

User-Centric Waste Management Through Reward-Based Digital Systems

Ama Muzni Mahmudi*

Information Technology, Pradita University Tangerang
Regency, Banten 15810, Indonesia
ama.muzni@student.pradita.ac.id

**Corresponding author*

Teddy Mantoro

Informatic Engineering, Nusa Putra University, West
Java 43152, Indonesia
teddy@ieee.org

 Submitted: 2025-05-24; Accepted: 2025-06-03; Published: 2025-06-05

Abstract— The effective management of household and urban waste is a critical challenge in achieving sustainability within the fields of waste management and circular economy practices. Traditional waste sorting systems face inefficiencies due to low user participation, limited accountability, and inadequate transparency in tracking and reporting waste contributions. This research addresses these challenges by introducing a reward-based digital platform that incentivizes users to sort and deposit waste at designated collection points. The platform assigns points based on the type and quantity of waste submitted, tracks contributions, and provides detailed reports to users, fostering transparency and trust. The proposed solution demonstrates potential to increase user engagement, improve waste sorting accuracy, and enhance reporting capabilities, supporting the transition toward sustainable and circular waste management systems.

Keywords— Waste Management, Reward Systems, Digital Platforms, Circular Economy, Transparency

I. INTRODUCTION

Global resource depletion, greenhouse gas (GHG) emissions, and waste generation are critical challenges exacerbated by traditional linear systems, which often lead to substantial amounts of reusable and recyclable materials being discarded into landfills. Anthropogenic systems, for instance, are synonymous with linear economies that cause widespread resource waste and environmental degradation (Hatley et al., 2024). Under the triple pressure of urbanization, population growth, and urban sprawl, collecting waste and valorising its re-use is one of the grand challenges urban societies face today (Möslinger et al., 2023). Consequently, current linear models, defined by a "take-use-dispose" framework, fail to address these issues adequately, necessitating a crucial shift toward circular principles that prioritize reuse, recycling, and resource efficiency (Nicol et al., 2024).

The global push toward sustainability and circular economy practices has heightened the urgency of developing effective waste management systems. Traditional linear waste practices have contributed to critical environmental and resource challenges such as overflowing landfills, carbon emissions, and resource scarcity (Evertsen & Knotten, 2024). Moreover, internal

household factors also pose significant challenges, as not everyone has the time or dedication to meticulously categorize their waste, thus hindering the sorting process and rendering it inefficient and unsustainable (Sianturi et al., 2024). Furthermore, extending beyond household efforts, it is crucial to invest in environmental education to make commercial establishments aware of the importance of paying for the management of commercial solid waste, following the same principle already established for the payment of services such as electricity and water (Neves et al., 2025). The adaptation of production systems to the Circular Economy is also inherently difficult, as many specific processes involved in circular production that restore discarded products create operational difficulties and uncertainties (Denu et al., 2023). Limited technology adoption in community-based circular waste systems is another notable challenge, as previous solutions often focused on municipal- or city-level management and neglected community-managed operations like waste banks, which are particularly prevalent in Indonesia (Tundjungsari et al., 2025).

In this context, addressing broader environmental concerns is also paramount. In recent years, energy-related (power and heating) emissions accounted for 43%, transportation-related emissions contributed 26%, and the combined manufacturing and construction sectors accounted for 17% of global emissions, with the potential for the greatest increase in carbon emission in both sectors lying with the manufacturers (Yadav et al., 2023). Similarly, E-waste management presents a huge challenge and poses significant risks to the techno-enabled world (Vishwakarma et al., 2022). To address these multifaceted issues, the transition to circular models has become a focal point in both academic research and real-world application (Adekan & Sharmina, 2024; Kolade et al., 2024).

Digital platforms have thus proven to be transformative tools in facilitating circular economy goals by directly addressing inefficiencies in traditional waste management systems. These platforms enable enhanced tracking, transparency, and collaboration among stakeholders in circular ecosystems (Kolade et al., 2024; Nicol et al., 2024). However, while advancements in technologies are closely associated with offering solutions to global warming, the digital discourse also highlights the negative impacts of their widespread use in the context of waste

products, resource usage, and CO₂ emissions (Dwivedi et al., 2022). In this vein, studies have analyzed the direct, indirect, and nonlinear influencing mechanisms of the digital economy on carbon emissions from an energy efficiency perspective, applying mediation models and panel threshold models (Zhang et al., 2022). Despite their immense potential, corporate incubation strategies for digital platforms, such as PlatformCE, face inherent challenges like aligning stakeholder priorities and operational frameworks, which can consequently hinder their scaling (Nicol et al., 2024).

Reward-based digital platforms represent a promising innovation for enhancing user participation and fostering accountability in waste management. By incentivizing sustainable behaviors, these platforms directly address challenges such as limited engagement in waste sorting and inadequate transparency in reporting contributions (Adelekan & Sharmina, 2024; Kolade et al., 2024). Nevertheless, the efficacy of monetary cues in all contexts remains an area of active research, as it is unclear whether the detrimental effect of being exposed to money cues applies universally or if certain situations may be exempt from this effect (Chan et al., 2021). Collaborative business models, in this regard, play a vital role in creating effective circular ecosystems. For example, within the plastics sector, digital platforms have enabled the creation of new value chains that simplify waste collection, sorting, and recycling (Adelekan & Sharmina, 2024). Studies on closed-loop supply chains further emphasize the necessity for user-centric designs that effectively engage individuals in waste management practices, enabling both transparency and efficiency (Bjorklund et al., 2024; Evertsen & Knotten, 2024). When plastic waste is sorted and graded, it can be used to produce value-added products, thereby creating opportunities for SMEs to develop innovative business models (Chaudhuri et al., 2022). Optimizing operational efficiency in plastic recycling, particularly for non-profit initiatives with limited resources, requires careful attention to facility locations, collection methods, and logistics (Petchrompo et al., 2025). Furthermore, acknowledging the broader scope of waste reduction, several efforts have been dedicated by the research community to the design and development of smart fridges capable of tracking, monitoring, and managing data related to food products, eating habits, and user patterns, thereby supporting consumers in daily practices and reducing waste (Cappelletti et al., 2022). Ultimately, by assigning points based on waste type and quantity, reward-based platforms foster trust and accountability through transparent reporting. This user-centric approach incentivizes sustainable practices and contributes to broader efforts to establish efficient, transparent, and scalable waste management systems.

II. RELATED WORK

The integration of reward-based digital platforms into waste management aligns with global efforts to enhance sustainable practices and user engagement. Previous studies emphasize the role of motivational incentives,

user-centric technologies, and collaborative systems in achieving measurable improvements in sorting behaviours and fostering trust among participants.

In Digitally Enabled Business Models for a Circular Plastic Economy in Africa (Kolade et al., 2024), the authors highlight the importance of incentive-based systems for promoting circular economy practices. Platforms such as Trashmonger and Yo-Waste demonstrate how digital systems enhance waste sorting and collection by creating real-time linkages between waste producers, collectors, and aggregators. These platforms foster economic opportunities while driving engagement through incentives like financial rewards or subsidies.

Collaborative Digitally-Enabled Business Models for a Circular Economy (Adelekan & Sharmina, 2024) underscores the need for multi-stakeholder collaboration and trust-building mechanisms. The study highlights that real-time transparency dashboards and traceability tools effectively address stakeholder concerns by providing visibility into individual and collective contributions, thereby fostering trust and accountability. The findings further emphasize the importance of refining user experiences through interactive technologies to ensure system scalability.

In Sustainability Potentials of Digitally Based Platforms for the Circularity of Household Items (Bjorklund et al., 2024), reward systems are identified as critical enablers for consistent user participation. Tangible rewards aligned with essential needs, such as grocery discounts and utility credits, have been shown to drive measurable improvements in waste sorting behaviors. This study also identifies persistent challenges, such as technical disruptions and limited reward options, which hinder long-term user satisfaction and engagement.

The role of digital platforms in improving material recovery and waste tracking is explored in Toward a Collaborative Circular Ecosystem within the Built Environment (Evertsen & Knotten, 2024). The study highlights the potential of digital tools to provide real-time feedback and improve sorting performance through clear guidelines and transparency features. However, challenges remain, particularly regarding inconsistent infrastructure and user education gaps for complex waste streams.

Finally, Circular Economy and the Role of Incentive-Based Systems (Nicol et al., 2024) emphasizes that user engagement in circular waste systems relies heavily on customized rewards and feedback mechanisms. The study shows that platforms offering a variety of reward categories, tailored to user preferences, achieve higher redemption rates and sustained behavioral change. However, addressing technical barriers, such as QR code scanning errors, is essential to optimize user satisfaction and overall platform performance.

Collectively, these studies underscore the importance of integrating motivational rewards, usability-focused technologies, and transparency tools to improve waste management practices. The findings from this study build upon these insights, offering a detailed evaluation of how reward-based digital platforms effectively drive

behavioral change while identifying areas for further optimization, such as expanding reward options and addressing technical challenges.

III. METHODOLOGY

The study employs an exploratory mixed-methods approach to investigate the implementation and impact of reward-based digital systems on waste management practices as figure 1 show. This methodology integrates qualitative and quantitative methods to comprehensively evaluate user engagement, behavior change, and system effectiveness, ensuring a holistic understanding of how reward-based systems can drive sustainable waste sorting practices.

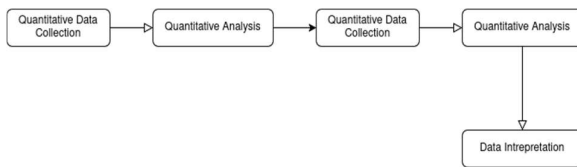


Figure. 1. Research Context

Drawing inspiration from prior research, particularly (Bjorklund et al., 2024) in Sustainability Potentials of Digitally Based Platforms for the Circularity of Household Items, this study adopts a mixed-methods approach to address the complexities of user-centric waste management. Additionally, (Kolade et al., 2024) in Digitally Enabled Business Models for a Circular Plastic Economy in Africa highlights the importance of combining qualitative insights and quantitative metrics to evaluate the scalability and impact of digital platforms in circular economy frameworks. Similarly, (Adelekan & Sharmina, 2024) in Collaborative Digitally-Enabled Business Models for a Circular Economy emphasizes the role of co-design and stakeholder collaboration in creating effective and adaptable circular economy solutions. Together, these papers underscore the necessity of integrating behavioral insights with measurable outcomes to design systems that align with user needs and promote sustainable practices.

The qualitative component explores user motivations, barriers, and perceptions of reward-based systems through focus groups and interviews, providing rich insights into behavioral drivers and challenges. This aligns with methodologies in (Bjorklund et al., 2024), where qualitative data revealed the human factors influencing engagement with circular systems. Additionally, (Leone et al., 2024) highlights the importance of iterative feedback to refine systems that prioritize user needs. The quantitative aspect measures behavioral changes, such as waste sorting frequency and accuracy, offering objective evidence of how reward-based systems influence sustainable behaviors. This dual approach captures both the human and operational dimensions needed to evaluate the system's potential for scalability and long-term impact.

By integrating these perspectives, the research seeks to develop actionable insights into the role of reward-based digital systems in fostering sustainable waste management

practices. The study evaluates how the system's core features—such as incentivization through points, transparent reporting of user contributions, and accessible digital tools—can drive user engagement and improve sorting behaviors. These findings aim to inform the design and implementation of future user-centric systems that address persistent challenges in sustainability and waste management.

A. Data Collection and Analysis

The study employed a three-month data collection process that integrated qualitative and quantitative methods to comprehensively evaluate the reward-based digital system's impact on waste management practices. This combination of methods ensured a balanced understanding of user engagement, behavior change, and system performance.

B. Qualitative Data Collection

The qualitative component of the study was critical for gaining a deeper understanding of user motivations, barriers to participation, and perceptions of the reward-based system. These insights provided the contextual foundation needed to design a system that aligns with the needs and expectations of its users. Data was collected through the following methods:

1. Stakeholder Engagement Workshops

Workshops were conducted at the initial stages of the study to engage key stakeholders, including:

- Households:** Community members who would directly interact with the reward-based system.
- Local Waste Management Authorities:** Officials overseeing waste collection, sorting processes, and compliance with regulations.
- Partnering Businesses:** Organizations contributing to the reward system by offering tangible incentives, such as discounts on groceries, utility payments, or other services. Their involvement ensured the feasibility and attractiveness of the rewards for end-users.

During the Stakeholder Engagement Workshops, the research team adopted a structured approach to guide discussions and achieve actionable outcomes. This section outlines the steps taken, including specific discussion prompts, sorting guidelines provided to stakeholders, and the outcomes that led to the identification and prioritization of challenges.

The research team initiated the workshops with clear objectives and discussion prompts, ensuring active participation from all stakeholder groups. The framework included the following key stages:

a. Opening Discussion:

To understand the current challenges in waste sorting and collection systems within the community, stakeholders including households, local authorities, and partnering businesses were invited to voice their experiences and initial difficulties. To ground the discussion in practical contexts, the research team presented pre-identified sorting guidelines based on best practices and system requirements. These guidelines included the use of color-coded bins to visually

demonstrate how waste categories (organic, recyclable, and non-recyclable) are separated. Furthermore, specific sorting rules were detailed, outlining items suitable for each bin, such as plastics, paper, organic waste, and hazardous materials. To build trust and understanding, flowcharts illustrating the recycling process were also shown, depicting how correctly sorted waste is processed and reused. Stakeholders were asked: "Do these sorting guidelines align with your current understanding and practices? Where do you see gaps or confusion?"

b. Structured Feedback and Categorization:

To gather detailed feedback, stakeholders were divided into three distinct groups: households, local authorities, and businesses. Each group was equipped with sticky notes and large sheets of paper to document the specific challenges they encounter in adhering to the presented sorting guidelines. They were also encouraged to identify any additional guidelines or clarifications they felt were necessary. Subsequently, each group presented their collected feedback, which the research team then organized and categorized by theme.

2. Focus Group

Focus groups were conducted with diverse participants, including households and waste management personnel, at two key points during the study to measure changes in behavior and engagement with the system:

a. Baseline (Start of Pilot Phase):

The objective of this phase was to establish baseline data regarding current behaviors, existing challenges, and stakeholder expectations before the implementation of the reward-based system. Specifically, the research tracked current waste sorting behaviors, including the accuracy and frequency of compliance with sorting guidelines. It also aimed to identify existing motivations for participating in waste sorting, as well as any barriers preventing participation. Lastly, the study gathered insights into system expectations, encompassing any anticipated benefits or potential concerns stakeholders had regarding the upcoming reward-based platform.

b. Post-Pilot (End of Pilot Phase):

The purpose of this subsequent phase was to assess any changes in behavior and perception after participants had interacted with the reward-based system over a defined period. The research specifically tracked behavioral changes, such as improvements in the accuracy, frequency, and consistency of waste sorting. It also gathered feedback on system usability, focusing on the ease of using platform features like the application or QR codes. Furthermore, the effectiveness of the rewards was evaluated to determine the extent to which incentives motivated better sorting practices. Finally, any persistent challenges or remaining barriers to engagement or compliance were also identified.

3. Semi-structured interviews

Semi-structured interviews were conducted during the Post-Pilot Phase to gain in-depth insights from thirty active users of the reward-based system. These interviews focused on evaluating participants' experiences after using the platform during the pilot phase.

The research explored several key topics, beginning with the usability of the platform's features, specifically examining the ease of using mobile app functions such as QR code tracking and monitoring rewards. Another significant area of investigation was the influence of rewards on behavior, assessing the degree to which incentives like discounts or utility benefits motivated changes in waste sorting habits. Finally, the study delved into participant perceptions of trust and transparency concerning the platform's feedback mechanisms, particularly focusing on the perceived accuracy and reliability of the information provided.

Quantitative data was collected to objectively evaluate behavioral changes and the performance of the reward-based digital system during the pilot phase. This process relied on platform usage tracking and complementary waste audits:

a. Platform Usage Metrics

The research tracked various user interactions with the platform, including activities such as logging waste, the rates at which rewards were redeemed, and the frequency of application usage. This data was collected automatically through the platform's backend system, which provided real-time and objective metrics on user engagement.

b. Waste Audits

To verify the accuracy of waste sorted by users, periodic audits were conducted to calculate the percentage of correctly sorted materials. The results from these audits were then compared with metrics from the platform to validate the system's actual influence on waste sorting behaviors. Separately, baseline data was established before the platform's deployment to serve as a benchmark for evaluating subsequent changes. This initial measurement captured waste sorting frequency, accuracy, and user engagement levels, allowing for a comparative analysis with performance data collected after the pilot program.

The qualitative data collected from stakeholder engagement workshops, focus groups, and semi-structured interviews was analyzed using thematic analysis.

Data gathered from workshops concerning challenges, gaps, and clarifications needed for sorting practices were transcribed and coded to pinpoint recurring themes. Similarly, discussions from both baseline and post-pilot focus groups underwent thematic analysis to identify patterns related to behaviors, motivations, system usability, and existing barriers. Finally, data from post-pilot semi-structured interviews were analyzed to gain deeper insights into user experiences with specific platform features, the influence of rewards on their actions, and their level of trust in the system.

Thematic analysis was applied to identify patterns across the datasets. Key themes informed the evaluation of system performance, user engagement, and areas for refinement.

Quantitative data derived from platform usage metrics and waste audits were analyzed to assess behavioral changes and system performance.

Descriptive statistics were applied to summarize user activity trends, including waste logging frequency, reward redemption rates, and app usage patterns. To determine

whether there were significant differences between baseline data and post-pilot results, paired t-tests were conducted. This analytical method is employed to determine if the observed changes in key performance indicators are statistically significant. These indicators include sorting accuracy, which is measured by the percentage of correctly sorted waste identified through periodic audits. Another key metric is the frequency of waste deposits, reflecting the level of user engagement with the waste sorting process. Finally, reward redemption patterns are analyzed, with utilization rates serving as a measure of how effective the incentives are in motivating users.

Findings from qualitative and quantitative analyses were triangulated to ensure a comprehensive evaluation of the platform's impact. Quantitative results, such as changes in sorting accuracy, waste sorting frequency, and reward redemption rates, were analyzed alongside qualitative feedback on system usability, rewards, and engagement barriers. Paired t-test results provided statistical evidence of differences between baseline and post-pilot measurements, which were contextualized with qualitative insights to identify key drivers of and barriers to engagement. Discrepancies or alignment between behavioral data and participant perceptions were examined to provide a holistic understanding of the platform's impact.

The study adhered to rigorous ethical standards to ensure the protection of participant rights and the integrity of the research process. Prior to data collection, all participants—households, local waste management authorities, and partnering businesses—were provided with detailed information about the study's objectives, procedures, and their role within it. Informed consent was obtained from all participants, emphasizing their voluntary participation and the option to withdraw at any stage without any consequences.

To maintain confidentiality, all collected data, including qualitative inputs from workshops, focus groups, and interviews, as well as quantitative platform usage metrics and waste audit results, were anonymized. Data handling and storage followed strict protocols to safeguard participant identities and ensure compliance with ethical research standards.

IV. RESULT & DISCUSSION

The study employs an exploratory mixed-methods approach to investigate the implementation and impact of reward-based digital systems on waste management practices as table 1 show. This methodology integrates qualitative and quantitative methods to comprehensively evaluate user engagement, behavior change, and system effectiveness, ensuring a holistic understanding of how reward-based systems can drive sustainable waste sorting practices.

A. Quantitative Result s

The qualitative findings as table 1 were derived from three stakeholder engagement workshops, two focus group sessions (baseline and post-pilot), and 30 semi-structured

interviews. The results provide insights into the drivers of participation, challenges encountered, and the role of platform features in influencing user engagement and behavior. Thematic analysis identified recurring patterns, with participant responses categorized into key themes to inform system strengths and areas for improvement.

Table 1. Qualitative Result

Challenges in Compliance	52 participants (61%)	Users reported confusion regarding sorting guidelines for specific items and occasional disruptions caused by QR code scanning errors.
Motivation through Rewards	65 participants (76%)	Rewards emerged as the primary driver for participation. Tangible incentives, such as grocery discounts and utility credits, were perceived as highly valuable.
Trust and Transparency	48 participants (56%)	Real-time dashboards fostered trust and accountability by allowing users to monitor individual and community-level progress.
Usability	58 participants (68%)	Mobile app features, including detailed sorting instructions and QR tracking, were described as intuitive and effective in supporting accurate sorting practices.
Barriers	40 participants (47%)	Limited reward options, technical glitches, and the absence of multilingual support were identified as barriers to sustained engagement.

The qualitative findings demonstrate that rewards and platform usability played a pivotal role in driving user engagement and encouraging consistent participation in waste sorting practices. Participants widely acknowledged that tangible incentives, such as grocery discounts and utility credits, provided immediate and meaningful value, making the reward system an effective motivator. The integration of real-time feedback through transparency dashboards significantly contributed to fostering trust and accountability, as users were able to monitor their personal progress alongside community-level contributions. This visibility not only reinforced a sense of achievement but also encouraged continued participation by establishing a connection between individual actions and collective impact.

Despite these positive outcomes, the findings revealed persistent challenges that hindered optimal performance of the platform. Technical issues, such as intermittent failures in QR code scanning, were a recurring concern that disrupted user experiences and discouraged some participants. Furthermore, confusion surrounding sorting

guidelines for certain waste categories indicated a need for clearer and more intuitive instructional content within the platform. While the reward system was well-received, users expressed dissatisfaction with the limited diversity of reward options, suggesting that broader and more personalized incentives could better cater to diverse user preferences and sustain long-term engagement.

These findings emphasize the dual nature of the platform's impact—while rewards and usability succeeded in driving behavioral change and enhancing user trust, addressing identified barriers is essential to ensure the platform achieves its full potential. Refinements in technical reliability, clarity of guidelines, and the expansion of reward offerings are key priorities for improving user experiences and maintaining high levels of engagement over time.

B. Quantitative Result

Quantitative data collected from platform usage metrics and periodic waste audits provided measurable evidence of changes in waste sorting behaviors and user engagement shown in table 2. The paired t-tests were employed to determine whether the observed improvements in key performance indicators were statistically significant:

Table 2. Quantitative Result

Metric	Before Deployment	After Deployment	Improvement
Waste Sorting Frequency	1.5 deposits/week	4.2 deposits/week	+180%
Sorting Accuracy	68%	92%	+35%
Waste Collection Volume	20 kg/month	50 kg/month	+150%
Reward Redemption Rate	N/A	75% of rewards	High engagement observed

C. Statical Analysis

The paired t-test (1) was used to assess the significance of changes between baseline (before platform deployment) and post-pilot (after platform deployment) data. The paired t-test compares two related datasets by analyzing the differences within pairs of observations, ensuring the observed improvements are not due to random chance.

$$t = \frac{\bar{d}}{\frac{S_d}{\sqrt{n}}} \quad (1)$$

Where (1):

t = t-statistic

$\bar{d}$ = mean of the differences between baseline and post-pilot measurements.

S_d = standard deviation of the differences.

d = number of paired observations

The quantitative results not only highlight significant improvements in sorting behaviors but also provide clear evidence of the platform's ability to influence user engagement and system performance. These insights are directly applicable to optimizing reward-based waste management systems and driving further behavioral change.

Sorting Frequency:

1. Baseline: 1.5 deposits/week
2. Post-pilot: 4.2 deposits/week
3. The paired t-test confirmed a statistically significant improvement ($p < 0.01$).
4. Application: The increase in deposit frequency reflects a meaningful behavioral shift driven by rewards and usability. This suggests that consistent, real-time user feedback paired with immediate, tangible incentives effectively encourages users to engage with sorting practices more regularly. Future implementations can emphasize frequent, low-effort actions paired with visible rewards to sustain participation.

Sorting Accuracy:

1. Baseline: 68% correctly sorted waste
2. Post-pilot: 92% correctly sorted waste
3. The paired t-test showed a significant increase ($p < 0.01$).
4. Application: Improved sorting accuracy highlights the role of clear and accessible sorting guidelines combined with digital tools like real-time tracking. Providing users with easy-to-understand instructions and feedback mechanisms can significantly enhance waste sorting performance. Platforms should focus on visual cues (e.g., color codes), instructional reminders, and instant confirmation to reinforce correct sorting behaviors.

Waste Collection Volume:

1. Before: 20 kg/month per household
2. After: 50 kg/month per household
3. The 150% increase observed reflects improved participation and sorting consistency.
4. Application: The increase in waste collection volume suggests that reward-based systems not only enhance individual user behavior but also lead to a tangible increase in waste diverted for proper management. Scaling such systems to larger communities could have broader environmental benefits, including reductions in landfill contributions and increased recycling rates.

D. Reward Utilization and Preferences

Reward utilization data were extracted from the platform usage metrics collected during the pilot phase. The results as table 3 indicate a 75% reward redemption rate, reflecting strong user engagement with the reward system. This data was further analyzed to determine user preferences for reward categories.

Table 3. Reward Utilization and Preferences

Reward Category	Percentage of Redemptions	Redemption Count (n = 3,200 rewards)
Grocery Discounts	40%	1,280
Utility Credits	35%	1,120
Local Services	25%	800

The data indicates that most users preferred rewards that addressed their essential needs, particularly those related to food and utilities (Bjorklund et al., 2024). Grocery discounts emerged as the most frequently redeemed reward, accounting for 40% of redemptions, which suggests that users prioritized immediate and tangible

benefits. Utility credits followed closely at 35%, reinforcing the trend of users favoring support for everyday expenses. Although local services were redeemed less frequently, with 25% of users opting for them, they still held value for individuals interested in community-based offerings.

The total reward redemption rate of 75% highlights the platform's success in engaging users through relevant incentives.

E. Integrated Results

The integration of qualitative and quantitative findings provides a holistic understanding of the reward-based platform's impact on user engagement, behavioral change, and system performance shown in table 4. The alignment of measurable outcomes with user-reported experiences offers valuable insights into both the strengths and limitations of the system.

Table 4. Integrated Result

Integrated Insights	Quantitative Evidence	Qualitative Context
Sorting Improvements	Sorting accuracy increased by 35%.	Participants attributed the improvement to the platform's clear sorting guidelines and usability features , particularly the instructional content and QR code tracking that simplified the sorting process. Users noted that visual aids and step-by-step instructions reduced uncertainty about sorting requirements.
Increased Engagement	Waste deposit frequency rose by 180%.	Rewards were consistently identified as the primary motivator for increased and sustained participation. Participants emphasized the role of tangible incentives, such as grocery discounts and utility credits, in creating a sense of achievement and immediate value.
High Reward Utilization	75% of rewards were redeemed.	Qualitative data revealed that rewards addressing essential needs were most valued. Participants expressed preference for practical incentives, which aligned with high redemption rates for groceries (40%) and utilities (35%). Local services (25%) were seen as relevant but less prioritized.
Trust and Transparency	High usage of real-time dashboards.	Users reported that real-time feedback and visibility into individual and community-level progress fostered a sense of trust and accountability. Transparency dashboards provided measurable proof of contributions, reinforcing user confidence in the platform's fairness and effectiveness.
Barriers	Technical glitches in QR code scanning.	Participants reported frustration due to technical disruptions , such as QR code scanning failures, which interrupted engagement. Additionally, limited reward diversity reduced motivation for some users, suggesting the need for broader and more personalized options to sustain interest.

The integrated results reveal a clear connection between the quantitative improvements in user behaviour and the qualitative insights regarding user motivations, system features, and challenges. The observed 35% increase in sorting accuracy is strongly supported by user feedback emphasizing the value of sorting instructions and platform usability, which simplified waste categorization. Similarly, the 180% rise in sorting frequency aligns with

participants' reports that tangible rewards served as key motivators, driving consistent participation and engagement.

High levels of reward redemption (75%) further reinforce the platform's ability to align incentives with user priorities. Rewards for essential needs, such as groceries and utility credits, were redeemed most frequently, reflecting user preferences for practical and

immediate benefits. This alignment between reward utilization patterns and qualitative preferences highlights the effectiveness of the platform's incentive design.

The integration of real-time transparency dashboards played a pivotal role in fostering trust and accountability among users. Quantitative evidence of high dashboard usage correlates with participant feedback that visibility into progress enhanced confidence and reinforced their commitment to waste sorting efforts. By connecting individual actions to broader community outcomes, the platform successfully engaged users on both personal and collective levels.

Despite these successes, persistent barriers remain. Technical disruptions, particularly with QR code scanning, were identified in both qualitative feedback and platform data, indicating a need for enhanced system reliability. Additionally, limited reward diversity emerged as a factor reducing engagement for some users, highlighting the importance of expanding reward options to sustain long-term participation.

The integrated findings confirm that the reward-based platform effectively combined motivational incentives, usability features, and transparency mechanisms to drive measurable improvements in waste sorting behavior and user engagement. However, addressing identified barriers, such as improving technical performance and diversifying reward options, will be critical to further optimizing the platform and ensuring its long-term impact.

V. CONCLUSION

The results of this study demonstrate the effectiveness of the reward-based digital platform in improving waste sorting behaviours and fostering user engagement. The integration of qualitative and quantitative findings provides a comprehensive understanding of the platform's impact and highlights its strengths, as well as areas requiring further refinement.

Statistically significant improvements were observed in user behaviour, with waste sorting frequency increasing by 180% (from 1.5 to 4.2 deposits per week), sorting accuracy rising by 35% (from 68% to 92%), and waste collection volume growing by 150% (from 20 kg to 50 kg per household per month). A 75% reward redemption rate reflected strong user engagement, with a clear preference for rewards addressing essential needs, such as grocery discounts (40%) and utility credits (35%).

Qualitative findings provided context for these quantitative improvements, emphasizing the role of motivational rewards, platform usability, and transparency features in driving participation and building user trust. Clear sorting guidelines and intuitive platform tools simplified the sorting process, while real-time dashboards enhanced accountability by connecting individual actions to collective outcomes. However, persistent barriers, such as technical glitches in QR code scanning and limited reward diversity, were identified as challenges that require attention.

The integrated results confirm that the platform's combination of incentives, usability, and transparency successfully influenced measurable changes in waste

management behavior. To maximize its long-term impact, future iterations of the platform should focus on addressing technical reliability, expanding reward options, and enhancing user support to cater to diverse needs. These findings underscore the potential of reward-based digital systems as scalable solutions for promoting sustainable waste management practices, with clear implications for broader implementation across community and organizational contexts.

REFERENCES

- Adelekan, A., & Sharmina, M. (2024). Collaborative digitally-enabled business models for a circular economy: Sustaining, managing and protecting value in the UK plastics sector. *Journal of Cleaner Production*, 438.
- Bjorklund, M., Gustafsson, S., & Skill, K. (2024). Sustainability potentials of digitally based platforms for the circularity of household items. *Cleaner Logistics and Supply Chain*, 10.
- Cappelletti, F., Papetti, A., Rossi, M., & Germani, M. (2022). Smart strategies for household food waste management. *Procedia Computer Science*, 200.
- Chan, H. F., Moy, N., Schaffner, M., & Torgler, B. (2021). The effects of money saliency and sustainability orientation on reward based crowdfunding success. *Journal of Business Research*, 125.
- Chaudhuri, A., Subramanian, N., & Dora, M. (2022). Circular economy and digital capabilities of SMEs for providing value to customers: Combined resource-based view and ambidexterity perspective. *Journal of Business Research*, 142.
- Denu, M., David, P., Landry, A., & Mangionem, F. (2023). Exploring opportunities and barriers of digital technologies in circular manufacturing systems: An overview and a research roadmap. *Sustainable Production and Consumption*, 43.
- Dwivedi, Y. K., Hughes, L., Kar, A. K., Baabdullah, A. M., Grover, P., Abbas, R., Andreini, D., Abumoghli, I., Barlette, Y., Bunker, D., Kruse, L. C., Constantiou, I., Davison, R. M., De', R., Dubey, R., Fenby-Taylor, H., Gupta, B., He, W., Kodama, M., ... Wade, M. (2022). Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. *International Journal of Information Management*, 63.
- Evertsen, P. H., & Knotten, V. (2024). Toward a collaborative circular ecosystem within the built environment. *Sustainable Production and Consumption*, 52.
- Hatley, G., Pahlow, M., Bello-Mendoza, R., & Gutiérrez-Ginés, M. J. (2024). Identifying leverage points using material flow analysis to circularise resources from urban wastewater and organic waste. *Journal of Environmental Management*, 369.
- Kolade, O., Oyinlola, M., Ogunde, O., Ilo, C., & Ajala, O. (2024). Digitally enabled business models for a circular plastic economy in Africa. *Environmental Technology & Innovation*, 3.

- Leone, D., Pietronudo, M. C., Gabteni, H., & Carli, M. R. (2024). Reward-based crowdfunding for building a valuable circular business model. *Journal of Business Research*, 157.
- Möslinger, M., Ulpiani, G., & Vettters, N. (2023). Circular economy and waste management to empower a climate-neutral urban future. *Journal of Cleaner Production*, 421.
- Neves, J. S., Yamane, L. H., Santos, R. P., & Siman, R. R. (2025). Challenges in commercial solid waste management: Generation indicators and willingness to pay for management. *Cleaner Waste Systems*.
- Nicol, C., Kostis, A., Lidström, J., & Holmström, J. (2024). Corporate incubation for platform growth and the transition to platform scaling: Between a rock and a hard place in the circular economy. *ScienceDirect*.
- Petchrompo, S., Chitniyom, R., Peerwantanagul, N., Laesanklang, W., Suwanapong, J., & Borrisuttanakul, S. (2025). Enhancing operational efficiency in a voluntary recycling project through data-driven waste collection optimization. *Waste Management*, 200.
- Sianturi, R. I., Suryatiningsih, S., Aji, P., & Preciosa, B. (2024). User Experience Satisfaction Analysis of the CLEIN Plastic Bottle Waste Saving Mobile Application. *Procedia Computer Science*, 245.
- Tundjungsari, V., Putranto, B. P. D., Ulum, M. B., & Anwar, N. (2025). *An Integrated Model for Circular Waste Management Using the Internet of Things*. Semantic Web.
- Vishwakarma, S., Kumar, V., Arya, S., Tembhare, M., Rahul, D. D., & Kumar, S. (2022). E-waste in Information and Communication Technology Sector: Existing scenario, management schemes and initiatives. *Environmental Technology & Innovation*, 27.
- Yadav, S., Samadhiya, A., Kumar, A., Majumdar, A., Garza-Reyes, J. A., & Luthra, S. (2023). Achieving the sustainable development goals through net zero emissions: Innovation-driven strategies for transitioning from incremental to radical lean, green and digital technologies. *Resources, Conservation and Recycling*, 197.
- Zhang, L., Mu, R., Zhan, Y., Yu, J., Liu, L., Yu, Y., & Zhang, J. (2022). Digital economy, energy efficiency, and carbon emissions: Evidence from provincial panel data in China. *Science of The Total Environment*, 852.