SITEKNIK
Sistem Informasi, Teknik dan Teknologi Terapan
E-ISSN: 3032-3991 P-ISSN: 3090-1626
Vol. 3, No. 3 July 2026. Pages. 129-138

Dashboard-Based Distribution Requirements Planning for Reverse Logistics Scheduling Optimization in Community Waste Collection

Nia Novitasari[1], Gisti Ayu Pratiwi[2]✉
nianovitasari@telkomuniversity.ac.id[1], gistiayupratiwi@telkomuniversity.ac.id[2]
[1,2] Logistics Engineering, School of Industrial and System Engineering, Telkom University, Indonesia

Keywords: Distribution Requirements Planning, Waste Collection Scheduling, Reverse Logistics, Monitoring Dashboard, Community Waste Bank

Submitted: 02/07/2026
Revised: 16/07/2026
Accepted: 20/07/2026

Abstract

This study aims to develop a dashboard-based waste collection scheduling system using the Distribution Requirements Planning (DRP) approach to improve the effectiveness of sorted gallon waste collection at Bank Sampah Bersinar (BSB), Bojongsoang. BSB manages six recycle points with a total weekly collection demand of 4,050 kg, while the available fleet consists of only one pick-up vehicle with a capacity of 1,000 kg. The absence of a structured collection schedule previously caused simultaneous collection activities and potential over-dimension and over-load problems. This study applies DRP to allocate collection activities based on demand volume, fleet capacity, operational time, and BSB's three-day collection policy. The result shows that all weekly waste volume can be collected within three operational days by visiting two recycle points per day, with two trips conducted each day. In addition, a monitoring dashboard was developed to support daily trip tracking, collection volume monitoring, and recycle point performance evaluation. The proposed system provides a practical solution for improving reverse logistics operations, reducing fleet overload risk, and supporting data-based decision-making in community waste management.

Corresponding Author:
Gisti Ayu Pratiwi
Logistics Engineering, School of Industrial and System Engineering, Telkom University
Jl. Telekomunikasi No 1, Bojongsoang, Kab. Bandung, Jawa Barat
Email: gistiayupratiwi@telkomuniversity.ac.id

INTRODUCTION

Municipal solid waste management has become one of the most critical environmental challenges worldwide due to rapid urbanization, population growth, and increasing consumption patterns. According to the latest global waste projections, municipal solid waste generation is expected to increase substantially over the coming decades, creating significant environmental, economic, and operational challenges if collection and recycling systems are not properly managed (Kaza et al., 2023; UNEP, 2024). Efficient waste collection systems therefore play an essential role in supporting circular economy initiatives by reducing landfill disposal, promoting resource recovery, and improving environmental sustainability.

In Indonesia, Bank Sampah (Waste Bank) has become an important community-based initiative for encouraging waste segregation and recycling while generating economic value for local communities. Through this system, recyclable waste is collected, sorted, and exchanged for monetary incentives before being transferred to recycling facilities. As the number of collection points continues to increase, however, waste banks face operational challenges related to collection scheduling, fleet utilization, and monitoring of collection performance. These challenges directly affect service efficiency and operational costs, particularly for organizations operating with limited transportation resources.

PT Solusi Rahayu Indonesia, operating as Bank Sampah Bersinar (BSB) in Bandung, functions as a central waste bank responsible for collecting recyclable gallon plastic waste from six affiliated recycle points located in the Bojongsoang area. These recycle points collectively generate approximately 4,050 kg of recyclable waste per week, while BSB currently operates only one pickup vehicle with a carrying capacity of 1,000 kg. Under existing operations, waste collection activities are performed without a structured scheduling system. Consequently, multiple recycle points often request collection simultaneously, resulting in inefficient fleet utilization, overloaded vehicles, inconsistent service times, and difficulties in monitoring collection performance. Furthermore, operational records are still maintained manually using paper-based delivery notes, limiting data visibility and delaying operational decision-making.

From a supply chain perspective, these activities represent a reverse logistics process, where recyclable materials flow from collection points back to a centralized processing facility for value recovery rather than moving from producers to customers. Reverse logistics has become increasingly important as organizations seek to improve sustainability, resource recovery, and operational efficiency while minimizing environmental impacts (Govindan et al., 2015). Recent studies also emphasize that digital technologies such as dashboards, Internet of Things (IoT), and data analytics can significantly improve visibility, transparency, and decision-making within reverse logistics operations (Sun et al., 2022; Hassan & Osman, 2025).

Various optimization techniques have been proposed to improve reverse logistics operations, including Vehicle Routing Problem (VRP), Mixed Integer Linear Programming (MILP), and metaheuristic algorithms. These approaches mainly focus on minimizing transportation distance or routing costs. However, relatively limited attention has been given to operational scheduling, particularly for community-based waste collection systems operating with limited fleet capacity and fixed collection periods. In practice, organizations such as waste banks require not only optimal routes but also systematic scheduling that considers vehicle capacity, collection frequency, operational time windows, and service policies simultaneously.

One planning approach that can address these operational requirements is Distribution Requirements Planning (DRP). Originally developed for coordinating inventory replenishment across multi-echelon distribution systems, DRP integrates demand information, transportation capacity, replenishment frequency, and scheduling decisions into a structured planning framework (Chopra & Meindl, 2022). Previous studies have demonstrated that DRP improves distribution planning efficiency and resource utilization in manufacturing and distribution systems (Rizkya et al., 2018; Situmorang et al., 2019). Nevertheless, existing DRP applications have predominantly focused on forward logistics and inventory replenishment, while its implementation for reverse logistics waste collection scheduling remains limited.

Another important issue identified in previous studies is the lack of integrated monitoring systems that support operational control after scheduling decisions have been generated. Many small and medium-sized waste collection organizations continue to rely on manual documentation, making it difficult to evaluate daily vehicle utilization, collection volumes, service performance, and operational achievements. Recent literature indicates that integrating digital monitoring systems into logistics operations significantly enhances operational visibility, supports data-driven decision-making, and improves organizational responsiveness (Rodrigues et al., 2025).

Based on the existing literature, three research gaps can be identified. First, most previous studies investigate DRP within conventional outbound distribution systems rather than reverse logistics operations. Second, studies integrating scheduling optimization with dashboard-based monitoring systems for community waste collection remain scarce. Third, existing research primarily emphasizes routing optimization while paying less attention to operational scheduling under practical fleet capacity constraints and fixed collection policies.

Therefore, this study proposes a dashboard-based Distribution Requirements Planning (DRP) framework to optimize recyclable waste collection scheduling at Bank Sampah Bersinar. The proposed framework simultaneously considers weekly waste demand, vehicle capacity, operational time windows, collection frequency, and digital monitoring requirements. Unlike previous studies, this research integrates DRP scheduling with a monitoring dashboard that enables real-time visualization of collection activities, trip performance, and waste collection volumes. The proposed approach is expected to improve operational efficiency, eliminate vehicle overloading, enhance decision-making, and provide a practical contribution to reverse logistics management for community-based waste collection organizations.

RESEARCH METHODS

This study employed a quantitative case study approach to develop and evaluate a waste collection scheduling system for Bank Sampah Bersinar (BSB), Bandung. A case study was selected because it enables an in-depth investigation of operational problems within a real logistics environment while facilitating the development of practical solutions for reverse logistics operations (Yin, 2018). The proposed framework integrates Distribution Requirements Planning (DRP) with a dashboard-based monitoring system to improve scheduling efficiency and operational visibility. The research consisted of four sequential stages: problem identification, data collection, DRP-based scheduling, and dashboard development, as illustrated in Figure 1.

Problem Identification and Data Collection

The study began by identifying operational problems through direct observations and semi-structured interviews with the operational manager of Bank Sampah Bersinar. The investigation revealed that waste collection activities were performed without a structured schedule, resulting in simultaneous collection requests, vehicle overloading, and inefficient fleet utilization. In addition, operational monitoring relied on paper-based delivery notes, making it difficult to evaluate daily collection performance.

Primary data were obtained through field observations and interviews, while secondary data were collected from the company's operational records. The collected data consisted of recycle point locations, weekly recyclable waste generation, fleet specifications, operational working hours, collection lead time, collection policies, and administrative recording procedures.

Table 1. Recycle points location

Bank Sampah	Alamat	Average Pick Up Demand (kg)
Bank Sampah Melati 08 (Maryam)	Komplek. Griya Bandung Asri 3 Blok K Jl. Mawar RT 03 RW 08 Cipagalo, Bojongsoang, Kabupaten Bandung, Jawa Barat	750
Bank Sampah Sakura 20 (Liya)	Komplek. Bumi Asri Indah 1 Blok J No.6 RT 05 RW20 Kec. Baleendah, Kabupaten Bandung, Jawa Barat	650
Bank Sampah Raresik (Eni)	Komplek Griya Bumi Asri 3 Blok A12 No.11 RT 08/10 Cipagalo, Bojongsoang, Kabupaten Bandung, Jawa Barat	700
Bank Sampah Mawarsari 16 (Enung)	Bojongsoang Asri 1 Blok C6 No.06 RT 03 RW 04 Kel.Bojongsoang, Kabupaten Bandung, Jawa Barat	650
Bank Sampah Mawarsari 04 (Yani)	Bojongsoang RT 03 RW 04 Kel. Bojongsoang, Kabupaten Bandung, Jawa Barat	750
Bank Sampah Paralon (Maya)	Jl. Bojongsoang No. 95 RT 04/12 Desa Bojongsoang, Kabupaten Bandung, Jawa Barat	550

These operational parameters served as the primary inputs for the DRP scheduling process. Similar input variables have commonly been employed in DRP implementation, including demand, lead time, inventory or available quantity, transportation capacity, and safety stock considerations (Chopra & Meindl, 2022; Rizkya et al., 2018).

Distribution Requirements Planning (DRP)

Distribution Requirements Planning (DRP) was adopted as the primary scheduling approach because it systematically determines distribution activities by considering demand, available capacity, replenishment frequency, and operational constraints. Although DRP was originally designed for outbound distribution planning, its planning logic can also be adapted to reverse logistics applications where recyclable materials are periodically collected from multiple collection points (Chopra & Meindl, 2022; Pramono et al., 2021).

Unlike conventional DRP applications that focus on inventory replenishment, this study modified the planning logic to schedule waste collection activities. The weekly waste volume generated at each recycle point was treated as collection demand, while vehicle capacity represented the transportation constraint. The scheduling procedure considered several operational parameters, including Weekly waste generation at each recycle point, Pickup vehicle capacity (1,000 kg), Maximum collection period (three operational days), Average service time per location (30–45 minutes), and Daily operational working hours.

The scheduling algorithm was implemented using Python to automate trip allocation while ensuring that vehicle capacity and operational time constraints were satisfied. Python was selected because of its flexibility in implementing logistics optimization algorithms and handling operational datasets efficiently.

The scheduling procedure consisted of the following steps:
Import operational data.
Initialize scheduling parameters.
Calculate remaining waste volume for each recycle point.
Allocate pickup trips based on available vehicle capacity.
Update remaining vehicle capacity after each trip.
Continue allocation until all waste volumes were scheduled.
Validate that all weekly waste was collected within the three-day operational policy.

This scheduling logic follows the fundamental DRP principle of balancing demand and available distribution resources while minimizing unnecessary transportation activities (Rizkya et al., 2018; Setiawannie et al., 2023).

Dashboard Development

Following the scheduling process, a monitoring dashboard was developed to visualize operational performance and support managerial decision-making. Dashboard development has become increasingly important in logistics operations because it improves operational transparency, facilitates performance monitoring, and enables faster responses to operational changes. The dashboard was designed to display several operational indicators, including Daily pickup schedules, Number of completed trips, Waste collection volume, Vehicle utilization, and Collection performance for each recycle point. The dashboard provides real-time visualization of collection activities, allowing managers to evaluate operational achievements and monitor waste collection performance more efficiently.

Research Framework

The overall research framework consists of three major phases:

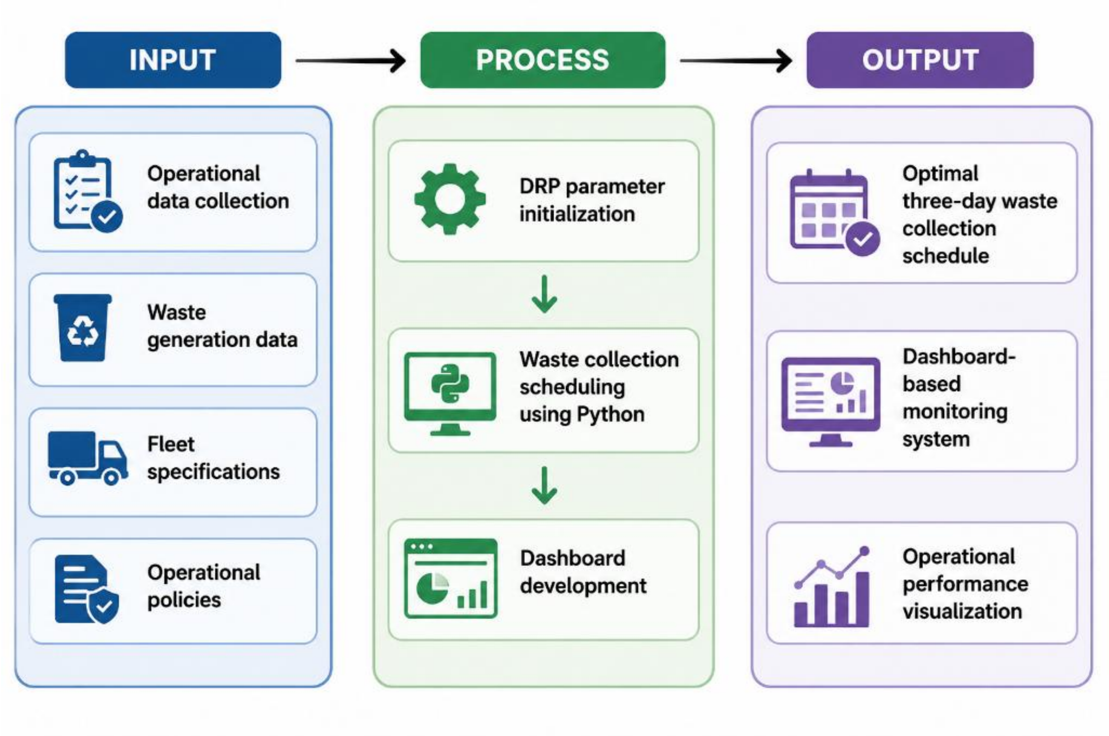

Figure 1. Research Framework

The proposed framework integrates scheduling optimization and digital monitoring into a single decision-support system, enabling Bank Sampah Bersinar to improve reverse logistics operations while maintaining compliance with fleet capacity limitations.

RESULTS AND DISCUSSION

Existing Operational Conditions

Bank Sampah Bersinar (BSB) serves as the central collection facility responsible for transporting recyclable gallon plastic waste from six affiliated recycle points located throughout the Bojongsoang area. Based on field observations and interviews, the six recycle points generate a total average waste volume of 4,050 kg per week. However, BSB currently operates only one pickup vehicle with a carrying capacity of 1,000 kg, which creates operational limitations during collection activities.

Table 2. Summarizes the average weekly waste generation from each recycle point.

Recycle Point	Weekly Demand (kg)
Melati 08	750
Sakura 20	650
Raresik	700
Mawarsari 16	650
Mawarsari 04	750
Paralon	550
Total	4.050

Under the existing operational practice, waste collection requests were performed without predetermined scheduling. Consequently, several recycle points frequently requested pickup simultaneously, resulting in overloaded transportation, inefficient vehicle utilization, and inconsistent collection times. Furthermore, all operational records were maintained manually using paper-based delivery notes, making monitoring and reporting both time-consuming and prone to human error.

These findings indicate that the primary operational challenge was not merely vehicle availability but also the absence of a systematic scheduling mechanism capable of balancing waste demand with limited transportation capacity. Similar challenges have been reported in community-based reverse logistics systems, where inefficient scheduling significantly reduces operational efficiency and increases transportation costs (Govindan et al., 2015).

DRP-Based Waste Collection Scheduling

To overcome these operational challenges, Distribution Requirements Planning (DRP) was applied to develop an optimal waste collection schedule. Unlike conventional DRP applications used for inventory replenishment, this study adapted the planning logic to schedule reverse logistics activities by considering waste generation as demand and vehicle capacity as the primary operational constraint.

The scheduling process was implemented using Python by incorporating several operational parameters, including weekly waste demand, vehicle capacity, collection frequency, service time, and three-day collection policy.

The scheduling algorithm allocated collection activities sequentially while ensuring that the vehicle capacity was never exceeded during each trip.

```
📅 Jadwal untuk Hari 1:

📅 Jadwal untuk Hari 2:

📅 Jadwal untuk Hari 3:

📅 Hari 1 – Total Trip: 2
  1. Bank Sampah Melati 08 ( Maryam ) – 750 kg
  2. Bank Sampah Sakura 20 ( Liya ) – 650 kg
  👉 Total Volume Hari Ini: 1400 kg

📅 Hari 2 – Total Trip: 2
  1. Bank Sampah Raresik ( Eni ) – 700 kg
  2. Bank Sampah Mawarsari 16 ( Enung ) – 650 kg
  👉 Total Volume Hari Ini: 1350 kg

📅 Hari 3 – Total Trip: 2
  1. Bank Sampah Mawarsari 04 ( Yani ) – 750 kg
  2. Bank Sampah Paralon ( Maya ) – 550 kg
  👉 Total Volume Hari Ini: 1300 kg

🔍 Volume yang Belum Terangkut setelah 3 hari:
✅ Semua volume berhasil diangkut dalam 3 hari.
```

Figure 2. Optimization Results

The optimization results indicate that all six recycle points can be completely served within the company's operational policy of three collection days. Each operational day consists of collections from two recycle points, requiring two trips to accommodate the total waste volume while maintaining compliance with the vehicle capacity limitation. The resulting schedule is presented in Table 3.

Table 3. Optimized Waste Collection Schedule

Day	Recycle Points	Total Waste (kg)
Day 1	Melati 08 – Sakura 20	1.400
Day 2	Raresik – Mawarsari 16	1.350
Day 3	Mawarsari 04 – Paralon	1.300

The optimized schedule successfully distributes collection activities evenly across three operational days. Rather than performing simultaneous pickups from multiple recycle points, the proposed schedule balances transportation demand according to vehicle capacity and operational time availability.

Table 4. Optimization Results

Indicator	Result
Recycle points served	6
Weekly waste collected	4,050 kg
Collection period	3 days
Trips per day	2
Vehicle capacity	1,000 kg/trip
ODOL occurrence	0

This result demonstrates that DRP can effectively synchronize waste generation with transportation resources, thereby preventing over-dimension over-load (ODOL) conditions while maintaining complete weekly waste collection.

Dashboard Development

Following the scheduling optimization, a dashboard monitoring system was developed to improve operational visibility and support managerial decision-making.

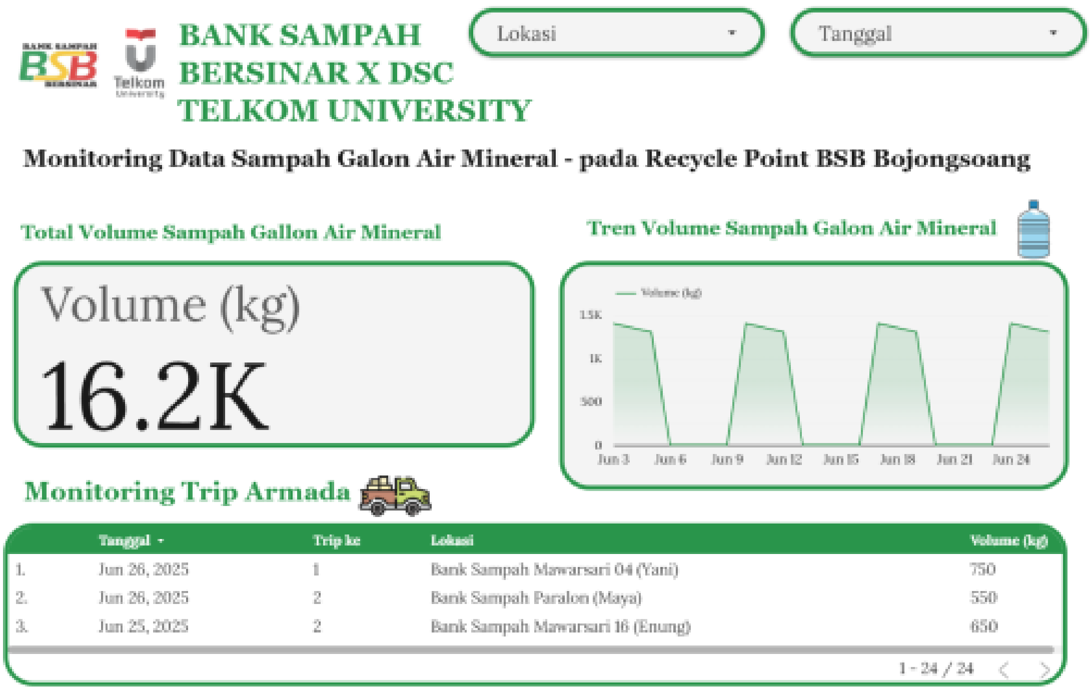

Figure 3. Dashboard Monitoring

The dashboard integrates the scheduling output with operational performance indicators, allowing managers to monitor collection activities in real time. Several Key Performance Indicators (KPIs) are displayed, including Daily pickup schedule, Number of completed trips, Daily waste collection volume, Collection performance by recycle point, and Historical collection records.

Compared with the previous manual recording system, the developed dashboard centralized operational information into a single interface, enabling managers to monitor collection schedules, vehicle utilization, collection volume, and recycle point performance without relying on paper-based delivery records.

Discussion

The implementation of the proposed Distribution Requirements Planning (DRP) framework successfully addressed the primary operational challenges identified at Bank Sampah Bersinar (BSB), namely the absence of a structured collection schedule, inefficient fleet utilization, and limited operational monitoring. By integrating weekly waste generation data, vehicle capacity, collection frequency, and operational time constraints into a unified planning framework, the developed scheduling system ensured that all recyclable waste generated from six recycle points could be collected within the company's three-day operational policy using only one pickup vehicle.

The scheduling results demonstrate that DRP can effectively synchronize collection demand with available transportation resources. The optimized schedule distributes collection activities evenly across three operational days, with two recycle points served each day through two pickup trips. This allocation prevents vehicle overloading by ensuring that the transported waste volume remains within the vehicle capacity of 1,000 kg per trip while maintaining complete weekly waste collection. As a result, the proposed scheduling framework not only improves transportation efficiency but also minimizes the risk of Over Dimension Over Loading (ODOL), which is an important operational issue in waste transportation.

In addition to scheduling optimization, the development of the monitoring dashboard significantly enhanced operational visibility compared with the previous paper-based recording system. Previously, operational records were manually documented using delivery notes, making it difficult to monitor collection progress, evaluate recycle point performance, and generate operational reports. The dashboard consolidates these operational data into a single interface that provides real-time information on daily collection schedules, completed trips, waste collection volume, vehicle utilization, and historical collection performance. This centralized information enables operational managers to monitor field activities more efficiently and supports faster, data-driven decision-making.

The integration of DRP and dashboard technology provides additional practical value beyond scheduling optimization. Rather than functioning solely as a planning tool, the developed system supports continuous operational monitoring and performance evaluation. Managers can identify delays, monitor transportation capacity utilization, evaluate recycle point productivity, and maintain consistent collection performance without increasing transportation resources or administrative workload. Consequently, the proposed framework contributes not only to operational efficiency but also to better organizational control and transparency in reverse logistics activities.

Overall, the developed framework demonstrates that combining Distribution Requirements Planning with a dashboard-based monitoring system offers a practical and scalable solution for community-based waste collection organizations operating under limited transportation resources. The approach can be adapted by other waste banks or small-scale reverse logistics organizations facing similar operational constraints, particularly those requiring systematic scheduling, improved operational visibility, and data-driven decision support.

CONCLUSIONS AND SUGGESTIONS

Conclusion

This community service program successfully developed a dashboard-based DRP framework for reverse logistics scheduling at Bank Sampah Bersinar. The proposed scheduling system successfully allocated 4,050 kg of recyclable waste from six recycle points into a three-day collection schedule using one pickup vehicle with two trips per day, while fully complying with the vehicle capacity constraint of 1,000 kg per trip. In addition, the dashboard centralized operational monitoring by displaying collection schedules, waste volume, fleet utilization, and recycle point performance. The proposed framework improves operational efficiency, prevents potential ODOL conditions, and provides a practical decision-support tool that can be adopted by other community-based waste collection organizations.

Suggestion

Although the proposed framework has demonstrated promising results, several opportunities remain for future research and practical implementation.

From an operational perspective, future studies may integrate the proposed scheduling model with Vehicle Routing Problem (VRP) optimization to simultaneously determine both the optimal collection schedule and the most efficient travel routes. Additional operational constraints, such as traffic conditions, fuel consumption, travel distance, and multiple vehicle availability, could also be incorporated to better represent real-world waste collection operations.

From a technological perspective, the dashboard can be further enhanced by integrating Global Positioning System (GPS) tracking, mobile applications, and Internet of Things (IoT) technologies to enable real-time vehicle monitoring and automatic collection status updates. Furthermore, implementing cloud-based databases and predictive analytics could improve operational planning by forecasting future waste generation and supporting dynamic scheduling decisions.

Finally, the proposed framework should be validated in larger-scale waste management systems involving more collection points, multiple vehicle fleets, and different categories of recyclable materials to evaluate its scalability and generalizability. Such extensions would further strengthen the applicability of DRP as a decision-support approach for reverse logistics and sustainable waste management.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to Telkom University for providing financial support through the Community Service Grant (Hibah Pengabdian kepada Masyarakat) 2025, Period 1. This support made the implementation of this community service program and the completion of this research possible.

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