Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx **DOI:** https://doi.org/xx

DISTRIBUTION ROUTE OPTIMIZATION FOR WASTE COOKING OIL COLLECTION WITHIN A CLOSED-LOOP SUPPLY CHAIN IN SURABAYA USING THE VRPSPD MODEL

Dea Dita Krisnasari[1*], Kevin Asali[2], Eka Pratiwi Briant Pakiding[3], A.M Adhitya A. Walenna[4]

[1,3,4]Industrial Engineering Department, Institut Teknologi Kalimantan, Balikpapan, 76127, East Kalimantan, Indonesia

[2]Industrial and Systems Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia.

*dea.krisnasari@lecturer.itk.ac.id

Abstract: Improper disposal of waste cooking oil (WCO) poses significant environmental risks, particularly to water ecosystems and public health in Indonesia. Despite the increasing volume of WCO generated from restaurants and food service industries, systematic collection and recycling systems remain limited. This study proposes a Closed-Loop Supply Chain (CLSC) system integrated with a Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) approach to optimize simultaneous WCO collection and empty-container distribution activities. The study employs a simulated case study involving 15 restaurants in Surabaya, Indonesia, with routing calculations solved using the Nearest Neighbor algorithm. Within the proposed CLSC framework, motorcycles simultaneously distribute empty jerry cans to restaurants and collect filled containers containing WCO for recycling purposes such as biodiesel production. The results demonstrate that the WCO collection system can be effectively modeled using the VRPSPD approach. The proposed routing system generated three vehicle routes with a total travel distance of 131.9 km, a total operational cost of IDR 1,793,916.46, and a total travel time of 4 hours and 21 minutes. Furthermore, the integration of forward and reverse logistics activities within a single transportation network improves transportation efficiency, reduces unnecessary trips, and supports sustainable waste management practices aligned with circular economy principles.

Keywords: *Closed-Loop Supply Chain; Nearest Neighbor Algorithm; VRPSPD; Waste Cooking Oil (WCO).*

(Received 2026-05-28, Accepted 2026-05-29, Available Online by 2026-05-31)

1. Introduction

Indonesia is known as a country with abundant natural resources, specifically in vegetable oil production dominated by palm oil (Setyawardhani & Satiawardana, 2025). Since 2020, Indonesia has produced more than 45 million tons of palm oil annually, contributing approximately 60% of the global palm oil production (Farobie & Hartulistiyoso, 2021). The massive production and consumption of palm oil have also led to a significant increase in waste generation, particularly waste cooking oil. These waste cooking oil, after evaporating and reaching a maximum number of usages, need to be safely disposed. From the cooking process, 40-60% of palm oil becomes waste (Fernandez et al., 2022). Waste Cooking Oil (WCO) is a growing threat to the environment. However, waste management in Indonesia is still far from optimal. Large quantities of WCO are improperly disposed into drainage systems, rivers, and soil, causing environmental pollution and threatening aquatic and terrestrial ecosystems (Perdana, 2021).

The volume of WCO increases annually due to the lack of adequate waste management infrastructure and the high consumption of from industrial, restaurants, hotels, and household activities. This issue can be addressed by recycling WCO into value-added products such as biodiesel (Suzihaque et al., 2022). Biodiesel derived from WCO has several environmental advantages, including lower greenhouse gas emissions, biodegradability, and enhanced engine lubricity compared to traditional

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

fossil (Nor et al., 2013). Moreover, utilizing it for biodiesel addresses waste disposal issues, reducing the contamination of land and water resources (Sreelekha et al., 2024). Therefore, WCO recycling is a priority sustainable step to reduce environmental impacts and support sustainable resource management.

One potential approach to support sustainable WCO management is the implementation of a Closed-Loop Supply Chain (CLSC) system (Gan, 2015; Jodlbauer et al., 2024). In this paper, we focused on restaurants that has many branches located in Surabaya, Indonesia. While the use of palm oil is widespread, the collection and retrieval systems for WCO from restaurants are often uncoordinated. Restaurants generate large amounts of WCO from daily cooking activities, which are commonly stored in dedicated containers before being collected by recycling companies or distributors. However, WCO collection systems in Indonesia are still largely managed conventionally, where collection activities are conducted separately from container distribution, resulting in inefficient transportation routes, increased operational costs, and higher environmental impacts.

To address these issues, this study proposes a Closed-Loop Supply Chain (CLSC) system integrated with a Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) approach. Previous studies on VRPSPD have mainly focused on plastic recycling, bottle return systems, and industrial waste collection. The development of the Periodic Vehicle Routing Problem with Simultaneous Pickups and Deliveries (PVRPSPD) model was previously conducted by Haryanto (2014) for determining vehicle routes responsible for product distribution and empty bottle collection with the objective of minimizing operational costs. The study considered vehicle capacity and time constraints within the routing process. A Genetic Algorithm approach was applied to obtain near-optimal routing solutions with relatively fast computation time. Research by Quintiana et al. (2022) demonstrated that VRPSPD can optimize WCO collection routes and improve vehicle utilization efficiency, achieving vehicle capacity utilization of up to 70%. Fernandez et al. (2022) showed that WCO collection systems are logistically feasible and economically beneficial for biodiesel production. These findings indicate that simultaneous pickup and delivery routing models can effectively improve logistics efficiency and are relevant for application in waste cooking oil (WCO) collection systems within a Closed-Loop Supply Chain (CLSC) framework.

However, studies discussing VRPSPD implementation for WCO collection in the Indonesian restaurant sector remain limited. Therefore, this study develops a routing strategy for simultaneous WCO collection and empty-container distribution using the VRPSPD approach within a CLSC framework. The study applies a simulated case study involving 15 restaurants in Surabaya, Indonesia, and solves the routing problem using the Nearest Neighbor algorithm to minimize transportation distance and operational costs while satisfying vehicle capacity constraints.

Although advanced metaheuristics may generate more optimal solutions, the Nearest Neighbor algorithm is widely recognized in operations research for its computational efficiency and simplicity in implementation, making it highly effective for generating initial solutions in real-time logistics scenarios that are well-suited for the small-to-medium-scale urban collection systems (Ekayanti et al., 2024). However, it often does not stand alone but rather as an initial stage in a methodology or as a baseline for comparison (Peya et al., 2019; Masudin et al., 2019; Fatahayu et al., 2022). In this study, nearest neighbor used as the initial stage in CLSC framework. This method works by identifying the closest point to the second-to-last point along a path that is to be traveled.

Thus, this study contributes to the literature in three ways. First, it develops an integrated CLSC–VRPSPD framework for WCO recovery in the restaurant sector. Second, it demonstrates the operational feasibility of simultaneous pickup–delivery routing under realistic urban logistics constraints. Third, it provides managerial insights for sustainable WCO collection systems in emerging economies.

2. Research Methods

This study employs a quantitative approach to optimize recovery logistics routes within a sustainable framework. The methodology is divided into several key stages: system design, mathematical modeling, and the application of a heuristic solution.

2.1. *Closed-Loop Supply Chain*

Closed-Loop Supply Chain (CLSC) management, which integrates circular economy principles into supply chain activities, has recently attracted significant attention in sustainable logistics and waste management research (Mishra et al., 2023). In the other hand, which is in logistic terminology, a Closed-Loop Supply Chain (CLSC) is a network that integrates forward and reverse supply chain activities simultaneously (Papen & Amin, 2024). The forward supply chain manages the flow of products from suppliers to customers, while the reverse supply chain involves recovering products from customers for

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

recycling, remanufacturing, or reuse purposes (Kannan et al., 2010). The concept of CLSC promoted by this regulatory framework encompasses the management of the forward and reverse logistics to maximize value creation over the entire life cycle of a product (Aiello et al., 2025). Therefore, the CLSC concept is considered an important approach for maintaining supply sustainability and supporting efficient resource utilization (Chaabane et al., 2012).

In particular, the development of reverse logistics systems for collecting and recycling waste materials has become an important strategy to improve environmental and economic sustainability. In the context of this study, the implementation of a CLSC system for waste cooking oil (WCO) collection from 15 restaurants enables the integration of forward and reverse logistics activities within the same transportation network. Through this system, empty jerry cans are distributed to restaurants while filled containers containing WCO are simultaneously collected for further recycling processes such as biodiesel production. Therefore, the CLSC concept supports sustainable waste management by integrating distribution and waste collection activities within the same logistics system.

2.2. *Vehicle Routing Problem with Simultaneous Pick-up and Delivery* (VRPSPD)

The logistics challenge is identified as a Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD). The core characteristic of this model is that each customer has simultaneous delivery and pickup demands that must be served by the same vehicle during a single visit. The VRPSPD concept was first introduced by Min (1989), who studied the distribution and collection of books between a central library and 22 local libraries under limited vehicle capacity constraints. VRPSPD is one of the most widely studied variants of the One-to-Many-to-One (1-M-1) routing problem, where two different commodity flows are involved: products are delivered from the depot to customers, while returned items are collected from customers and transported back to the depot (Paolo & Daniele, 2014). The objective of VRPSPD is to minimize total transportation costs while ensuring that each customer's delivery and pickup requests are fulfilled in a single visit without exceeding vehicle capacity limitations (Wassan & Nagy, 2014).

In the context of this study, the VRPSPD problem is solved using the Nearest Neighbor algorithm. The Nearest Neighbor algorithm iteratively constructs vehicle routes by selecting the nearest unvisited restaurant and inserting it into the route while considering vehicle capacity and VRPSPD constraints. In the proposed system, middlemen or WCO collectors simultaneously deliver empty jerry cans to restaurants and collect filled jerry cans containing waste cooking oil (WCO) within the same visit. The same routing procedure is repeated for the remaining vehicles until all restaurants have been served or the vehicle capacities have been reached (Gunawan, 2012).

2.3. *Mathematical Formulation: Nearest Neighbour Algorithm*

Nearest Neighbor algorithm is selected due to its simplicity, computational efficiency, and suitability for solving routing problems in closed-loop distribution systems involving simultaneous pickup and delivery activities (Ekayanti et al., 2024). The algorithm follows a constructive heuristic logic:

1. Initialization: The vehicle starts at the central depot (node 0).
2. Selection: The algorithm identifies the unvisited customer location with the shortest distance from the current node.
3. Feasibility Check: Before insertion, the system verifies that the addition of the new customer does not violate the vehicle's maximum capacity (Q) for either pickup or delivery demands.
4. Iteration: Steps 2 and 3 are repeated until all nodes are served or the vehicle capacity is reached, after which the vehicle returns to the depot.
5. Multi-route Generation: If unserved customers remain, a new route is initialized with a subsequent vehicle until all demand is fulfilled.

The mathematical model of the VRPSPD used in this study is adapted from the three-index Mixed Integer Programming (MIP) formulation proposed by Montane and Galvao (2006). The model consists of parameters, an objective function, and constraint functions for the VRPSPD problem.

a. Parameters

C_{ij} = transportation cost incurred when traveling through arc (i,j)
d_i = empty jerry cans demand delivered to restaurants i (delivery demand)
P_i = full jerry cans demand collected from restaurants i (pickup demand)
y_{ij} = quantity of full jerry cans transported along arc (i,j)
z_{ij} = quantity of empty jerry cans transported along arc (i,j)
Q = maximum vehicle capacity (40 liters = 2 jerry cans)

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

The parameters used in the VRPSPD mathematical model are defined as follows. C_{ij}represents the transportation cost incurred when a vehicle travels through arc (i, j). $d_i$denotes the delivery demand at restaurant i, represented by the number of empty jerry cans delivered to the restaurant. Meanwhile, $P_i$indicates the pickup demand at restaurant i, represented by the number of filled jerry cans containing waste cooking oil (WCO) collected from the restaurant. Furthermore, y_{ij}represents the quantity of filled jerry cans transported along arc (i, j), while z_{ij}represents the quantity of empty jerry cans transported along the same arc. The parameter Qdenotes the maximum vehicle capacity used in the routing system. In this study, each motorcycle vehicle is assumed to have a maximum carrying capacity of 40 liters, equivalent to two jerry cans, which is considered during the simultaneous pickup and delivery routing process.

b. Decision Variable (Xijk)

$$Xijk = \begin{cases} 1 & if\ vehicle\ k\ travels\ directly\ from\ location\ i\ to\ location\ j \\ 0 & otherwise \end{cases}$$

The binary decision variable x_{ijk}indicates whether vehicle $k$travels between two locations. In this study, the decision variable represents the movement of collection vehicles from the WCO collection depot to restaurant locations for simultaneous delivery and pickup activities. A value of $x_{ijk} = 1$ indicates that vehicle k is assigned to travel from location i to location j to distribute empty jerry cans and collect filled jerry cans containing WCO. Meanwhile, a value of $x_{ijk} = 0$ indicates that the route between the two locations is not selected in the routing system.

c. Set and Objective Function

V : Set of restaurants
K : set of vehicle

$$minimize \sum_{k \in K} \sum_{i \in V} \sum_{j \in V} CijXijk \tag{1}$$

The objective function aims to minimize the total transportation cost incurred by all vehicles while serving delivery (empty jerry cans or containers) and pickup demands (full containers or jerry cans contains WCO). The transportation cost is determined based on the travel cost between locations and the selected vehicle routes. Through this objective function, the model seeks to generate the most efficient routing strategy for collecting waste cooking oil and distributing empty jerry cans simultaneously.

d. Constraints Function

$$\sum_{j \in V} \sum_{k \in K} Xijk = 1 \qquad \forall i \in V \{0\} \tag{2}$$
$$\sum_{j \in V} - \sum_{j \in V} Xjik = 0 \qquad \forall i \in V, k \in K \tag{3}$$
$$\sum_{j \in V} Xoik \leq 1 \qquad \forall k \in K \tag{4}$$
$$yij + Zij \leq QXijk \qquad \forall i, j \in V \tag{5}$$
$$\sum_{j \in V} yij - \sum_{j \in V} yji = Pi \qquad \forall i \in V \backslash \{0\} \tag{6}$$
$$yij \geq 0 \qquad \forall i, j \in V \tag{8}$$
$$xijk \in \{0,1\} \quad \forall i, j \in V, k \in K \tag{9}$$

Constraint (2) ensures that each customer node is visited exactly once by a vehicle. Constraint (3) represents the flow conservation constraint, ensuring that every vehicle entering a customer location must also leave the same location, thereby maintaining route continuity. Constraint (4) states that each vehicle in the fleet can depart from the depot at most once. Constraint (5) ensures that the total number of empty jerry cans delivered and filled jerry cans containing waste cooking oil (WCO) collected along a route does not exceed the motorcycle capacity. In this study, each motorcycle has a maximum capacity of 40 liters, equivalent to two jerry cans ($Q = 2$). Therefore, the combined pickup and delivery loads

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

transported on any selected route must remain within this capacity limit. This constraint is essential to maintain the feasibility of the simultaneous pickup and delivery operations within the proposed Closed-Loop Supply Chain (CLSC) system. Constraint (6) defines the pickup flow balance, where the net flow of pickup commodities at each customer node must satisfy the pickup demand. Similarly, Constraint (7) defines the delivery flow balance, ensuring that the delivery demand at each customer node is fulfilled. Constraint (8) specifies the non-negativity requirement for pickup flow variables, while Constraint (9) defines the binary decision variable, where a route between two nodes is either selected (1) or not selected (0).

2.4. Data Collection

The data used in this study were developed based on a simulated case study approach. The research considers a WCO collection system involving 15 noodle and dimsum restaurants located in Surabaya, Indonesia. Restaurant locations and travel distances were adjusted to actual geographical conditions and road networks in Surabaya to represent realistic routing scenarios. The quantity of waste cooking oil generated was estimated based on the average daily cooking oil consumption of the restaurants, which is approximately 80 liters per day. Referring to the study by Fernandez et al. (2022), it is assumed that approximately 40-60% of the consumed cooking oil becomes waste cooking oil, resulting in an estimated WCO generation of 32–40 liters per day for each restaurant. Each container or jerry can is assumed to have a capacity of 20 liters; therefore, maximum capacity for pickup and delivery are two filled containers containing WCO. Furthermore, vehicle capacities were determined based on operational assumptions reflecting common practices in WCO collection activities. Therefore, this study evaluates the applicability of the VRPSPD model and the Nearest Neighbor algorithm for optimizing WCO collection routes within a Closed-Loop Supply Chain system.

The distribution map of restaurants and the WCO collection depot is illustrated in Figure 1, while the location indices are presented in Table 1.

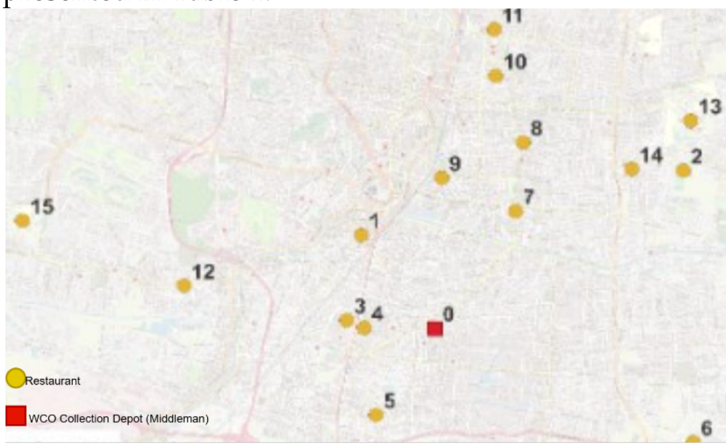

Figure 1. Geographical Map (Distribution) of Restaurants and WCO Collection Depot

Table 1. Location Index Restaurant and WCO Collection Depot

No	Name
0	Waste Cooking Oil Depot Collection (Middleman)
1	Resto Margorejo
2	Resto Soekarno Hatta 2
3	Resto Ahmad Yani
4	Resto Ambengan
5	Resto Wiyung
6	Resto Mayjend Sungkono
7	Resto MERR
8	Resto Kenjeran
9	Resto Manyar Kertoajo
10	Resto Kendedes
11	Resto Ngagel
12	Resto Manukan

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

13	Resto Puri
14	Resto Teuku Umar
15	Resto Ponti

The transportation system utilizes three motorcycles as collection vehicles. Each motorcycle is assumed to have a carrying capacity adjusted to common operational practices in WCO collection activities. The operational costs considered in this study consist of transportation costs of Rp 946.15 per kilometer, delivery handling costs of Rp 2,000 per liter for empty jerry cans, and pickup handling costs of Rp 4,000 per liter for filled jerry cans containing waste cooking oil. The pickup demand is measured in liters and converted into the number of jerry cans based on the assumption that one jerry can has a capacity of 20 liters. Each restaurant is assumed to simultaneously require delivery of empty jerry cans and pickup of filled jerry cans containing WCO. While, some locations may only involve either pickup or delivery activities. The detailed pickup and delivery demand data presented by amount of jerry cans (20 L) for each restaurant are presented in Table 2.

Table 2. Demand for Pickup and Delivery

Restaurant Code	Divery (JerryCans)	Pick-up (Jerry Cans)
1	1	0
2	2	2
3	2	2
4	1	1
5	2	2
6	0	1
7	0	1
8	0	1
9	2	2
10	2	2
11	2	2
12	1	1
13	2	2
14	1	0
15	1	0

3. Result and Discussion

3.1. WCO Distribution and Collection Routes

Figure 2 illustrates the results of the three vehicle routes used for simultaneous pickup and delivery activities in the WCO collection system. The routes were generated using the Nearest Neighbor algorithm within the VRPSPD model framework. The first vehicle route is represented in yellow, the second vehicle route in green, and the third vehicle route in blue.

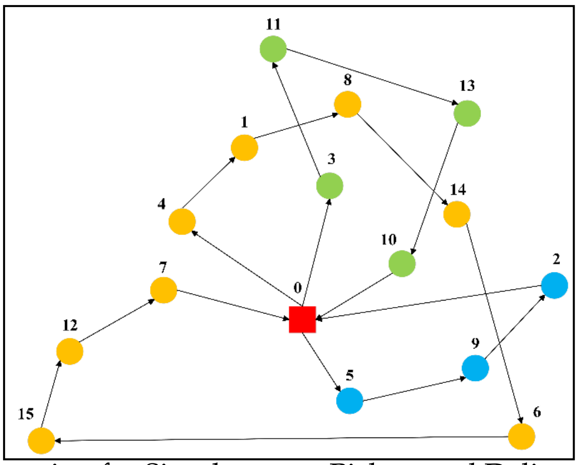

Figure 2. Routes Illustration for Simultaneous Pickup and Delivery Waste Cooking Oil

The proposed routing system reflects the implementation of a Closed-Loop Supply Chain (CLSC), where forward and reverse logistics activities are integrated within the same transportation network. In

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

the forward flow, vehicles distribute empty jerry cans to restaurants for future WCO storage, while in the reverse flow, the same vehicles simultaneously collect filled jerry cans containing waste cooking oil from restaurants and transport them back to the WCO collection depot. By integrating pickup and delivery activities into a single route, the CLSC system improves transportation efficiency, reduces unnecessary travel distances, and minimizes operational costs and environmental impacts associated with WCO collection activities.

3.2 Discussion

3.2.1 Distribution Route for Fleet 1

Figure 3 illustrates the sequence of locations visited in Route 1. Table 3 presents the travel distances between locations, the pickup and delivery loads handled at each customer point, and the operational costs incurred throughout the route. Fleet 1 follows the route sequence 0–4–1–8–14–6–15–12–7–0, where node 0 represents the WCO collection depot (middleman). The routing calculation was performed using the Nearest Neighbor algorithm, with each jerry can assumed to have a capacity of 20 liters. In this study, no maximum carrying capacity constraint was applied to Fleet 1. The total travel distance for Fleet 1 is 66.8 km, with a vehicle utilization rate of 53.43%. Furthermore, the total operational cost generated along this route is IDR 1,343,202.82.

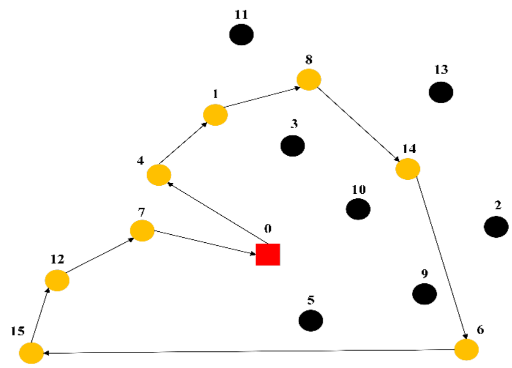

Figure 3. Routes Illustration for Fleet 1

Table 3. Travel Distances Location for Fleet 1

Fleet 1	Distance (km)	Cap. Delivery (Jerry Cans)	Pickup Capacity (Jerry Cans)	Operational Cost (IDR)
0	0	0	0	0
4	3.7	1	1	123,500.76
1	7.5	1	0	47,096.13
8	6.7	0	1	86,339.21
14	2.8	1	0	42,649.22
6	7.4	0	1	87,001.51
15	19.8	1	0	58,733.77
12	6.0	1	1	125,676.90
7	9.3	0	1	88,799.20
0	3.6	0	0	3,406.14
		Total Cost		**663.202.82**

3.2.2 Distribution Route for Fleet 2

Figure 4 illustrates the sequence of locations visited in Route 2. Table 4 presents the travel distances between locations, the pickup and delivery loads handled at each customer point, and the operational costs incurred throughout the route. Fleet 2 follows the route sequence 0–11–13–3–10–0, where node 0 represents the WCO collection depot (middleman). The total travel distance for Route 2 is 39.3 km, with a vehicle utilization rate of 21.54%. In addition, the total operational cost generated along this route is IDR 386,586.82.

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

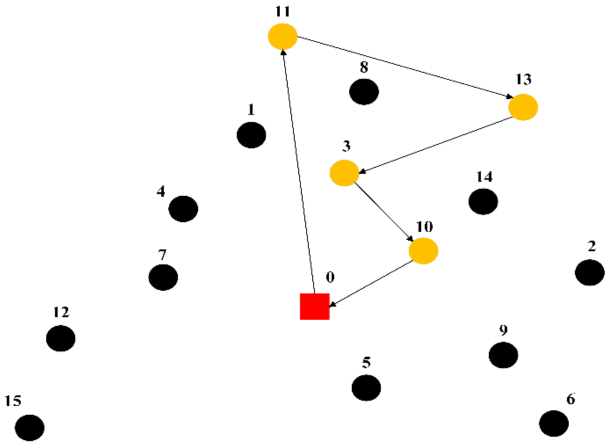

Figure 4. Routes Illustration for Fleet 2

Table 4. Travel Distances for Fleet 2

Fleet 1	Distance (km)	Cap. Delivery (Jerry Cans)	Pickup Capacity (Jerry Cans)	Operational Cost (IDR)
0	0	0	0	0
11	8.4	2	2	123,500.76
13	5.5	2	2	47,096.13
3	10.8	2	2	86,339.21
10	7.3	2	2	42,649.22
0	7.3	0	0	87,001.51
		Total Cost		**386,586.82**

3.2.3 Distribution Route for Fleet 3

Figure 5 illustrates the sequence of locations visited in Route 3. Table 5 presents the travel distances between locations, the pickup and delivery loads handled at each customer point, and the operational costs incurred throughout the route. Fleet 3 follows the route sequence 0–5–9–3–0, where node 0 represents the WCO collection depot. The total travel distance for Route 3 is 39.3 km, with a vehicle utilization rate of 41.48%. Furthermore, the total operational cost generated along this route is IDR 744.126.83.

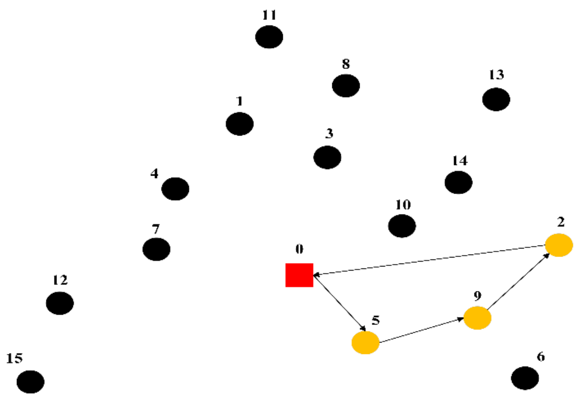

Figure 5. Routes Illustration for Fleet 3

Table 5. Travel Distances for Fleet 3

Fleet 3	Distance (km)	Cap. Delivery (Jerry Cans)	Pickup Capacity (Jerry Cans)	Operational Cost (IDR)
0	0	0	0	0
5	3.6	2	2	243,406.14
9	6.8	2	2	246,433.82
2	6.4	2	2	246,055.36
0	8.7	0	0	8,231.51
		Total		**744.126,83.**

Journal of Agroindustrial Development and Innovation
Vol.1, No.1, May 2026, pp.17-26
ISSN: xxxx-xxxx DOI: https://doi.org/xx

The results indicate that Route 1 has the longest travel distance because the pickup and delivery loads assigned to this route are relatively smaller compared to the other vehicle routes. As a result, Vehicle 1 is capable of visiting a greater number of restaurant locations for simultaneous empty jerry can distribution and WCO collection activities. In contrast, Routes 2 and 3 carry larger loads at each customer location, particularly Route 3, causing the number of visited restaurants to be relatively fewer due to vehicle capacity limitations. The total operational cost required to execute all three routes is IDR 1,793,916.46. Assuming a constant vehicle (motorcycles) speed of 40 km/h, the total travel time for Route 1 is 2 hours and 12 minutes (132 minutes), while Route 2 requires 1 hour and 18 minutes (78 minutes), and Route 3 requires 51 minutes.

The routing results obtained using the VRPSPD model and the Nearest Neighbor algorithm are consistent with the characteristics of simultaneous pickup and delivery systems reported in previous studies. Furthermore, the proposed routing strategy successfully integrates forward and reverse logistics activities within a Closed-Loop Supply Chain (CLSC) framework. In the forward flow, vehicles distribute empty jerry cans to restaurants, while in the reverse flow, the same vehicles simultaneously collect filled jerry cans containing WCO and transport them back to the WCO collection depot for further recycling processes. All restaurant demand points were successfully served without violating the vehicle capacity and routing constraints defined in the VRPSPD model.

4. Conclusion

In this study, a systematic approach was developed to support routing strategy optimization within a Closed-Loop Supply Chain (CLSC) system with the objective of minimizing operational costs and improving the efficiency of waste cooking oil (WCO) collection and empty-container distribution activities. The results demonstrate that the WCO collection system can be effectively modeled using the Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) approach within a CLSC framework.

The implementation of the CLSC concept enables the integration of forward and reverse logistics activities into a single transportation system. The study was conducted using a simulated case study involving 15 restaurants in Surabaya, Indonesia. The routing results generated three vehicle routes for simultaneous pickup and delivery activities, namely: 0–4–1–8–14–6–15–12–7–0; 0–11–13–3–10–0; and 0–5–9–2–0, with a total operational cost of IDR 276,986. The total travel time required for all routes was 4 hours and 21 minutes. The findings indicate that the proposed VRPSPD-based CLSC system successfully integrates WCO collection and empty-container distribution activities without violating vehicle capacity constraints. In addition, the routing strategy contributes to reducing transportation inefficiencies and supports circular economy principles by ensuring that waste cooking oil is returned into the supply chain as a recyclable resource rather than being improperly discarded into the environment.

Considering that the total operational time remains significantly below the standard driver working shift of 8 hours per day, the coverage area and number of customer demand points for pickup and delivery activities can still be expanded in future implementations. However, this study is limited by several operational assumptions used in the simulated case study. Therefore, future research may develop more comprehensive CLSC routing models by incorporating larger service areas, real operational data, additional routing constraints, or alternative optimization algorithms to improve routing efficiency and sustainability performance.

References

A. Chaabane, A. Ramudhin, M. Paquet. (2012). Design of sustainable supply chains under the emission trading scheme. International Journal of Production Economics. 135(6), 37-49

Aiello, G., Muriana, C., Quaranta, S., & Abusohyon, I. A. S. (2025). A sustainable inventory management model for closed loop supply chain involving waste reduction and treatment. Cleaner Logistics and Supply Chain, 16, 100244.

Ekayanti, E., & Efendi, I. B. (2024). Capacitated vehicle routing problem (CVRP) with sweep and nearest neighbor algorithm. Sinergi International Journal of Logistics, 2(1), 17-29.

Fatahayu, N. R., Waluya, F. N., Atthoriq, M. F., & Sukarno, I. (2022). Optimization of blood bag distribution routes using AMPL software and nearest neighbor algorithm (Case Study of the Indonesian Red Cross Jakarta). J. Logist. Indones, 6, 1-12.

Gan, S. S. (2015). Closed-loop Supply Chain as an Agent of Sustainable Development. Journal of Industrial Engineering: Research & Application/Jurnal Teknik Industri, 17(1).

Kannan, G., Sasikumar, P., Devika, K. (2010). A genetic algorithm approach for solving a closed loop supply chain model: a case of battery recycling. Applied Mathematic Modelling. 34(1), 655–670

F. A. T. Montane, R. D. Galvao. (2006). A tabu search algorithm for the vehicle routing problem with simultaneous pick-up and delivery service. Computers & Operations Research. 33, 595–619.

Farobie, O., & Hartulistiyoso, E. (2021). Palm Oil Biodiesel as a Renewable Energy Resource in Indonesia: Current Status and Challenges. Springer US. https://link.springer.com/article/10.1007/s12155-021-10344-7

Fernandez, C., Bernal, A., Leon, P., Gelves, O., & Malagon-Romero, D. H. (2022). Optimization of a Route for Collecting Waste Cooking Oil in Bogotá. https://doi.org/10.3303/cet2291105

Gunawan, P. (2012). Enhanced Nearest Neighbors Algorithm for Design of water Network. Chemical Engineering Science. 84 (1), 197-206

Jodlbauer, H., Thürer, M., & Thienemann, A. K. (2024). On cost and revenue in circular supply chains: Where to close the loop?. Cleaner logistics and supply chain, 13, 100194.

L.C. Haryanto. (2014). Pengembangan Model Periodic Vehicle Routing Problem with Simultaneous Pickups and Deliveries Studi Kasus: Sistem Distribusi di CV. Faromas Timor Distribution Atambua. Calyptra: Jurnal Ilmiah Mahasiswa Universitas Surabaya. 3(2): 1-17

Masudin, I., Sa'diyah, R. F., Utama, D. M., Restuputri, D. P., & Jie, F. (2019). Capacitated vehicle routing problems: nearest neighbour vs. Tabu search. International Journal of Computer Theory and Engineering, 11(4), 76-79.

Min, H. (1989). The multiple vehicle routing problem with simultaneous delivery and pick-up points. Transportation Research Part A: General, 23(5), 377-386.

Mishra, A., Badhotiya, G. K., Patil, A., Siddh, M. M., & Ram, M. (2023). Servitization in the circular supply chain: delineating current research and setting future research plan. Management of Environmental Quality: An International Journal, 34(4), 1035-1056.

Nor, H., Sulaiman, H., & Nurrul, R. (2013). Biodiesel Production Based on Waste Cooking Oil (WCO). Int. J. Mater. Sci. Eng., 1(2), 94–99. https://doi.org/10.12720/ijmse.1.2.94-99

Setyawardhani, D. A., & Satiawardana, T. H. (2025). Innovative approach to vegetable oil production and refining technology in Indonesia: a review. https://link.springer.com/article/10.1007/s43938-025-00099-4

Sreelekha, Dubey, N., & Avinashe, H. (2024). Utilizing Waste Cooking Oil for Sustainable Biodiesel Production: A Comprehensive Review. Journal of Scientific Research and Reports, 30(6), 222–234. https://doi.org/10.9734/jsrr/2024/v30i62036

Papen, P., & Amin, S. H. (2024). Network configuration of a bottled water closed-loop supply chain with green supplier selection. Journal of Remanufacturing, 9(2): 149-157.

Paolo, T., & Daniele V. (2014). Vehicle Routing Problems, Methods, and Applications Second Edition. Siam.

Perdana, B. E. G. (2021). Circular economy of used cooking oil in Indonesia: current practices and development in special region of Yogyakarta. Journal of World Trade Studies, 6(1), 28-39.

Peya, Z. J., Akhand, M. A. H., Sultana, T., & Rahman, M. M. (2019). Distance based sweep nearest algorithm to solve capacitated vehicle routing problem. International Journal of Advanced Computer Science and Applications, 10(10), 259-264.

Quintana, L., Herrera-Mena, Y., Martínez-Flores, J. L., Coronado, M. A., Montero, G., & Cano-Olivos, P. (2020). Design of waste vegetable oil collection networks applying vehicle routing problem and simultaneous pickup and delivery. Acta Logistica, 7(4), 261-268.

Suzihaque, M. U. H., Syazwina, N., Alwi, H., Ibrahim, U. K., Abdullah, S., & Haron, N. (2022). A sustainability study of the processing of kitchen waste as a potential source of biofuel: Biodiesel production from waste cooking oil (WCO). Materials Today: Proceedings, 63, S484-S489.

Wassan, N. A., & Nagy, G. (2014). Vehicle routing problem with deliveries and pickups: modelling issues and meta-heuristics solution approaches. International Journal of Transportation, 2(1), 95-110.