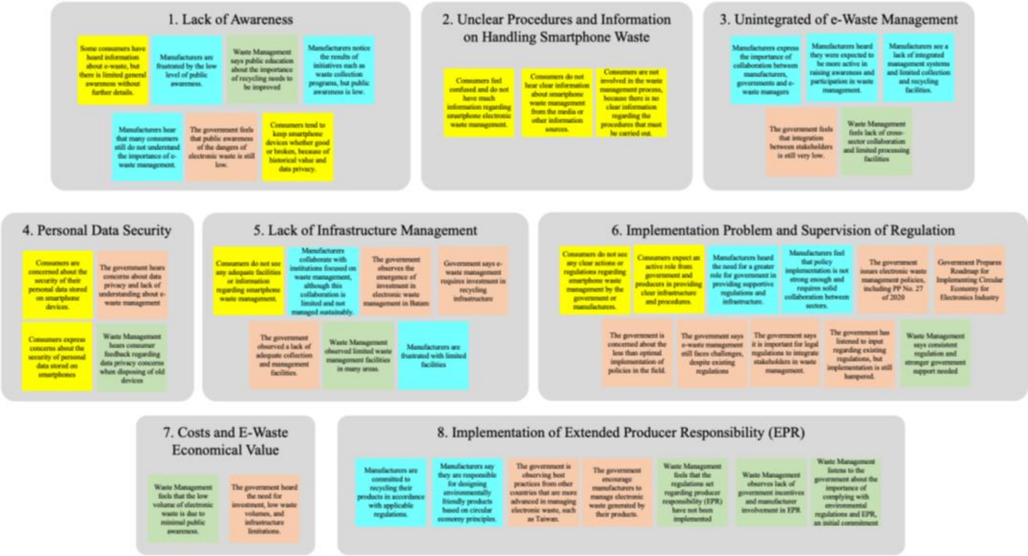
Concrete steps like take-back programs and the implementation of Extended Producer Responsibility (EPR) ensure that manufacturers remain accountable for their products throughout their lifecycle. EPR encourages producers to design more durable, repairable, and recyclable products, significantly reducing waste burdens. The adoption of EPR principles in Indonesia is reflected in Law No. 18 of 2008 on Waste Management (Article 15), which mandates producers to take responsibility for the disposal of non-compostable or difficult-to-compost products and packaging.

Define Phase

The role of define stage to understand the needs, behaviors, and challenges experienced by stakeholders in the smartphone waste management ecosystem. There are three main activities in define phase including grouping problems using affinity diagrams, analyzing causal relationships using causal loop diagrams to further understand the relationships between the problems found, and finalize the problem statement.

The affinity diagram serves to categorize data and research findings based on certain similarities, facilitating the identification of key problems and stakeholder needs. Each finding is recorded as individual points to simplify the grouping process. The data is then organized into clusters based on emerging themes or patterns. These clusters are labeled to capture the essence of the findings. This process enables a more focused analysis to define the core problems and needs that must be addressed in smartphone waste management.

Figure 4. Affinity Diagram Result

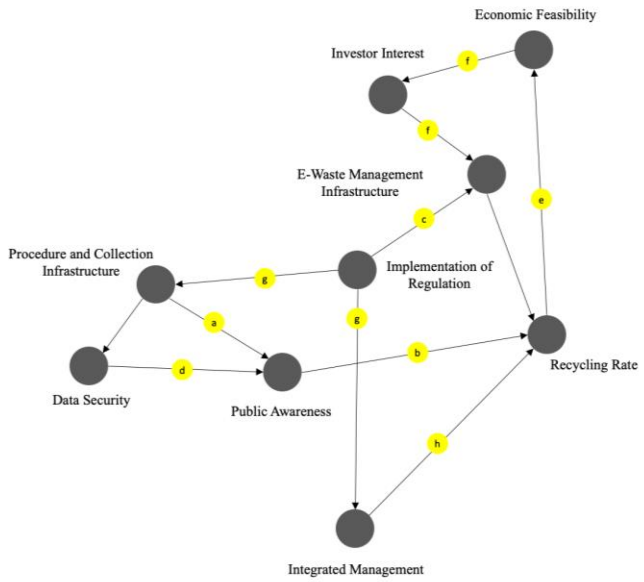


The following summary of problem grouping in affinity diagram:

a. **Lack of awareness:** People lack information about drop-box locations, collection processes, and recycling procedures, discouraging proper disposal. This results in low recycling volumes, making sustainable recycling businesses difficult to achieve.
b. **Unclear procedures and information of handling smartphone waste:** Without an integrated system, smartphone waste processing is fragmented and poorly coordinated, reducing recycling effectiveness.
c. **Personal data security concern:** Consumers fear data misuse due to unclear processes for secure data deletion, making them hesitant to recycle their devices.
d. **Lack of infrastructure management:** Inadequate facilities like drop-boxes and accessible recycling centers hinder public participation, leading to low recycling rates and waste accumulation.
e. **Cost and e-waste economical value:** Managing smartphone waste is expensive, and recycling yields low economic returns, discouraging investment in the industry.
f. **Implementation problem and supervision of the regulation:** Although regulations exist, poor implementation and oversight reduce their impact on improving waste management.

Based on the affinity diagram, the researcher identified interconnections between various factors influencing smartphone waste management, which interact and affect one another. A Causal Loop Diagram (CLD) is used to illustrate cause-and-effect relationships and system dynamics, including both positive and negative feedback loops. This approach enables a more holistic understanding of the interactions between factors and helps identify potential intervention points to improve the effectiveness of waste management.

Figure 5. Causal Loop Diagram Explained the Interconnected Between Factors in Smartphone E-Waste Management



a. Clear procedures positively impact public awareness by providing adequate information on waste management.
b. Public awareness influences collection rates, which directly increase the recycling rate.
c. Adequate infrastructure strengthens collection rates and enhances management effectiveness.
d. Data security affects consumer trust; when personal data security is assured, awareness rises, positively impacting collection rates and, consequently, the recycling rate.
e. Economic viability is influenced by higher recycling rates, making waste management more economically feasible and attracting investors to expand infrastructure.
f. Economically viable waste management encourages investor interest, which leads to improved waste management infrastructure.
g. Effective regulatory implementation, including Extended Producer Responsibility (EPR), promotes more integrated smartphone waste management and better collection procedures.
h. Integrated waste management directly enhances collection rates, which improves the recycling rate.

At last step of define phase, the researcher identifies the need for an integrated smartphone waste management system that ensures all related aspects are effectively addressed. Accordingly, the following is the problem statement summarizing the key issues:

Table 4. Problem Statement Result

Problem Statement
How an integrated smartphone waste management system be designed to address the challenges of low public awareness, unclear procedures, stakeholder engagement, inadequate infrastructure, and cost constraints? The integrated system design should aim to increase recycling participation and development of a sustainable circular economy."

Ideate Phase

The SCAMPER method is used to encourage creativity and generate various ideas based on the identified problems. By analyzing each element using the approaches of substitute, combine, adapt, modify, put to another use, eliminate, and reverse, potential ideas are generated to address challenges. With its systematic approach, SCAMPER enables the researcher to view problems from new perspectives, leverage available resources, and identify unique opportunities to create relevant and effective solutions. There are several initial ideas found during SCAMPER approach as follows:

a. Substituting traditional manual processes with a digital platform would streamline the waste management process, providing users with easy access to essential information, including drop-box locations, recycling guidelines, and waste collection procedures. This platform could also integrate various services, such as waste collection, pick-up, and recycling management, ensuring greater collaboration among stakeholders such as producers, consumers, and recycling centers.

b. Adapting best practices from countries with successful e-waste management frameworks, such as European nations, could help tailor a regulatory approach suitable for Indonesia, enhancing the structure of the local system. Modifications to existing systems could include redesigning drop-boxes to be more accessible and user-friendly, utilizing local partners like electronics stores or logistics couriers to make them more visible and convenient. Simplifying waste collection procedures through home pick-up services could increase participation from the community, ensuring a more comprehensive recycling network.
c. Repurposing the materials from recycled smartphones could also add value by supporting industries such as renewable energy or creative technology sectors, contributing to both environmental sustainability and economic growth. Recycling centers could also be leveraged for educational purposes, offering training and raising awareness about the importance of responsible waste disposal.
d. Eliminating fragmented or inefficient waste management systems, a more integrated approach, based on national standards, could be established, improving the overall system's effectiveness.
e. Reversing the conventional approach to regulation could offer promising results. Instead of solely focusing on punitive measures, providing incentives for those who comply with regulations—such as credit or cashback—could foster greater participation.
f. Shifting the focus of educational campaigns from merely highlighting the detrimental effects of e-waste to proactive engagement before solutions are provided could lead to more meaningful societal change.
g. Transforming the waste collection process from a passive model, where individuals must actively drop off their old devices, to an active pick-up system could significantly boost community involvement. By incorporating these approaches, supported by incentives and certifications like R2 Certified to ensure responsible data handling and recycling practices, a more efficient and sustainable smartphone waste management system can be established.

After execution of SCAMPER method, the idea selection process is implemented to filter the ideas based on criteria such as feasibility, impact, and affordability. This ensures that the selected solutions are not only relevant but also can be effectively implemented to create a sustainable circular economy-based waste management system. At idea selection stage, the researcher filters and selects the best ideas from the exploration in the ideate phase. This process helps ensure that the selected ideas are relevant, feasible, and have a significant impact on addressing smartphone waste management issues. By using selection criteria such as technical feasibility, social impact, economic sustainability, and accessibility, the idea selection method allows the team to evaluate various ideas in a systematic and objective manner.

To support the ideas and evaluations, the researcher uses the following parameters, which are then used to prioritize the selected ideas. There are four main parameters used in determining the priority of the chosen ideas as follows:

Table 4. Idea Selection Evaluation Criteria

No	Criteria	Description
1	Technical Visibility	The technical feasibility parameter is used to ensure that the selected idea can be implemented with the available technology and aligns with the resources available for its development.
2	Social Impact	This parameter is used to ensure that the chosen solution can have a direct impact to social community.
3	Economic Sustainability	This parameter is chosen to ensure that the solution developed can provide long-term economic value, benefiting industry players, the government, and the community.
4	Accessibility	The accessibility parameter is chosen to ensure that the solution is easy for the general public to access and use, which increases its chances of widespread adoption and sustained use. By focusing on accessibility, the solution can reach a larger audience, including individuals with varying levels of digital literacy, socioeconomic status, and geographic location.

The results of the idea selection phase represent a crucial step in identifying the best solution from the various ideas generated in the previous stage.Based on the predefined parameters, each idea is thoroughly evaluated to ensure its relevance, effectiveness, and feasibility for implementation. This process not only helps filter the most promising ideas but also focuses attention on solutions capable of delivering tangible and sustainable impacts. Below are the results of the evaluation conducted on the potential ideas:

Table 5. Idea Selection Evaluation Result

No	Idea	Description	Idea Evaluation Result
1	Incentive Program for Consumers	Incentive programs are a strategic way to increase public participation in waste management. Offering benefits like vouchers, discounts, or loyalty points motivates people to hand over their used electronics. These programs are easy to implement using existing digital or retail networks.	- **Technical Visibility:** High - **Social Impact:** Medium - **Economic Sustainability:** High - **Accessibility:** High
2	Integrated Application Based Digital Platform	Developing an integrated app-based digital platform is highly feasible due to the availability of supporting technologies, such as commonly used app development tools. The platform also has a strong social impact, as it can be widely accessible, provide education, and simplify smartphone waste management. Economically, it offers the potential for long-term value through collaboration with producers. Its accessibility is a key strength, allowing users to engage with the platform anytime.	- **Technical Visibility:** High - **Social Impact:** High - **Economic Sustainability:** High - **Accessibility:** High
3	Development of Drop-Box and Pick-Up Services for Waste Collection with Standardized Procedures	Modifying the drop-box design to be more accessible, such as through local partners like electronics stores or logistics couriers, with a user-friendly and easily recognizable approach, can help enhance convenience and encourage greater participation. Additionally, ensuring the design is visually appealing will increase its appeal and visibility to users.	- **Technical Visibility:** High - **Social Impact:** High - **Economic Sustainability:** Medium - **Accessibility:** High
4	Educational Campaign	The idea of an educational campaign has a significant social impact and easy accessibility. It raises public awareness directly, making a broad social impact. However, its technical feasibility is moderate, as it requires the development of educational materials and ongoing activities, necessitating an effective campaign strategy to reach the audience. From an economic sustainability perspective, this idea requires constant funding to maintain continuity. Accessibility can vary depending on the execution strategy.	- **Technical Visibility:** High - **Social Impact:** High - **Economic Sustainability:** Medium - **Accessibility:** Medium
5	Strengthening Regulation	Strengthening regulations is chosen for its high social impact but low technical feasibility. Regulations have the potential to drive widespread behavioral changes at both the community and industry levels. However, developing regulations involves a complex political process and takes time. From an economic sustainability perspective, strengthening regulations does not provide immediate economic value but can create a more supportive long-term ecosystem. Its accessibility is also considered low, as the public will need time to experience the direct effects of the regulation's implementation.	- **Technical Visibility:** Low - **Social Impact:** High - **Economic Sustainability:** Low - **Accessibility:** Low

After analyzing various proposed ideas, the integrated app-based digital platform was chosen as the main solution because it offers an integrated, inclusive, and sustainable approach. This platform effectively addresses key challenges such as low public awareness, unclear waste management procedures, and data security issues. Digital technology enables wide access to information, waste collection coordination, and incentive distribution, while also facilitating integration among various stakeholders, including consumers, producers, collectors, and waste managers. Additionally, this main idea is supported by complementary ideas. The incentive program can be integrated into the platform to motivate the public, the development of drop-boxes and standardized pick-up services can be incorporated to strengthen the operational elements of the platform, and the educational campaign helps raise awareness about the importance of smartphone waste management. Together, these ideas enhance the platform's functionality and impact, creating a more effective and comprehensive solution.

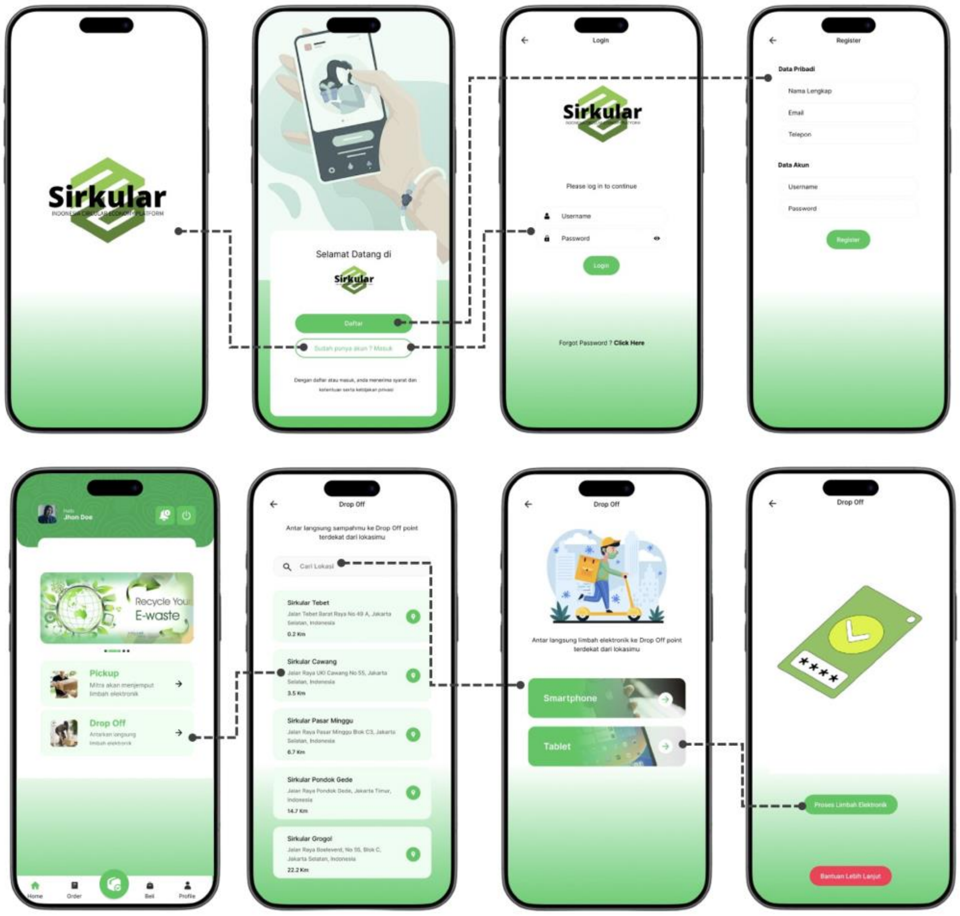
Prototype Phase

The researcher developed a service blueprint as the basis of prototype functions in line with its main goal of simplifying waste management, while also ensuring that each element of the app is relevant to user needs. The development of the service blueprint aims to outline the entire user journey, from start to finish, in managing waste efficiently and standardized. This service blueprint helps design a seamless user experience by mapping out the user's direct interactions with the app and the various internal processes that support the platform.

Figure 6. Initial Service Blueprint in Prototype Phase

The high-fidelity prototype includes an intuitive user interface, an integrated waste management system, and various interactive features that allow users to take actions such as scheduling pick-ups, accessing educational materials, and utilizing incentives. Each element in the prototype is designed to support a seamless user experience, which is also reflected in the service blueprint, from waste collection processes to reward distribution. This prototype not only provides a clear visual representation but also ensures that all operational aspects outlined in the service blueprint can be directly tested, allowing the team to make necessary adjustments before the platform is fully launched. The high-fidelity prototype developed for the smartphone waste management platform, named "Sirkular," is based on the service blueprint that was created. Sirkular is the first circular economy platform in Indonesia, focusing on smartphone waste management.

Figure 7. Initial High Fidelity Prototype of “Sirkular” Platform



Test Phase

The testing results show that most users are comfortable with the app's navigation and can complete tasks like finding drop-boxes and scheduling waste pick-ups without difficulty. However, several areas for improvement were identified. To gather feedback for improvements, the researcher used a feedback capture grid approach to collect both positive and negative feedback, as well as questions and new ideas that emerged from the test provided by users. The researcher collected feedback from four main respondent of smartphone consumers, smartphone producers, waste collectors and managers, and government representatives as follows:

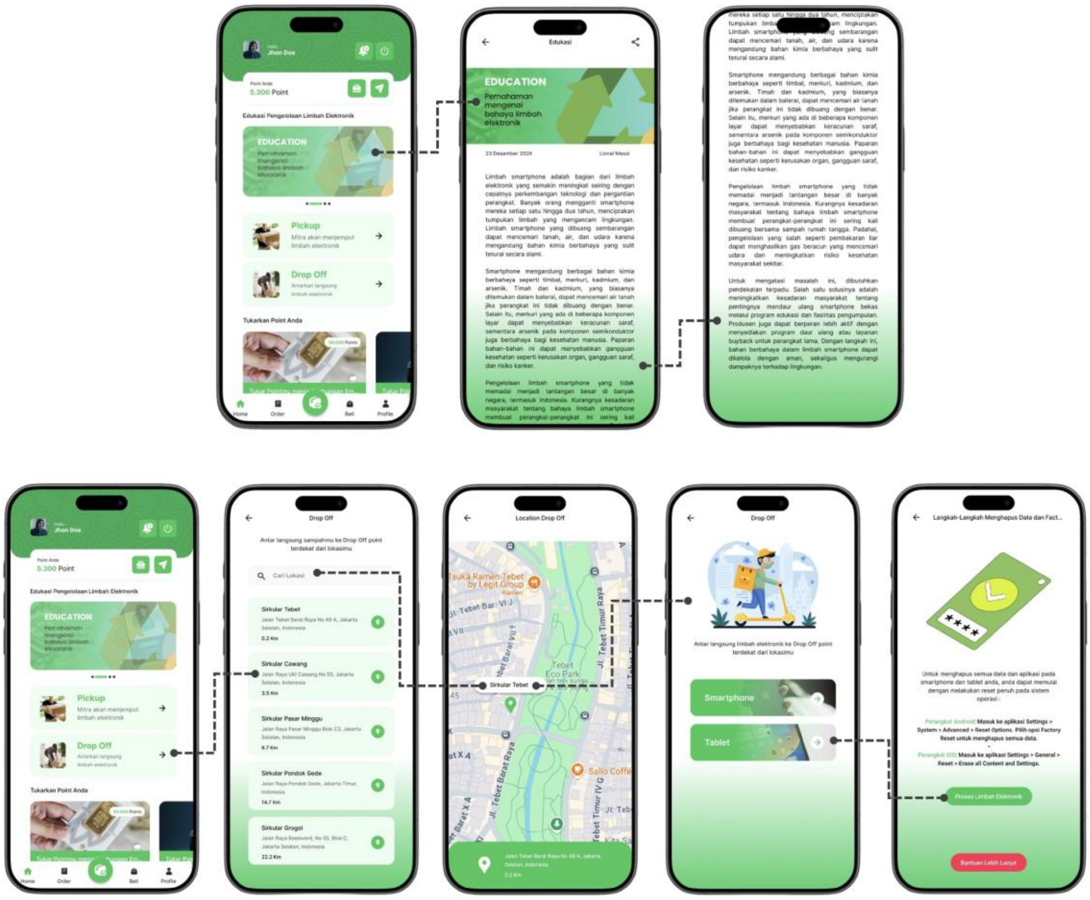
1. Consumer feedback highlighted several issues, including the lack of clear information on the prototype regarding smartphone waste management and data deletion procedures. Consumers also reported difficulty in finding drop-box locations and felt that the transaction information was not transparent. Furthermore, there was a lack of interest among consumers if no incentive mechanisms were provided.
2. Producer feedback emphasized the need for data and information on the quantity of waste collected to fulfill their responsibilities under Law No. 18 of 2008, a feature that is currently missing from the platform.
3. e-Waste management companies expressed concerns that awareness would not increase without incentive mechanisms and mentioned the insufficiency of waste processing facilities in certain areas, as well as high operational costs that remain unaddressed by the available incentives.
4. Government feedback pointed out the insufficient socialization of regulations integrated into the platform and the absence of incentive schemes for producers actively participating in e-waste management. Additionally, there are no established government standards for the platform's features, which may hinder the effectiveness and alignment of the platform with regulatory requirements. These insights suggest the need for improved communication, better incentives, and enhanced data management systems to ensure the platform's success in addressing smartphone waste management challenges and aligning with stakeholder expectations.

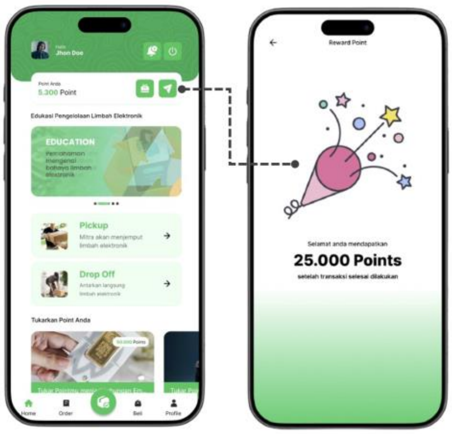
The revision of the smartphone waste management platform prototype was carried out based on feedback gathered from respondents and relevant stakeholders. The feedback capture grid process has been a crucial step in identifying areas for improvement and development opportunities. In this process, we analyzed aspects that were valued, emerging concerns, innovative ideas, and strategic questions that impact the platform's feasibility and implementation. This approach ensures that all relevant feedback is well-structured and provides a solid foundation for iterating the prototype. The results of this process have been used as the primary reference in revising the service blueprint and the new high-fidelity platform prototype.

Figure 6. Final Service Blueprint After Prototype Testing

The high-fidelity prototype that was developed was then revalidated with the respondents as a validation step. This process aimed to ensure that all revisions aligned with the needs and expectations of stakeholders. Respondents provided positive feedback on the improvements, confirming that the prototype supports better integration and collaboration in electronic waste management, in line with circular economy principles.

Figure 9. Final High Fidelity of "Sirkular" Platform After Prototype Testing





DISCUSSION

This research has produced a smartphone waste management platform prototype, designed using a design thinking approach to support the implementation of Extended Producer Responsibility (EPR) policies in Indonesia's smartphone industry. Through a collaborative approach involving various stakeholders, including consumers, producers, waste managers, and the government, the study contributes to circular economy-based smartphone waste management as follows:

1. **Key Problem Identification:** The main challenges in smartphone waste management in Indonesia include a lack of stakeholder integration, low public awareness of e-waste management, unclear procedures, insufficient waste management infrastructure, and concerns over data security.
2. **Circular Economy Opportunities:** Smartphone waste holds significant economic value when optimally managed through recycling and technology-based processing.
3. **Solution Prototype:** The developed and tested platform, named "Sirkular," includes features to support waste collection, provide transparent information, offer incentives to boost consumer participation, and ensure secure data management. This platform facilitates value exchange among stakeholders to create a more integrated system.
4. **Design Thinking Approach:** This approach effectively identifies the needs, expectations, and challenges faced by stakeholders while delivering innovative and practical solutions.

CONCLUSION

The "Sirkular" platform prototype can serve as a reference for the government and industry players to implement EPR strategies more effectively and raise public awareness about the importance of electronic waste management. This platform is expected to increase the recycling rate of smartphone waste, which is currently very low, while also reducing the negative environmental impacts of smartphone waste. In conclusion, this study demonstrates that circular economy-based smartphone waste management, supported by a design thinking approach, can provide a viable solution to facilitate the successful and integrated implementation of EPR in Indonesia.

LIMITATION

This study proposes several recommendations to enhance the management of electronic waste in Indonesia. First, optimizing the implementation of Extended Producer Responsibility (EPR) through technical regulations, strengthened government oversight, and active collaboration among producers, consumers, and waste management stakeholders. Clear and measurable responsibilities for producers, including waste collection, recycling facilities, and financial flow, are essential for an effective EPR framework. Second, public education campaigns are necessary to raise awareness about the circular economy, data security, and simple steps for recycling smartphone waste. Third, fostering integrated collaboration between key stakeholders—government, consumers, producers, and waste managers—is crucial for platform operations. Fourth, pilot testing the platform in high smartphone-usage areas, followed by periodic evaluations, can help identify challenges and refine features based on stakeholder feedback. Fifth, offering financial incentives, such as discounts for new product purchases or a points system, can boost consumer participation and align with producers' sustainability strategies. Lastly, integrating the platform with broader environmental policies, such as carbon emission reduction initiatives and renewable energy use, can amplify its impact on sustainability. These measures aim to establish an effective and sustainable smartphone waste management system in Indonesia.

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