



Designing a Location-Based Digital Waste Bank System Model: A Design Science Research Approach for Urban Waste Service Integration

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ABSTRACT

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Digital transformation provides new opportunities for improving community-based waste management, yet many waste bank services still face fragmented information, limited service coordination, and insufficient transaction traceability. This study proposes a location-based digital waste bank system model using a Design Science Research (DSR) approach to integrate urban waste collection and transaction-related processes. The research followed the DSR stages of problem identification, requirement analysis, artefact design, demonstration, and preliminary evaluation. The proposed model connects key service activities, including nearest waste bank identification, waste collection requests, administrator verification, driver task assignment, transaction recording, balance management, and operational monitoring. A functional prototype was developed using Unified Modelling Language (UML)-based modeling, three-layer system architecture design, and role-based interfaces for customers, waste bank administrators, drivers, and superadmins. The prototype was evaluated through black-box functional testing and a preliminary user perception assessment involving 32 early evaluators. The results showed that all core functions operated according to the expected scenarios, while the overall acceptance score reached 89.50%, indicating positive initial feasibility. This study contributes a structured information system artefact that represents waste banks as integrated service nodes rather than isolated collection points. Although further field validation is required for scalability, security, route efficiency, and long-term environmental impacts, the proposed model provides a foundation for future implementation and empirical assessment of digital waste bank services.

1. INTRODUCTION

1.1 Background

Urban waste management has shifted from a technical issue of collection to a complex matter of public service governance. Population growth, changing consumption patterns and the expansion of urban economic activities are increasing the volume of waste whilst simultaneously heightening the need for systems capable of reducing waste at source. Recent literature positions the sustainability of waste management as the result of the interaction between technical, environmental, social, economic, institutional and governance dimensions [1]. Consequently, an effective waste management system cannot rely solely on end-of-life facilities, but must strengthen waste sorting, collection, record-keeping, material recovery and coordination amongst service providers.

Waste banks are a form of local institution that is relatively well-suited to the nature of community-based waste management in Indonesia. Through mechanisms for depositing waste and recording its economic value, waste

banks can encourage changes in household behavior whilst broadening community participation in waste reduction. Recent research indicates that the practice of waste banks contributes to local environmental resilience [2], but their uptake and effectiveness are still influenced by organizational readiness, administrative regularity, and operational system support [3]. The problems that frequently arise are not merely the absence of waste banks, but rather a lack of readily accessible information regarding their locations, services, timetables, transactions, and collection arrangements.

In Makassar, the operational need for an integrated digital waste bank model is supported by recent local evidence. A comparative study of waste bank policy implementation in Makassar and Bantaeng [4] reported that implementation had not been optimal, particularly because stakeholder communication, community socialization, and public-private participation were still limited. A study of community-based waste banks in Makassar further showed that programme challenges were associated with sustainability and resource mobilization, including the need to strengthen stakeholder roles, strategic partnerships, and user-friendly technology [5].

A recent multi-stakeholder study in Makassar identified limited community involvement, inadequate resources and infrastructure, market instability, knowledge gaps, geographical-logistical constraints, fragmented authority, and communication breakdowns as major constraints in waste bank management [6]. These academic findings are consistent with broader Indonesian evidence showing that digitalization can strengthen waste-recycling platforms, improve transaction visibility, and support circular-economy practices [7], while the official waste bank portal listed 323 waste bank units and 7,252 customers in 2026, indicating the need for updated, integrated location and service data [8]. Evidence from community-based waste bank governance in Indonesian cities also shows that internal human-resource capacity, stakeholder support, and the ability to build a waste-management economic chain are important conditions for sustaining waste bank contributions [9].

The role of waste banks is becoming increasingly important as waste management is linked to the circular economy. Waste is no longer viewed as a final by-product, but rather as a material that can be returned to the value chain through sorting, collection, processing, and reuse. The integration of the circular economy into waste management in Indonesia is considered relevant in responding to urbanization and environmental pressures [10]. The waste hierarchy principle also emphasizes prevention, reuse, recycling, and resource recovery as the basis for more sustainable management [11]. Within this framework, waste banks can act as the initial hub for restoring material value, provided that service flows, user data, transactions, and collection are managed in an orderly and interconnected manner.

1.2 Literature review on waste banks and the circular economy

Studies on waste banks indicate that service continuity depends on the relationship between community participation, managerial capacity, and routine administrative control. Waste banks provide a channel for residents to sort and deposit recyclable materials [2], while national evidence shows that their effectiveness varies according to organizational readiness, operational discipline, and information-system support [3]. Evidence from Makassar strengthens this argument: collaborative policy implementation remains constrained by limited communication, socialization, and public-private participation [4], while community-based waste bank development requires stronger resource mobilization, clearer stakeholder roles, strategic partnerships, and user-friendly technology [5]. Accordingly, the operational issue is not only whether waste banks exist, but whether their customer data, service schedules, waste categories, deposit records, transaction values, and reports can be managed as a connected service process.

The circular economy literature clarifies why this operational integration matters. Circular waste management in developing economies requires policy coordination, community participation, economic incentives, and productive resource use [10]. Charging and incentive schemes must also consider user behavior and the financial logic of participation [11], while transition studies emphasize that institutional arrangements, infrastructure, and operational procedures must change together [12]. Recent evidence from Makassar adds a local operational layer to this argument by identifying limited community involvement, inadequate resources and

infrastructure, market instability, knowledge gaps, logistical barriers, fragmented authority, and communication breakdowns as constraints in waste bank management [6]. Thus, waste banks should not be treated only as community savings units; they should be designed as traceable service nodes that connect material flows, actor responsibilities, transaction records, and monitoring data.

The concept of waste as a recoverable resource provides the conceptual basis for this integration. Regenerative business models position municipal waste within an economic cycle [13]. Resource-recovery, waste-to-energy, and plastic-upcycling studies also show that material value depends on reliable collection and supporting data [14, 15]. However, these works mainly address downstream technologies or broader economic models. For waste bank services, the immediate design requirement is a model that records deposits, collection points, materials, calculated values, and verification.

1.3 Literature review on digitalization and smart waste management

Digitalization offers a practical response to weaknesses in waste bank services, particularly access to information, coordination, transparency, and monitoring. Internet of Things (IoT)-based smart waste management studies show the value of data connectivity, service-condition monitoring, and timely operational response [16-18]. Smart city research further demonstrates that digital technology can support the management of urban environmental services, including waste, water, air, and transport [19], and can improve coordination in municipal service delivery [20]. For waste banks, however, the relevant contribution is not the adoption of advanced sensing alone. The immediate need is an information system that connects location information, service requests, collection schedules, transaction records, balances, and reports in one workflow.

Digital transformation studies also indicate that information systems contribute to sustainability through data collection, decision support, organizational coordination, and technology adoption strategies [21-24]. Evidence from the use of a waste bank management application in Bandung shows a similar pattern: perceived usefulness and ease of use can be high, but actual use may remain limited when regulation is not mandatory, training is insufficient, digital literacy varies, technical assistance is weak, and operational data such as waste prices require manual updating [25]. This finding is directly relevant to the proposed model because a waste bank application cannot be evaluated only as an interface. It must also support reliable data entry, role-based responsibilities, updated service information, transaction accuracy, and sustained use by administrators and customers.

Several technical developments in smart waste management are useful as design references, but their relevance must be positioned carefully. Digital transformation literature shows that digitalization can support sustainability by improving data visibility, coordination, and decision-making across organizational and service processes [26]. In waste management, AI- and IoT-oriented architecture reviews emphasise the value of status data, notification mechanisms, and route-related information for municipal service coordination [22], while artificial intelligence studies show potential for classification, prediction, and optimization in urban waste management [27]. Nevertheless, the present study

does not implement IoT sensors, artificial intelligence, or digital twin technology. These studies are therefore used to derive design requirements related to data availability, service status, route information, and future extensibility, not to claim that those advanced technologies have already been deployed. Within this narrower scope, smart waste management frameworks support the integration of managerial processes and digital functions [28], which is aligned with the search for the nearest waste bank, collection-request allocation, status updates, transaction recording, and monitoring.

Traceability and coordination remain central to the proposed system model. Blockchain and multi-agent simulation studies show that smart waste systems require mechanisms for trust, traceability, and service evaluation [29, 30]. In this article, those mechanisms are translated into conventional information-system functions rather than blockchain implementation: verified service requests, actor-specific access, transaction histories, and auditable records. The path towards sustainable waste management in smart cities also depends on the alignment of policy, infrastructure, technology, and public participation [31]. Consequently, the proposed digital waste bank model must clarify data flows, actor roles, verification procedures, and transaction recording before broader performance, security, or optimization modules can be tested.

1.4 Research gaps

The reviewed literature indicates three streams of knowledge, but it also reveals a specific design gap. Studies on waste banks mainly emphasize community participation, organizational readiness, resource mobilization, and local operational constraints [2-6]. Circular economy studies explain policy coordination, incentive mechanisms, resource recovery, and the economic logic of returning materials to productive use [10-15]. Digital and smart waste management studies discuss IoT, artificial intelligence, simulation, traceability, mobile applications, and service optimization [18, 19, 25-29, 32]. However, these streams do not yet sufficiently explain how a community-based waste bank can be modelled as an integrated urban service that combines location search, pickup scheduling, transaction recording, balance management, administrator verification, driver assignment, and supervisory monitoring within a single artefact.

The gap is therefore practical, methodological, and conceptual. Practically, users need reliable information on nearby waste banks, available services, collection schedules, and transaction values, while managers need tools for request verification, waste-category recording, transaction validation, and service history monitoring. Existing application-oriented studies show the usefulness of location-based services, crowdsourcing, and digital transaction support for waste bank participation [32, 33]. Nevertheless, many of these studies focus on a particular application feature, user interface, or implementation case rather than a generalized system model that explains actor responsibilities, data movement, service verification, and monitoring logic. Methodologically, the present study uses Design Science Research (DSR) to produce a design artefact whose contribution is the explicit modelling of service processes, architecture, database relationships, and prototype functions. Conceptually, the study positions the waste bank not only as a community unit, but as a data-driven service node that links urban waste collection with circular-economy transaction records and future decision support [34].

1.5 Aims and contributions

This research aims to design and evaluate a DSR-based model for a location-based digital waste bank system. The model integrates nearest-waste-bank search, service recommendation, collection requests, scheduling, administrator verification, driver task assignment, transaction recording, balance management, and service monitoring. The design is tailored to urban waste bank services in Makassar and defines four main actors: customers, waste bank administrators, drivers, and superadmins. The study does not claim to measure city-wide operational effectiveness, recycling-rate improvement, route optimization performance, or long-term economic impact. Instead, it focuses on the development and preliminary evaluation of a system model and functional prototype that can be used as a basis for subsequent implementation and field testing.

The contribution of this research is threefold. First, it provides an artefact-oriented information system model that translates waste bank operations into linked use cases, activity flows, sequence interactions, class structures, database entities, architecture layers, and interface prototypes. Second, it clarifies the difference between a digital waste bank catalogue and an integrated service model by connecting location information, pickup coordination, transaction validation, account balance records, and monitoring dashboards. Third, it refines the application of smart waste management concepts to the institutional characteristics of waste banks, where community participation, administrator verification, and traceable transaction data are more central than sensor deployment or fully automated optimization. These contributions are intended to support future empirical testing of service efficiency, data accuracy, user adoption, system security, and scalability.

2. MATERIALS AND METHODS

2.1 Research design

This study employs DSR because the main output is an information system artefact, namely a location-based digital waste bank system model. DSR is appropriate for research that designs, builds, and evaluates artefacts to address organizational or public service problems [35]. The study follows the DSR activities of problem identification, objective formulation, artefact design, demonstration, evaluation, and communication [36]. Recent DSR literature also emphasizes that complex sociotechnical problems should be decomposed into coherent design concerns and reported transparently across the problem space, solution space, build process, evaluation, and contribution [37, 38].

In this study, each DSR activity was linked to a specific research activity. Problem identification was conducted through literature review, Makassar-specific waste bank evidence, document analysis, and observation of service requirements. Objective formulation translated the identified problems into design goals related to location search, pickup requests, transaction recording, balance management, and service monitoring. Artefact design produced Unified Modelling Language (UML) models, database design, service architecture, and interface prototypes. Demonstration was conducted through role-based service scenarios for customers, waste bank administrators, drivers, and superadmins.

Evaluation consisted of black-box functional testing and preliminary user perception assessment. Communication was carried out through the presentation of the design artefacts, evaluation results, limitations, and development recommendations in this manuscript.

2.2 Object and system scope

The research object is the urban waste bank service process in Makassar, particularly the interaction between residents, waste bank administrators, collection officers, and system supervisors. The object was selected because recent studies and local public information indicate that Makassar waste bank services face challenges related to stakeholder coordination, resource mobilization, infrastructure adequacy, geographical-logistical barriers, public participation, and the updating of waste bank location and service data [4-9]. Accordingly, the unit of analysis is not an individual waste bank alone, but the service workflow that links waste bank location data, customer requests, collection verification, transaction records, and monitoring needs.

The system scope covers four actors: customers, waste bank administrators, drivers or collection officers, and superadmins. The functional scope includes authentication, nearest waste bank search, service recommendation, pickup request submission, administrator verification, driver task assignment, transaction recording, balance management, and monitoring dashboards. The nearest waste bank feature is modelled using geographic distance between customer location data and registered waste bank coordinates; travel-time estimation, real-time route optimization, and live driver tracking are outside the present scope. The model also excludes payment gateway integration, IoT sensor deployment, artificial intelligence implementation, blockchain mechanisms, penetration testing, and city-wide production deployment. These exclusions are stated to keep the contribution aligned with system modelling, conceptual or functional prototyping, and preliminary evaluation.

2.3 Data sources and data collection methods

The study used four data sources. First, scientific literature was used to define the theoretical basis of waste banks, circular economy, smart waste management, information system modelling, and DSR. Second, local evidence from Makassar, including indexed studies and public information from the city government and local news, was used to specify the operational problem addressed by the system model [4-9]. Third, similar digital waste bank and smart waste management studies were reviewed to identify relevant functions, actors, and design limitations [32, 33]. Fourth, research documentation and preliminary field inputs were used to map service requirements, including information from waste bank managers, potential users, and academic reviewers involved in validating the initial design needs.

Data collection was conducted through literature review, document analysis, observation of service requirements, similar-system review, artefact modelling, black-box testing, and questionnaire-based user perception evaluation. The literature review and document analysis were used to formulate the problem and justify the design requirements. Observation of service requirements was used to identify actors, service pain points, information flows, and required system outputs. Similar-system review was used to compare

existing digital waste bank functions with the proposed integrated service model. Artefact modelling was used to transform requirements into use case diagrams, activity diagrams, sequence diagrams, class diagrams, database design, architecture, and interface prototypes.

The preliminary evaluation data were obtained from functional testing and a user perception questionnaire. Black-box testing examined whether the main functions produced the expected outputs, while the questionnaire assessed perceived ease of finding the nearest waste bank, usefulness of pickup services, interface usability, clarity of location and service information, and support for community participation. The questionnaire involved 32 respondents as early evaluators selected purposively from users or stakeholders familiar with waste bank services and digital service interaction. Because the evaluation was preliminary, the sample was not treated as a statistically representative sample of all Makassar residents. The results were therefore used to assess initial feasibility and user acceptance, not to claim operational effectiveness, route efficiency, security robustness, scalability, or long-term economic impact.

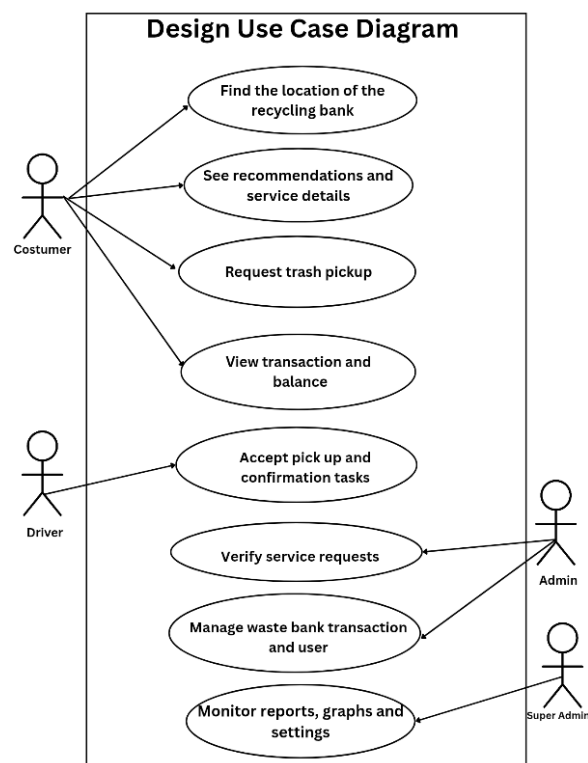


Figure 1. Use case diagram of the location-based digital waste bank system

2.4 Requirements analysis and system modelling

Requirements analysis was conducted by converting the operational problems identified in Makassar waste bank services into functional requirements, non-functional requirements, actors, data inputs, data outputs, and service flows. The analysis began by mapping the problems of location information, pickup scheduling, transaction recording, balance visibility, service-status updates, and monitoring needs. These requirements were then translated into UML artefacts. The use case diagram in Figure 1 presents the functional boundary of the proposed system by linking each actor to the main services that must be provided. Activity

diagrams specify the sequence of service activities, sequence diagrams describe message exchange between actors and system components, and class diagrams identify the main data objects and their relationships.

As represented in Figure 1, customer functions include finding the nearest waste bank, reviewing recommendations and service details, submitting pickup requests, and viewing transaction and balance information. Driver functions cover pickup acceptance and task confirmation, while administrator functions include service-request verification and waste bank transaction management. Superadmin functions are directed to monitoring reports, graphs, and system settings. This actor-function mapping was used to reduce ambiguity in role allocation and to clarify that the proposed artefact is a system model for coordinated service delivery rather than a general description of waste bank digitization.

2.5 Architectural design and prototyping

The system architecture was designed as a three-layer model consisting of the client layer, application layer, and data layer. The client layer represents role-based access for customers, drivers, waste bank administrators, and

superadmins. The application layer contains authentication, role management, location processing, recommendation logic, pickup-request management, administrative verification, driver-task management, transaction processing, balance calculation, reporting, and monitoring modules. The data layer stores user profiles, role data, waste bank identity and coordinates, service categories, pickup requests, driver status, waste categories, transaction records, account balances, dashboard summaries, and activity history. The service architecture design is shown in Figure 2.

The location-based function is modelled using registered waste bank coordinates and customer location data. The nearest waste bank is determined using geographic distance between latitude-longitude pairs, while the recommendation display can be ordered by distance, service availability, and waste bank status. Because this study focuses on system modelling and preliminary prototyping, the model does not yet include travel-time calculation, real-time route optimization, traffic data, live driver tracking, or automatic geocoding validation. Location data are assumed to be entered and updated by authorized administrators, while customers provide their pickup address and location point when submitting a service request.

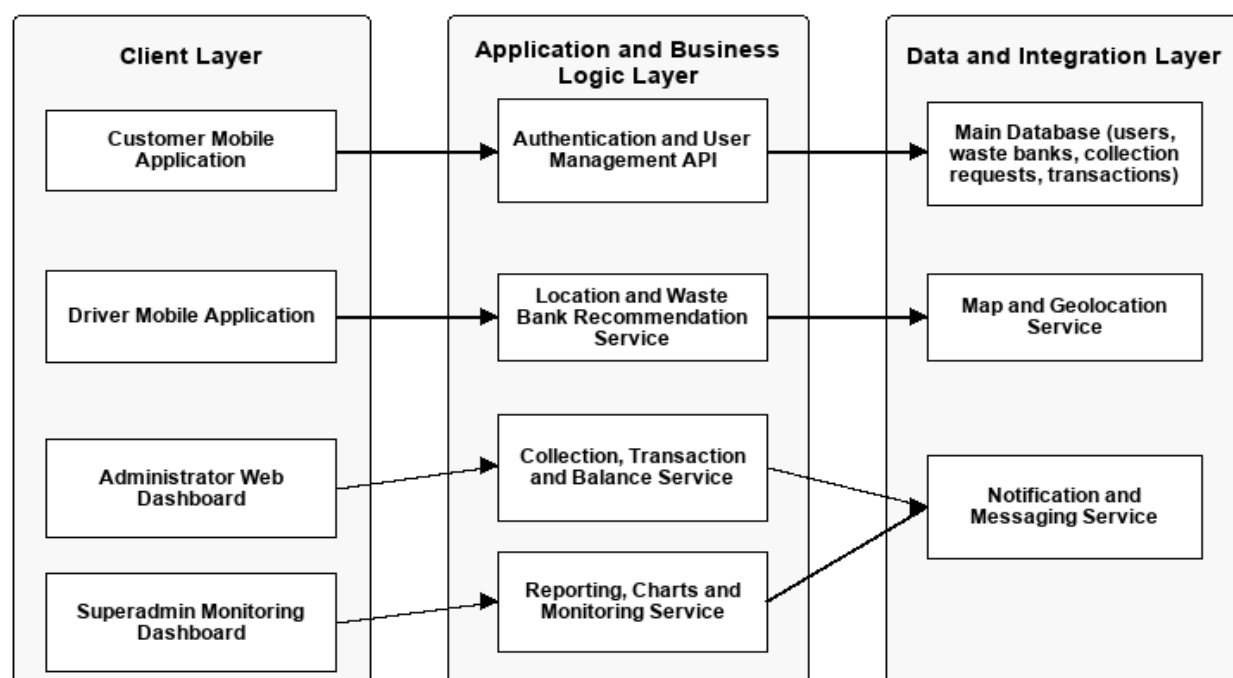


Figure 2. Three-layer service architecture of the location-based digital waste bank system

The prototype was developed as a conceptual and functional representation of the proposed model. It was used to demonstrate role-based workflows rather than to claim full production readiness. The prototype includes customer interfaces for searching waste banks and submitting pickup requests, administrator interfaces for verifying service requests and validating transactions, driver interfaces for viewing and updating pickup tasks, and superadmin interfaces for monitoring service summaries. For reproducibility, the model assumes a web-based or mobile-compatible client, an application service layer connected through structured service requests, and a relational database design that stores users, waste banks, pickup requests, transactions, balances, and activity logs. Security is represented at the design level through authentication, role-based access separation, and

administrator verification, while detailed encryption, penetration testing, and production infrastructure hardening are outside the scope of the current study.

2.6 System evaluation procedures

System evaluation was conducted in two stages. The first stage was black-box functional testing, which examined whether each major function produced the expected output based on predefined service scenarios. The tested functions included authentication, waste bank data management, nearest waste bank search, pickup request submission, administrator verification, driver task updating, transaction recording, balance management, graphs, and reports. The testing focused on input-output conformity and role-based functional

availability. It did not measure processing speed, system load, security vulnerabilities, scalability, network failure handling, or route optimization performance.

The second stage was a preliminary user perception evaluation using a five-point Likert scale questionnaire with 32 early evaluators. The evaluated aspects were ease of finding the nearest waste bank, usefulness of the pickup service, ease of interface use for administrators and customers, clarity of location, contact, and service information, and support for community participation. The questionnaire indicators were derived from the functional requirements and service problems identified during the requirements analysis. The items were reviewed for content relevance and wording clarity before being used in the preliminary evaluation. However, because the evaluation was exploratory and used a limited purposive sample, construct validity testing and reliability analysis using Cronbach's alpha were not performed at this stage. These psychometric tests are planned for a broader field evaluation after the prototype is implemented with a larger respondent base.

2.7 Data analysis techniques

System requirements data were analyzed using a descriptive-qualitative approach. The analysis categorized actors, service problems, functional requirements, non-functional requirements, information flows, data entities, and system outputs. The results were traced across use case diagrams, activity diagrams, sequence diagrams, class diagrams, database design, architecture, and prototype screens to ensure internal consistency. This traceability check was used to verify whether each actor had a clear role, whether each service process had an input and output, and whether transaction and monitoring data could be linked to the corresponding waste bank and user records.

Questionnaire data were analyzed using descriptive quantitative analysis. For each indicator, the total score was calculated from the frequency of responses on the five-point scale, and the average score was obtained by dividing the total score by the number of respondents. The percentage score was calculated using Eq. (1), where the maximum score for each item was the number of respondents multiplied by the highest Likert score. The results were interpreted as preliminary user acceptance and feasibility evidence, not as proof of operational effectiveness. Therefore, conclusions drawn from the evaluation were limited to perceived usefulness, usability, information clarity, and initial feasibility of the system model.

$$P = \frac{(5 \times SA) + (4 \times A) + (3 \times N) + (2 \times D) + (1 \times DA)}{X_{max}} \times 100\% \quad (1)$$

The user perception assessment used a five-point Likert-type response format: Strongly Agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly Disagree = 1. The use of ordered response categories and percentage-based descriptive summaries was intended to provide an initial indication of perceived feasibility, consistent with scale-development guidance that treats response options, item clarity, and measurement interpretation as central elements in questionnaire-based evaluation [39]. Performance testing, transaction-accuracy measurement, route-efficiency analysis, security testing, scalability testing, and long-term economic-impact assessment were not included in the present evaluation and are identified as future validation requirements.

3. RESULTS AND DISCUSSION

3.1 Results of stakeholder mapping and service requirements

The stakeholder mapping identified four actor groups and translated their roles into service requirements. Customers require access to nearby waste bank information, service availability, pickup request submission, transaction history, and balance visibility. Waste bank administrators require functions for updating waste bank data, verifying pickup requests, validating waste categories and weights, recording transaction values, and correcting service status. Drivers require assigned pickup lists, customer location information, schedule details, and status update functions. Superadmins require aggregate monitoring, activity summaries, reporting, and system-level control. This mapping responds to the operational fragmentation identified in Makassar waste bank services, where location data, service schedules, collection activities, and transaction records are not yet consistently connected [4-8].

The resulting requirements show that the system should not be treated as a simple waste bank directory. The core service requirement is an integrated workflow that connects actors, service requests, location data, verification decisions, collection execution, transaction recording, balance updates, and monitoring outputs. This finding is consistent with previous studies that emphasize the need for institutional readiness, operational support, and information-system strengthening in waste bank management [2, 3, 33]. The stakeholder mapping also clarifies role boundaries: customers initiate and monitor services, administrators validate operational and transaction data, drivers update field execution, and superadmins evaluate aggregated service performance.

3.2 Results of the service flow and system interaction design

The service flow design produced a sequential model that begins with customer location activation and nearest waste bank search. The customer then reviews available services, submits a pickup request, and provides address, waste type, estimated weight, and preferred schedule. The waste bank administrator verifies the request before assigning or confirming the driver task. The driver updates pickup status during field execution, while the administrator records the final waste weight, transaction value, and balance update after collection. These activities produce service data that are forwarded to the monitoring dashboard. Figure 3 presents this workflow as an activity model and shows the control points where requests, status changes, and transactions are verified.

The system interaction design in Figure 4 shows that the location service functions as the entry point for several subsequent processes rather than as a stand-alone map feature. Customer coordinates and registered waste bank coordinates are used to support nearest-waste-bank recommendations; the selected waste bank then becomes the reference for pickup scheduling, administrator verification, driver assignment, and transaction recording. This interaction pattern strengthens reproducibility because it clarifies which actor initiates each process, which component receives the request, which data are stored, and when service status is updated. It also addresses the reviewer's concern that location-based services should explain

the connection between distance calculation, service selection, and operational follow-up.

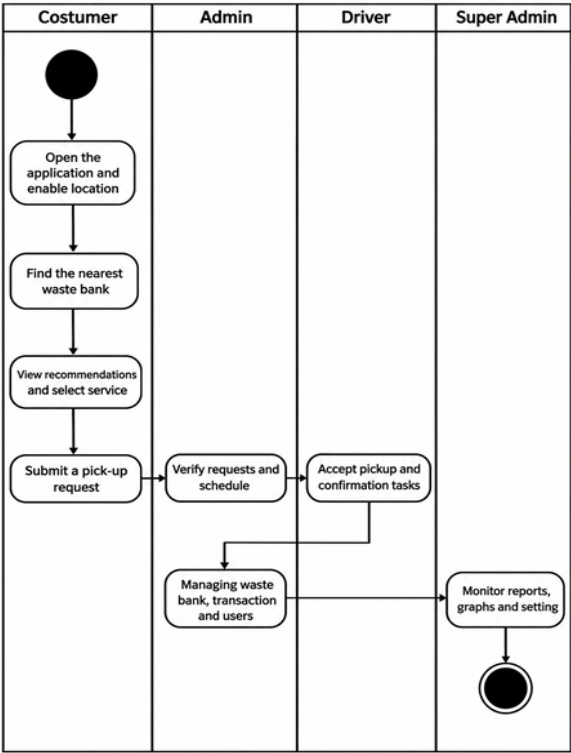


Figure 3. Activity diagram of the proposed waste bank pickup service

3.3 Results of the data structure and system architecture design

The data structure design resulted in a set of related entities that support actor identity, service location, pickup coordination, transaction validation, and monitoring. The class

diagram in Figure 5 represents users, customers, drivers, waste banks, pickup requests, and transactions as connected objects. The pickup request class acts as the operational link between customer demand, waste bank verification, driver assignment, and transaction recording. This relationship is important because one pickup request can generate service-status data, actual waste-weight data, transaction value, and balance updates. The model therefore supports traceability from the initial customer request to the final transaction record.

The database design in Figure 6 translates the class model into storage entities for users, customers, drivers, waste_bank, pickup_request, waste_category, transactions, balances, and activity history. The waste_bank entity stores identity, address, coordinates, service availability, and active status. The pickup_request entity stores customer identity, selected waste bank, pickup address, estimated waste type and weight, schedule, verification status, driver assignment, and completion status. The transaction entity stores verified weight, unit price, total value, balance update, and transaction date. These relationships allow administrators to check whether a transaction is linked to a valid customer, an active waste bank, and a completed pickup request.

The architecture result is a three-layer model consisting of the client layer, application layer, and data layer, as illustrated in Figure 2. The client layer separates access for customers, waste bank administrators, drivers, and superadmins. The application layer contains authentication, role management, location processing, recommendation ordering, pickup-request management, verification, driver-task management, transaction processing, balance calculation, reporting, and monitoring. The data layer stores operational records and provides the basis for dashboards and reports. The security boundary is designed through authenticated access, role-based function separation, administrator verification, and auditable activity history. At this stage, the architecture remains a design artefact; production-level encryption, penetration testing, scalability testing, and deployment infrastructure are reserved for later development.

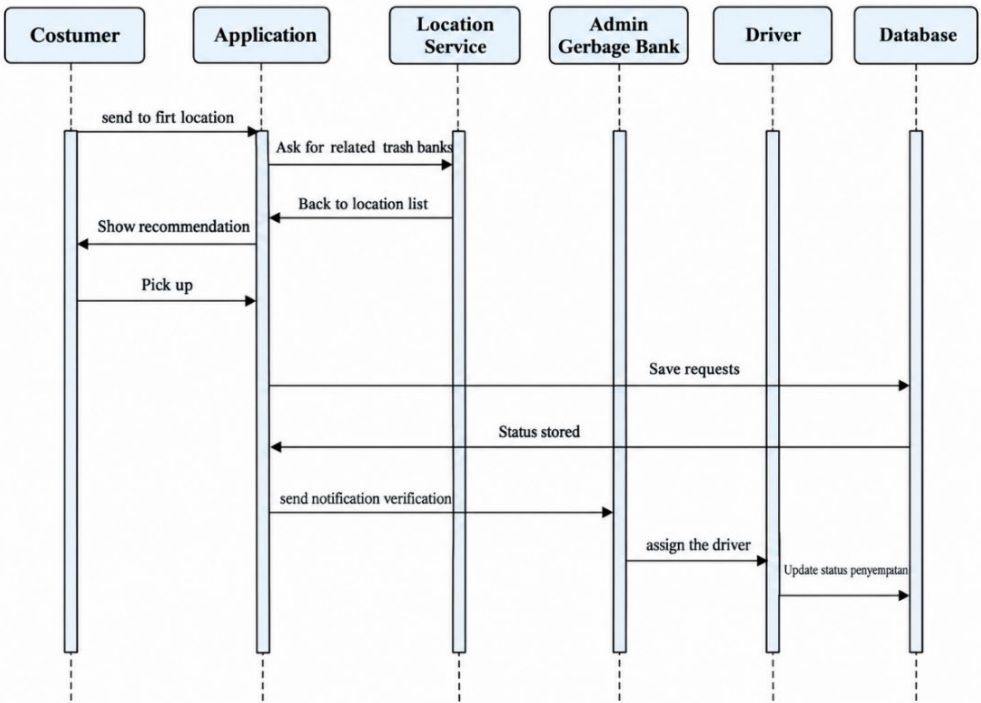


Figure 4. Sequence diagram of the pickup request process

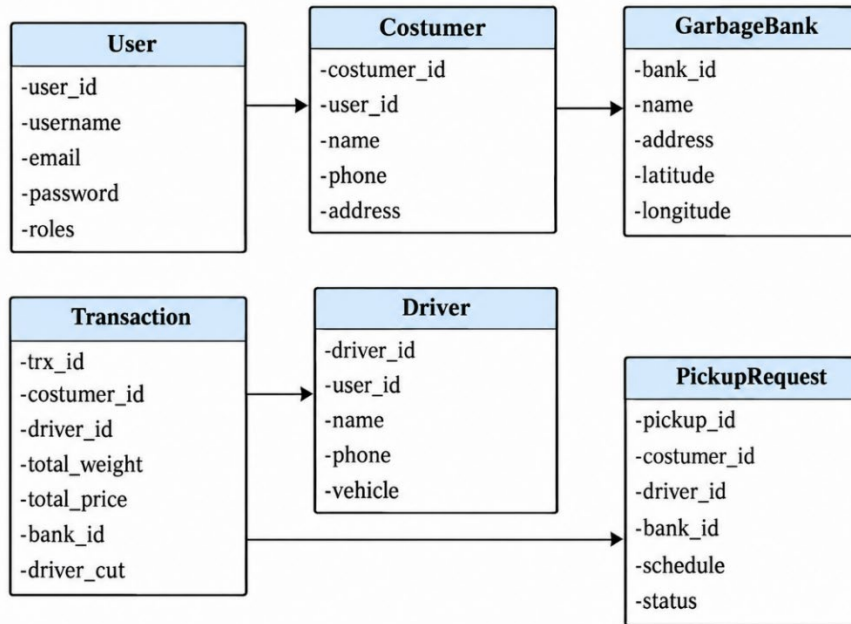


Figure 5. Class diagram of the digital waste bank system

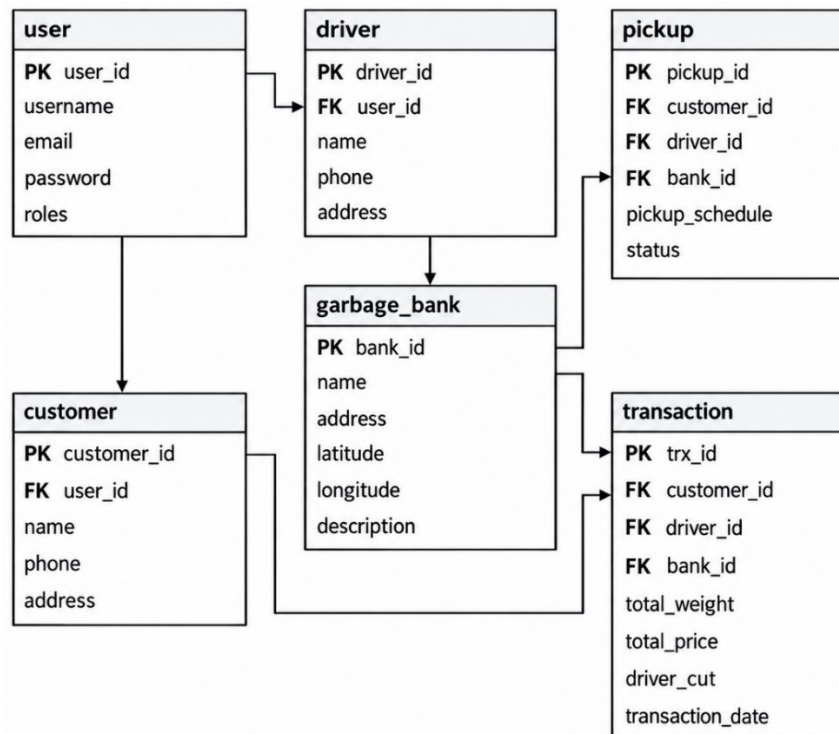


Figure 6. Database relationship design for the main service entities

3.4 Results of the system prototype design

The prototype result represents a functional demonstration of the proposed service model rather than a production-ready application. On the customer side, the prototype provides nearest-waste-bank search, service recommendation, pickup request submission, transaction history, and balance views. On the driver side, it provides assigned pickup tasks, customer address information, estimated waste data, schedule details, and status update functions. These modules demonstrate how customer requests are transformed into verified operational tasks and transaction records. Figure 7 summarizes the customer and driver modules.

On the administrator side, the prototype supports waste bank data management, pickup request verification, waste category checking, transaction validation, balance updating, and user management. On the superadmin side, the prototype provides dashboard summaries, service monitoring, activity records, and reporting functions. These modules are intended to show role separation and data traceability across the service workflow. They also clarify that the proposed artefact is not limited to a map or registration form, but combines location information, pickup coordination, transaction control, and monitoring in one model. Figure 8 summarizes the admin and superadmin modules.

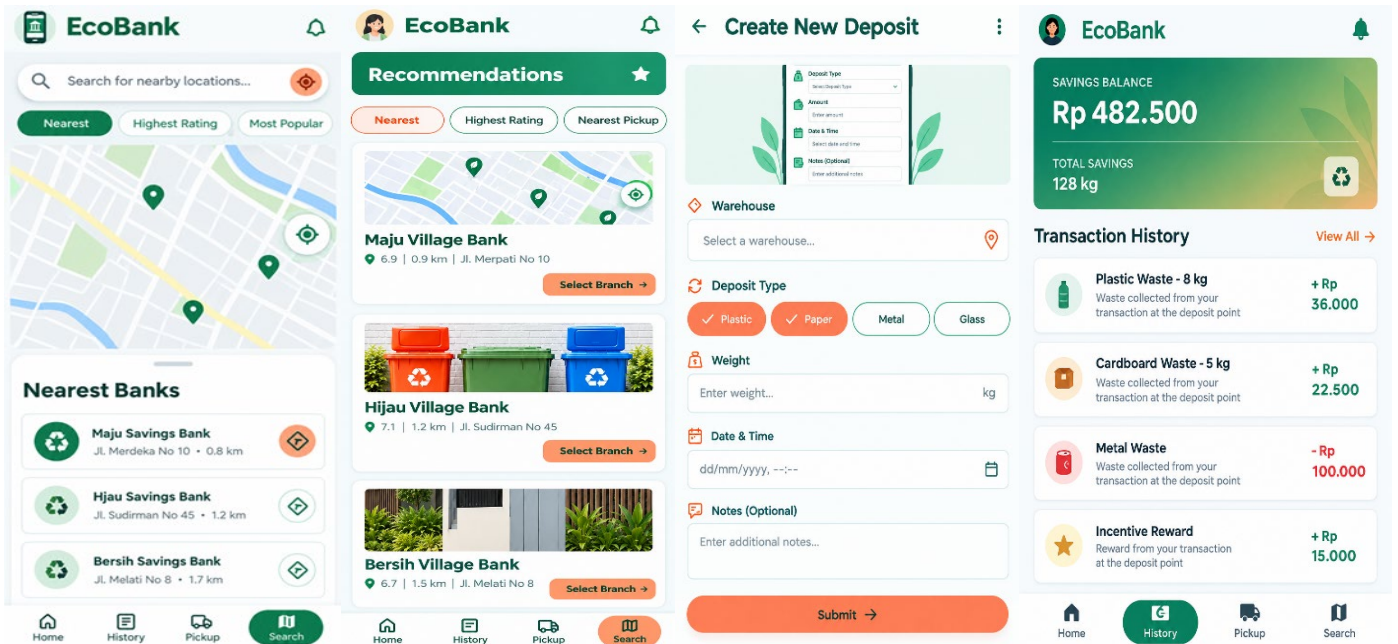


Figure 7. Mobile prototype modules for customers and pickup drivers

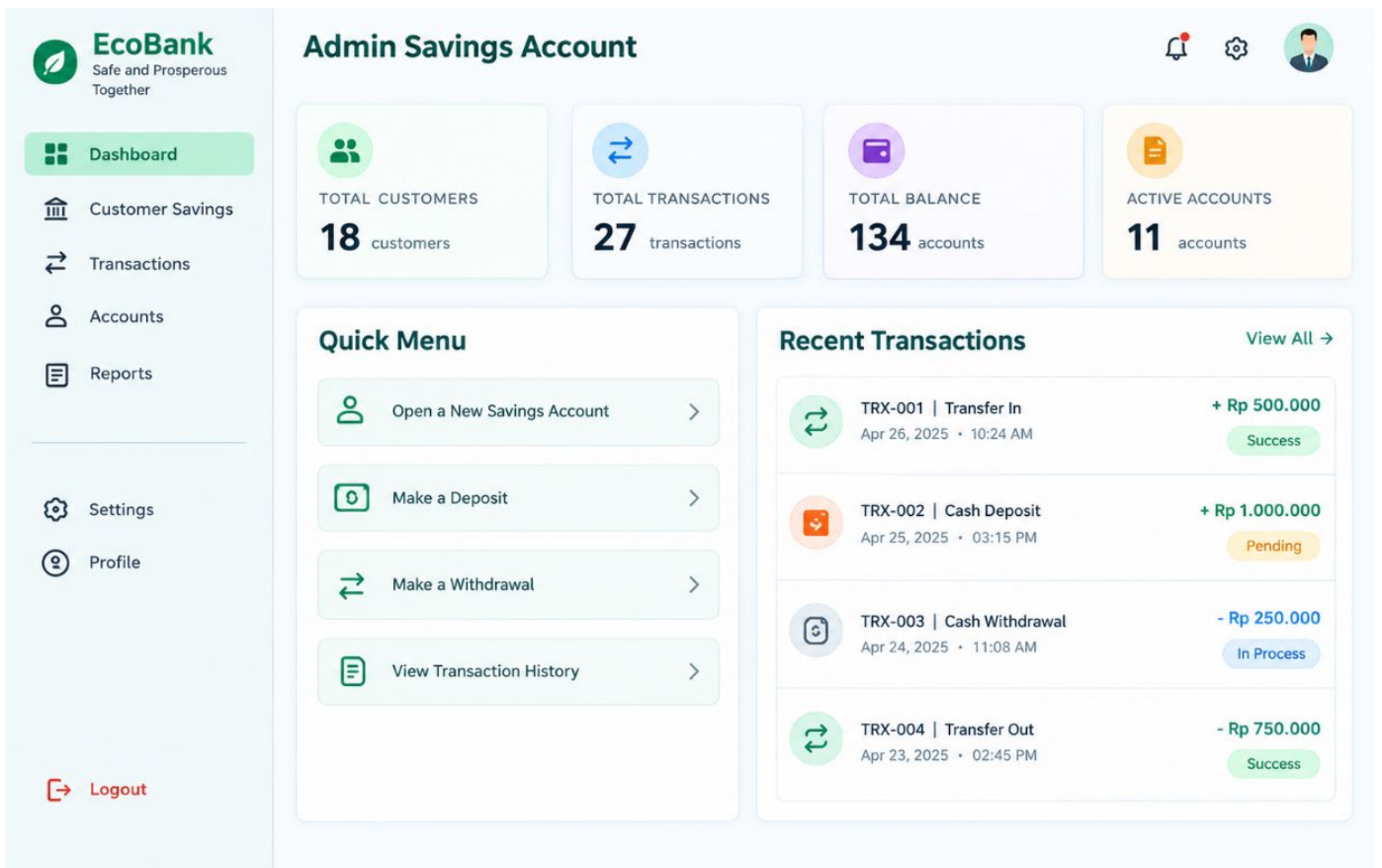


Figure 8. Dashboard prototype modules for waste bank admin and superadmin

3.5 Results of functional testing and user evaluation

Functional testing was conducted using black-box scenarios for the main functions of the prototype. The testing verified whether each function produced the expected output when accessed by the appropriate actor. The tested modules included authentication, waste bank search, pickup request submission, administrator verification, driver task updating, transaction and balance recording, and monitoring dashboards. The results

in Table 1 show that these functions were valid in terms of input-output conformity. However, the test was limited to functional behavior and did not evaluate response time, system load, security vulnerability, scalability, route optimization, data loss, or failure recovery.

The user perception evaluation involved 32 early evaluators and used five indicators derived from the system requirements. The overall acceptance score was 89.50%, which indicates a positive preliminary perception of the proposed design. The

highest scores were recorded for usefulness of the pickup service and support for community participation, each at 91.25%. These results suggest that respondents considered pickup support and participatory service access to be relevant features for waste bank use. The lowest score was interface ease of use at 86.25%, indicating that the collection form, administrator verification flow, and driver status update process still require simplification before broader field testing. The detailed results are presented in Table 2.

These evaluation results should be interpreted cautiously. The 32 respondents were early evaluators rather than a statistically representative sample of Makassar residents or all waste bank users. The questionnaire measured perceived usefulness, usability, information clarity, service relevance, and initial feasibility, but it did not measure operational performance. Therefore, the results support the feasibility of continuing system development, while further empirical testing is still required to measure transaction accuracy, service response time, route efficiency, security, scalability, and long-term economic or environmental impact.

Table 1. Summary of black-box functional testing

Module	Expected Output	Result
Authentication	User can access the system according to role.	Valid
Waste bank search	System displays nearby waste banks and service information. Customer can submit address,	Valid
Pickup request	waste type, estimated weight, and schedule.	Valid
Admin verification	Admin can approve, revise, or reject pickup requests.	Valid
Driver task	Driver can view assigned pickup tasks and update status.	Valid
Transaction and balance	System records weight, value, transaction history, and balance.	Valid
Monitoring dashboard	Superadmin can view service summaries, charts, and activity reports.	Valid

Table 2. User perception evaluation of the proposed system

Evaluation Aspect	Total Score	Average	Percentage
Ease of finding the nearest waste bank	143	4.47	89.38%
Usefulness of waste pickup service	146	4.56	91.25%
Ease of interface use for admin and customer	138	4.31	86.25%
Clarity of location, contact, and service information	143	4.47	89.38%
Support for community participation	146	4.56	91.25%
Overall acceptance	716	4.48	89.50%

3.6 Discussion

The findings indicate that the proposed model addresses a practical service gap in waste bank operations by linking location search, pickup requests, administrator verification, driver tasks, transactions, balances, and monitoring. This result extends previous waste bank studies that emphasize community participation, institutional readiness, resource mobilization, and operational support [2-6]. The contribution of the present study is not the claim that a full digital service

has already improved urban waste performance, but the modelling of an integrated service artefact that clarifies how actors, data, and service decisions can be connected before large-scale implementation.

From the perspective of the circular economy, the model supports the early information layer needed for material value recovery. Circular economy studies emphasize policy coordination, incentives, resource recovery, and the need to return materials to productive use [10-15]. The proposed model complements these studies by specifying how waste weight, transaction value, balance updates, and pickup history can be recorded as traceable service data. Nevertheless, the present study does not measure actual recycling rates, recovered material quantity, household income change, or landfill reduction. The circular-economy implication is therefore positioned as a design contribution that prepares measurable data for future evaluation, not as evidence of realized environmental impact.

The results are also consistent with smart waste management literature, but the scope of technological adoption is deliberately narrower. Studies on smart waste systems discuss IoT connectivity, artificial intelligence, simulation, route optimization, and decision support [18, 19, 30, 31, 40-42]. In this study, those references are used to inform the need for data connectivity, service status, traceability, and future extensibility. The prototype does not implement IoT sensors, artificial intelligence, blockchain, digital twins, or automated route optimization. This clarification is important because the proposed model is designed for the institutional characteristics of waste banks, where administrator verification, community participation, location data, and transaction validity are more immediate design needs than advanced automation.

The user evaluation provides preliminary support for the relevance of the model, especially because pickup services and community participation received the highest scores. This result is aligned with technology acceptance evidence from waste bank services, where perceived usefulness and ease of use influence the adoption of digital waste management applications [33]. At the same time, the lower score for interface ease of use indicates that acceptance cannot be assumed from feature availability alone. The prototype must be refined through task-based usability testing, clearer form design, simplified verification steps, and broader field evaluation with active waste bank operators and residents.

Overall, the study contributes to information systems research by demonstrating how DSR can structure a waste bank service problem into requirements, models, architecture, prototype modules, and preliminary evaluation. The discussion also defines the boundary of the contribution. The model provides a foundation for integrated digital waste bank services, but further studies are required to test performance, security, scalability, transaction accuracy, field adoption, and measurable circular-economy outcomes. This staged interpretation keeps the findings consistent with the evidence produced in the present study and avoids implying practical effectiveness that has not yet been experimentally verified.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This study produced a DSR-based model of a location-

based digital waste bank system for integrated urban waste collection and transaction services. The model integrates nearest-waste-bank search, service recommendation, pickup scheduling, administrator verification, driver task management, transaction recording, balance management, and service monitoring. The research artefacts consist of stakeholder mapping, UML models, database relationships, a three-layer service architecture, and conceptual or functional prototype modules. Black-box testing confirmed that the main prototype functions produced the expected outputs, and the preliminary user perception evaluation involving 32 early evaluators produced an overall acceptance score of 89.50%.

The findings indicate that the proposed model is feasible as a basis for further development, but they should not be interpreted as evidence of full operational effectiveness. The study has not yet measured city-wide service performance, response time, route efficiency, transaction accuracy under field conditions, security robustness, scalability, recycling-rate improvement, recovered material quantity, or long-term economic impact. The main contribution of the study lies in clarifying how waste bank actors, location data, pickup services, transaction records, balance information, and monitoring outputs can be structured as an integrated information system artefact. This contribution supports future implementation and empirical testing of digital waste bank services in Makassar and comparable urban areas.

4.2 Recommendation

Future work should implement the model in active waste bank operations and conduct field trials involving customers, waste bank administrators, drivers, and local service supervisors. The next evaluation stage should measure task completion time, response time, transaction accuracy, location-recommendation accuracy, route efficiency, user error, workload reduction, and service reliability. A broader respondent base is also required to conduct construct validity testing and reliability analysis of the questionnaire, including Cronbach's alpha, so that user acceptance can be assessed with stronger empirical support.

Further development should also strengthen the technical and governance components of the system. Technical development may include database validation, administrator-controlled location updates, application programming interface design, data security mechanisms, backup and recovery procedures, scalability testing, and failure-handling scenarios. Service development may include integration with active waste bank data, standardization of waste categories and prices, notification services, route optimization, analytics dashboards, and reporting tools for local government or supervisory users. These additions should be tested gradually so that the system evolves from a validated design artefact into an operational service platform.

From a policy and circular-economy perspective, the system should be supported by standardized waste bank data, updated location information, clear service verification procedures, training for administrators and drivers, and coordination between local government, waste bank managers, communities, and system developers. Future studies should also examine whether the system contributes to increased sorted-waste volume, improved material recovery, reduced manual administration, greater transaction transparency, and measurable economic value for customers. These recommendations keep the development agenda aligned with

the current evidence while avoiding claims beyond the results of the present study.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this manuscript.

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