

Digital Innovation In Household And Agricultural Waste Management In Pakusari Village, Jember Regency

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Abstract

Household and agricultural waste management in rural areas still faces various problems, including low public awareness in sorting, limited access to information, and not optimal use of waste as an economically valuable resource. This research aims to develop digital innovations in supporting household and agricultural waste management in Pakusari Village, Jember Regency. The research uses the Research and Development (R&D) method with a User Centered Design (UCD) approach which includes identifying user needs, designing, developing, and evaluating the system. The research data was obtained through observation, interviews, documentation, and questionnaires. The digital innovations developed provide information and education features on waste sorting, recording the type and amount of waste, point and incentive system, transaction history, and information on waste collection schedules. The results of the evaluation showed that the system obtained a usability rate of 88%, ease of use of 85%, user satisfaction of 84%, clarity of interface of 82%, and completeness of features of 80%. These results show that the digital innovations developed can be used to support household and agricultural waste management in a more structured manner and encourage the application of circular economy principles at the village community level. This innovation is expected to be an alternative to digital-based waste management models that can be developed and applied to other rural areas.

Keywords: Waste Management, Digital Systems, Household and Agricultural Waste, Circular Economy, User Centered Design

INTRODUCTION

Waste problems are one of the environmental challenges that continue to develop along with the increasing population, consumption activities, and changes in people's lifestyles. Less than optimal waste management not only has an impact on the environment and health, but also causes the potential of waste as a resource that has

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utility and economic value that has not been utilized optimally. The development of digital technology provides an opportunity to present innovations that can support more integrated waste management through the process of collecting, sorting, recording, monitoring, and delivering information in a more structured manner (Trofymenko et al., 2023; Czekala et al., 2023).

This problem is also found in waste management in rural areas, including Pakusari Village, Jember Regency. Waste produced by the community does not only come from household activities, but also from agricultural activities. Household waste in the form of plastic, paper, and organic matter has different characteristics from agricultural waste, such as plant residues and corn cobs. If not managed properly, the waste has the potential to be burned or thrown away without going through the proper sorting and utilization process. This condition shows the need to improve waste management innovations that are tailored to the characteristics of rural communities and are able to integrate environmental, social, and economic aspects (Amali et al., 2024).

Waste management that is still carried out conventionally causes waste sorting, collection, recording, and utilization activities to not run optimally. The public needs easily accessible information about the types of waste, how to sort, collection schedules, and its potential utilization. Therefore, digital innovation is needed as a supporting means that can help the community recognize, sort, record, collect, and utilize waste in a more targeted manner. The use of digital technology in managing waste is expected to increase the regularity of the management process while supporting community involvement in waste management activities (Czekala et al., 2023).

From an economic point of view, waste should not be considered always seen as a worthless material, but can be a resource that has economic potential if managed appropriately. The concept of the circular economy provides a relevant approach by placing materials so that they still have use value through reduction, reuse, utilization, and recycling. In the context of waste management, digital technology can support the application of circular economy principles through the provision of information, activity recording, monitoring, and waste management in a more structured manner. Thus, waste treatment is not only directed to reduce eco-friendly impacts, but can also provide social and economic benefits for the community (Trofymenko et al., 2023).

The use of digital technology in waste management has developed through various forms of systems and applications. Digitalization can be used to provide information about waste management, support the sorting process, optimize collection activities, and increase connectivity between the community and waste managers (Mozaffari, 2023; Sosunova & Porras, 2022). The development of an integrated information system for waste management also shows that digital technology can be a



supporting means in building more integrated waste management and oriented towards sustainable development (Amali et al., 2024).

Various previous studies have developed technology to support waste management. Deepa (2020) developed a mobile application to support waste management. Fallavi et al. (2017) discussed the use of the Internet of Things in smart waste management, while Das et al. (2023) developed automated waste separation technology using deep learning. Sinodlay et al. (2023) also demonstrated the implementation of intelligent waste bins technology equipped with notifications and image processing. In addition, blockchain technology has been studied as one of the technologies that can support greater visibility and traceability in waste management processes. The research shows that digital technology is capable of improve the effectiveness and systematic management of waste, although the approach and context of its application differ according to the characteristics of the user and the research region.

In addition to the technological aspect, the success of digital innovation in waste management is also influenced by the involvement of the community as users. Digital innovation needs to be designed by considering the needs, abilities, and characteristics of users so that they can be accepted and used in daily activities. At the community level, digital systems can support the delivery of information, recording activities, and providing points or incentives that can promote community engagement in waste sorting and management. The application of digital systems in TPS3R management and waste exchange systems into economic value shows that technology can be used as a means to strengthen community participation while increasing the use value of waste (Suryani, 2022; Utama et al., 2022).

Although various studies have discussed the use of digital technology in waste management, there is still room for development in the context of rural communities. Some research focuses on urban waste management, household waste, or the application of certain technologies such as the Internet of Things, deep learning, and blockchain. Meanwhile, studies on digital innovations that specifically integrate household waste management and agricultural waste in one system in the context of rural communities are still limited. In fact, rural areas have different waste management characteristics because waste sources come not only from household activities, but also from agricultural activities with various types and potentials for use. This condition shows the need for digital innovation that is not only technology-oriented, but also tailored to the needs and characteristics of local communities (Trofymenko et al., 2023; Kannan et al., 2024).

Based on these gaps, this research develops digital innovations that support a series of waste management activities ranging from education, sorting, recording, collection, to providing points or incentives. The integration of these features is expected



to make it easier for the community to obtain information, conduct waste management in a more structured manner, and increase participation in waste utilization. The approach is also directed to support the application of circular economy principles by placing waste as a resource that still has potential use and economic value (Kannan et al., 2024).

The originality of this research lies in the development of digital innovations that integrate the management of household waste and agricultural waste in one system aimed at rural communities. The innovations developed not only provide information about waste management, but also integrate educational features and sorting information, recording the type and amount of waste, a point and incentive system, transaction history, and information on waste collection schedules. The integration places the community not only as recipients of information, but as users involved in the process of sorting, recording, collecting, and utilizing waste.

The novelty of the research is also strengthened through the use of the User Centered Design (UCD) approach in the process of developing digital innovations. This approach is used to ensure that the design and features of the system are tailored to the needs, characteristics, and capabilities of users in rural environments. By integrating the characteristics of household and agricultural waste, community needs, waste management features, as well as points and incentive mechanisms, this research offers a digital approach that connects environmental aspects, community participation, and potential economic value. Thus, the innovations developed are not only oriented towards the use of technology, but are also directed to support the application of circular economy principles in waste management at the community level.

Based on this description, this research aims to develop digital innovations in household and agricultural waste management in Pakusari Village, Jember Regency, using the User Centered Design approach. This research is expected to contribute to the development of digital-based waste management innovations that are in accordance with the needs of rural communities, increase community participation in waste management, and support the use of waste as a resource that has environmental and economic value.

METHOD

2.1 Research Design

This study adopts a Research and Development (R&D) approach to develop digital innovations in supporting household and agricultural waste management in Pakusari Village, Jember Regency. The R&D method was chosen because the research is oriented towards product development that can be used as a means of supporting the solution of waste management problems at the community level.

The research process includes identifying problems and user needs, analyzing system needs, designing systems, developing products, testing, user evaluation, and



improving the system. The development of digital innovations uses *the User Centered Design* (UCD) approach which places users at the center of the design and development process. This approach is used to ensure that the developed system is in response to the identified user needs, characteristics, capabilities, and conditions of users in Pakusari Village.

The implementation of UCD allows user needs and input to be the basis for determining the function, flow, appearance, and ease of use of the system. The stages of UCD in this study include *Analyze the User Context, Identify User Requirements, Develop Appropriate Design Solutions, and Evaluate the Outcomes*. The four stages are carried out sequentially to Analyze the usage context and determine user needs, produce system designs, and evaluate the suitability of the system with user needs.

Table 1. Stages of System Development with the UCD Approach

CD Stages	Research Activities	Output
<i>Understand Context of Use</i>	Observation and interviews with communities, waste managers, and village officials to understand waste management conditions and user characteristics	Identify the problem, user characteristics, and context of use
<i>Specify User Requirements</i>	Analysis of user needs and system needs based on observations, interviews, and discussions	Functional and non-functional system requirements
<i>Produce Design Solutions</i>	Designing system flows, <i>use case diagrams</i> , databases, and user interfaces	System design and prototype
<i>Evaluate Design</i>	System testing and user evaluation of developed systems	Evaluation results and improvement recommendations

Source: Adapted from ISO 9241-210:2019 and Amali et al. (2024).

2.2 Needs Analysis and System Design

Needs analysis is carried out to identify waste management problems and user needs as the basis for system development. Information collection is carried out through observations, interviews, and discussions with the people of Pakusari Village, waste managers, and village officials. The information obtained is used to understand user characteristics, waste management activities, problems faced, and the need for a digital system.



The results of the needs analysis show that the community needs a system that is easy to use and able to provide relevant information about waste management. The main needs include information on waste sorting, recording the type and amount of waste, monitoring of waste management activities, information on collection schedules, and a point and reward system that can support community involvement.

These needs are translated into functional and non-functional system needs. Functional needs include educational features and waste management information, information on the type of waste, recording of waste data, activity or transaction history, points and reward systems, and information on waste collection schedules. Non-functional needs include ease of use, simple interface appearance, compatibility with smartphone devices, and ease of system access.

The design phase is guided by the findings of the user needs analysis. The design includes the preparation of *use case diagrams*, activity flows, database designs, and user interface designs. The design is then used as a basis for the development of digital innovations in waste management.

The developed system has two main user groups, namely community users and administrators. Community users can access educational information, enter waste data, view activity history, monitor points, and use the reward feature. Administrators function to manage user data, verify waste management data, manage educational information, and manage award data.

Table 2. System Functional Requirements

No.	User Needs	System Features	Supporting References
1	Understanding waste management	Information and education on waste management	Deepa (2020)
2	Knowing the type of waste	Information and classification of waste types	Das et al. (2023)
3	Record waste management activities	Input and recording of waste data	Amali et al. (2024)
4	Monitor waste management activities	Activity or transaction history	Sosunova & Porras (2022)
5	Getting an award for waste management activities	Points and reward system	Utama et al. (2022)
6	Obtaining information on waste collection	Schedule information and garbage collection	Kannan et al. (2024)

Source: Processed based on the results of needs analysis and previous research.

2.3 System Development and Testing

The development stage is carried out based on the design that has been produced in the *Produce Design Solutions stage*. The system design is translated into a digital product that contains features according to user needs. Development includes the implementation of educational features and waste management information, information on the type of waste, recording of waste data, activity or transaction history, points and award systems, and information on waste collection schedules.

After the product is developed, tests are carried out on the main functions of the system to ensure that each feature can be used according to the design. The test is carried out by trying the main functions of the system, ranging from access to information, recording waste data, monitoring activities, to the use of the points and rewards system. The test results are used to identify errors or functions that still need to be corrected before user evaluation.

2.4 System Evaluation

Evaluation is carried out after the system is developed and tested to determine the user's perception of the quality of using the system. The evaluation is carried out through a questionnaire to users who have tried the main features of the system, including educational features and information on waste management, waste recording, activity monitoring, waste collection information, and a points and reward system.

User evaluation includes five aspects, namely usability, ease of use, user satisfaction, interface clarity, and feature completeness. The *usability* aspect is used to describe the system's ability to support users in completing waste management activities. Ease of use is used to determine the level of ease of use of users in understanding and operating the system. User satisfaction is used to determine the level of user acceptance of the system as a whole. Clarity of the interface is used to assess the user's ease of understanding the appearance and navigation of the system, while the completeness of features is used to determine the suitability of the available features to the user's needs.

The data from the questionnaire results was analyzed descriptively by calculating the percentage of scores in each aspect of the evaluation. The percentage was obtained by comparing the actual score. The percentage was determined using the following formula: $\text{Percentage} = (\text{Actual Score} / \text{Maximum Score}) \times 100\%$.

The percentage results are used to describe the level of user assessment of the developed system. The results of the evaluation are then used as a basis to identify the advantages and disadvantages of the system and determine the parts that still need improvement.



RESULTS AND DISCUSSION

3.1 Results of User Needs Analysis

The results of observations and interviews show that the management of household and agricultural waste in Pakusari Village still faces several problems, especially in sorting, recording, delivering information, and coordinating waste management activities. This condition shows the need for media that can help the community obtain information and record waste management activities in a more organized manner.

The community needs a simple and easy-to-use system, especially to obtain information about the types of waste, sorting, collection, and utilization of waste that still has a useful value. In addition, users need information about waste management activities and forms of appreciation that can be given for their contributions.

These needs are the basis for the development of digital innovation with the User Centered Design (UCD) approach. This approach places user needs and characteristics as the basis for determining the function, features, and interface design of the system. These results are in line with Amali et al. (2024) who show the importance of adjusting waste management information systems to user needs.

3.2 Results of Digital Innovation Development

Based on the results of user needs analysis, digital innovations were developed that integrate information, recording, and management of household and agricultural waste activities in one system.

The digital innovations developed have several key features, namely:

1. information and education on waste management;
2. information on the type and sorting of waste;
3. recording of waste management activities;
4. user activity history;
5. garbage collection information; and
6. Points and reward system.

The information and education feature is used to provide knowledge to the public about the type, sorting, and management of waste. The recording feature is used to document the waste management activities carried out by the user, while the history feature allows the user to see the activities that have been carried out. The collection information helps users know the waste collection activities, while the points and rewards system is designed as a supporting feature to provide appreciation for user involvement.

The development of these features shows that digital innovation is not only directed as a medium for delivering information, but also as a means of supporting waste management activities. This is in line with the development of digitalization of waste



management that utilizes information technology to support the recording, monitoring, delivery of information, and coordination of waste management activities (Deepa, 2020; Sosunova & Porras, 2022; Amali et al., 2024).

The main characteristic of the innovation developed in this study is the integration of household and agricultural waste management in one digital system in the context of rural communities. This integration is an important part because the type of waste produced by the community does not only come from household activities, but also from agricultural activities that have different characteristics and utilization potential.

3.3 User Test and Evaluation Results

The test was carried out on the main functions of the system and aspects of the user interface. The test results showed that the system can be used to access information, record waste management activities, view activity history, and use the reward feature.

User evaluation is carried out to determine the user's perception of the convenience, usability, and experience of using the system. The results of the user assessment are presented in Table 3.

Table 3. User Evaluation Results

Indicator	Percentage
Usability	88%
Ease of use	85%
User satisfaction	84%
Clarity of the interface	82%
Feature completeness	80%

Source: Research data processed by the author.

The results of the evaluation showed that all indicators obtained a percentage above 80%. The highest score was found in the usability aspect of 88%, followed by ease of use at 85% and user satisfaction at 84%. These results show that users give a positive assessment of the usability and ease of use of the digital innovations developed.

The clarity of the interface obtained a score of 82%, which indicates that the system display is relatively understandable by the user. Meanwhile, the completeness of the features obtained the lowest score, which is 80%. Although it is still at a positive

assessment level, the results show that the aspect of the completeness of the features is one of the parts that still has room to develop.

These findings show that the application of UCD in the development process can help produce designs that are more in line with user needs. User involvement in the process of identifying needs and evaluating allows system development to be carried out based on direct input on functionality, appearance, and user experience.

DISCUSSION

The results of the study show that digitalization can be used as one of the approaches to support waste management at the village community level. The innovations developed not only provide information, but also integrate activity recording, activity history, collection information, and awards in one system.

These findings are in line with Sosunova and Porras (2022) who explain that digital technology can support monitoring and information management in waste management systems. Amali et al. (2024) also show that the development of information systems can help waste management in a more integrated manner.

From a circular economy perspective, household and agricultural waste management is not only related to disposal, but also to efforts to maintain materials so that they still have use value. In this context, the digital innovations developed can act as a supporting means to provide information, record activities, and connect waste management activities with their potential reuse. Trofymenko et al. (2023) explained that digitalization is related to the development of waste management and the circular economy through the use of technology in resource and waste management.

The points and awards feature is also a form of support for community involvement. The award system is designed to provide appreciation for user activities and has the potential to be one of the supporting mechanisms for participation in waste management. This is in line with Utama et al. (2022) who developed the concept of waste exchange into economic value through digital applications.

The novelty of this research lies in the development of digital innovations that integrate the needs of household and agricultural waste management in one system in the context of rural communities, using the UCD approach. The integration not only includes the delivery of information and education, but also the recording of activities, activity history, collection information, as well as a point and reward system.

Thus, the contribution of research lies not only in the use of digital technology in waste management, but also in efforts to adapt innovation to the characteristics of the needs of rural communities that produce waste from household and agricultural activities. The UCD approach is an important part of ensuring that the features developed are based on the needs of users.



The results of the evaluation showed that digital innovations obtained positive assessments on usability, ease of use, user satisfaction, interface clarity, and feature completeness. However, these results need to be understood as ****usability and user acceptance evaluation****, not as evidence that digital innovations have led to increased waste sorting, changes in community behavior, increased economic value of waste, or increased community income. These impacts require further testing through implementation within a certain period of time with more specific indicators.

3.5 Further Enhancements and Development

Based on the results of user evaluations, several aspects of digital innovation can still be further developed. Improvements are mainly directed at improving the completeness of features, presenting simpler and easier to understand information, developing a notification feature for garbage collection, increasing the variety of awards, and providing user guides.

The value of the completeness of the features that obtained the lowest percentage, which is 80%, is one of the bases for determining the next development priorities. The development of features also needs to consider the characteristics of rural communities, especially limited internet access and differences in digital literacy levels.

Therefore, further development can be directed at optimizing the system for limited network conditions, simplifying the interface, and developing features that are more adaptive to user needs. Further research can also test the implementation of the system over a longer period to determine its effect on changes in sorting behavior, community participation, waste reuse, and the potential economic value resulting from household and agricultural waste management.

CONCLUSION

This research produces a digital-based waste management system as an innovation in supporting household and agricultural waste management in Pakusari Village, Jember Regency. The development of the system is carried out using the R&D method with the UCD approach through the stages of user context identification, needs analysis, solution design, and system evaluation.

The developed system provides educational features and information on waste sorting, recording of waste management activities, activity history, collection information, as well as a points and reward system. The results of user evaluations show a positive assessment of the ease of use, clarity of the interface, completeness of features, satisfaction, and usability of the system.

These results show that digital-based waste management systems have the potential to support more organized community waste management and support the



application of circular economy principles. However, this study has not been able to conclude that there is a quantitative increase in the amount of waste sorted, the level of recycling, or community income because these aspects have not been tested through measurements before and after the use of the system.

Limitations and Future Research

This research has several limitations. First, the research was conducted in the context of the Pakusari Village community so that the research results could not be generalized to all rural areas. Second, the evaluation still focuses on the aspects of function, usability, and user response to the system. Third, limited internet access and differences in the level of digital literacy of the community are factors that need to be considered in the implementation of the system.

Further research can be carried out by involving a wider area and number of users and evaluating in a longer period of use. Subsequent research can also measure changes in the volume of waste sorted, the level of waste utilization or recycling, the frequency of user participation, and the economic value generated before and after the implementation of the system. The development of notification features, interactive guides, integration with waste banks, and optimization of use on limited internet networks can also be the next development direction.

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