Heterogeneous Vehicle Routing Problem with Simultaneous Pickup and Delivery to Optimize Last Mile Deliveries of Sustainable Retail

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ABSTRACT

Transportation, as one of many elements of logistics, accounts for 30-60% of the total logistics cost, making it essential to be arranged as efficient as possible as it contributes to greater competition in the market, greater economies of scale, and reduced prices of goods. One initiative to achieve transportation efficiency is the Vehicle Routing Problem. PT Siklus. The Vehicle Routing Problem is carried out in this research for PT Siklus Refil Indonesia or Siklus, an Indonesian-based sustainable retail startup, which mission is to reduce plastic wastes. Siklus offers a unique shopping experience, in which once the order is delivered to the customers, they can store used containers or waste, which will then Siklus collect and cultivate for greater good. However, due to the last mile delivery activities, maintaining the logistics cost to be minimum has been a never-ending challenge to overcome. Therefore, the Heterogeneous Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows is developed, striving to optimize the last mile deliveries of Siklus, hence minimum total cost is achieved. Based on the results, it is found that the proposed model leads to cost saving as much as 31.28% from the existing condition.

INTRODUCTION

OGISTICS plays a critical role in the decision-making of businesses, especially those in retail industries. Logistics is a part of the supply chain process that organizes, implements, and manages the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption to meet customers' requirements [1]. In the first quarter of 2021, logistics activities have accounted for 23.5% of the GDP of Indonesia [2]. Therefore, it is important for logistics to be arranged efficiently. According to [3], logistics systems consist of three main activities – order processing, inventory management, and freight transportation.

Transportation is the operational area of logistics that geographically moves and positions inventory [4]. It accounts for 30% to 60% of the logistics cost, making it essential for companies to manage their transportation costs to be efficient, as it also contributes to greater competition, economies of scale, and reduced prices of goods [1]. There are several basic functions in managing transportation, namely determining the transportation mode, consolidating information and delivery, planning the delivery schedule and routes, providing value-added service and managing inventory [5]. One initiative to manage transportation efficiently is to find the best routes a vehicle should travel is able to generate minimum time or distance to be achieved, where commonly such problem is addressed using the Vehicle Routing Problem or VRP.

Importance of logistics surely occurs as well in PT Siklus Refil Indonesia or Siklus, an Indonesian-based sustainable retail startup. Siklus provides affordable daily needs products while achieving its mission which is to reduce plastic waste. The customer orders are delivered into the customers' place. Furthermore, Siklus offers a unique shopping experience for its customers where they can store used containers or waste when their order is delivered which will Siklus then collect and cultivate.

However, the business model of Siklus has caused several problems maintaining the logistics cost as minimum as possible due to its last mile deliveries. In addition, an electric car and electric motorbikes are rented to perform the last mile deliveries to enhance sustainability. However, that decision is causing implications in the logistics cost. Despite renting the electric vehicle (EV), the utilization of fuel motorbike still occurs whenever the EVs have fully occupied, yet there are unfulfilled deliveries remaining.

Table 1 Sample Dataset for Model Verification

Node	Latitude	Longitude	Load (kg)		Time Windows (minutes)		Service Time
			Delivery	Pickup	Open	Close	(minutes)
1	-6.23277	106.6358	4.09	0.00	577	858	21
2	-6.26168	106.9506	4.50	0.23	590	879	23
3	-6.34663	106.8151	0.71	0.00	492	815	28
4	-6.24141	106.8404	11.28	0.23	502	85	20
5	-6.20238	106.8656	1.29	0.68	510	1011	21

Table 2 Manual Routing Result

From	To	Destination TW (min)		Depart Time (min)	Arrival Time (min)	Service Time (min)	Cum. Distance (km)	Total Carried Load (kg)
		Open	Close					
0	5	510	1011	503.6	510.0	21	3.2	21.87
5	4	502	855	531,0	541.3	20	8.36	21.26
4	3	492	815	561.3	585.4	28	20.39	10.20
3	2	590	879	613.4	648.9	23	38.15	9.49
2	1	577	858	671.9	742.1	21	73.26	5.22
1	0	480	1020	763.1	818.5	0	100.97	1.13

Table 3 VBA Excel Routing Result

From	To	Depart Time (min)	Arrival Time (min)	Service Time (min)	Travelled Distance (km)	Total Carried Load (kg)	Load of Delivery (kg)	Load of Pickup (kg)
0	5	503.6	510.0	21	3.2	21.87	1.29	0.68
5	4	531,0	541.3	20	8.36	21.26	11.28	0.23
4	3	561.3	585.4	28	20.39	10.20	0.71	0.00
3	2	613.4	648.9	23	38.15	9.49	4.50	0.23
2	1	671.9	742.1	21	73.26	5.22	4.09	0.00
1	0	763.1	818.5	0	100.97	1.13	0.00	0.00

Table 4 Running Model with Order Data of March 7, 2023

Vehicle[a]	Route	Load (kg)		Total Distance
		Delivery	Pickup	(km)
EM1	0 - 13 - 7 - 6 - 11 - 24 - 4 - 36 - 27 - 19 - 21 - 5 - 0	79.69	0.00	81.55
EM2	0 - 23 - 18 - 2 - 33 - 8 - 25 - 0	78.97	0.00	46.51
EM3	0 - 15 - 3 - 9 - 1 - 10 - 17 - 0	79.17	0.00	59.14
EM4	0 - 38 - 34 - 31 - 14 - 32 - 28 - 6 - 22 - 29 - 37 - 0	77.90	0.00	85.37
EM5	0 - 20 - 12 - 26 - 30 - 35 - 0	72.20	0.00	60.03
EC	-	-	-	-
FM1	-	-	-	-
FM2	-	-	-	-
FM3	-	-	-	-
Grand Total Distance (km)				332.60

[a]EM – *Electric Motorbike*, EC – *Electric Car*, FM – *Fuel Motorbike*

To some extent, the utilization of fuel motorbikes somewhat conflicting with the sustainability value that Siklus upholds, as according to the Committee on the Elimination of Leaded Gasoline, fuel motorbike contributes the most pollutant compared to other fuel vehicles as much as 60% - 70% in Jakarta [6]. The utilization of fuel motorbikes in Siklus is done whenever the EVs have all been occupied while there are remaining unfulfilled orders. However, such things worsen as the current routing practice of Siklus lacks proper calculation or modeling. The current routing arrangement depends on the subjectivity of the routing team. Thus, there is room for improvement to explore for better routing results.

Other than the fleet utilization, the absence of proper calculation or modeling for routing also impacts the utilization of motorist (an appellation for the delivery personnel of Siklus). Basically, there are two types of motorists hired by Siklus, namely Internal motorist, which is hired monthly, and Outsourced motorist which is hired daily if only the Internal motorist is fully occupied. With more proper routing, there is a potential to optimize motorist utilization hence less Outsourced motorists are needed, leading to less cost incurred.

Currently, Siklus operates from its warehouse located in Jakarta, and performs services for its customers which are spread within the *Jadetabek* area – Jakarta, Depok, Tangerang, and Bekasi. Looking at the condition, Siklus faces complexities due to the need to deliver the orders within this wide range of areas. Therefore, this becomes a challenge for Siklus to overcome every day, worsened by the absence of proper calculation for routing.

To overcome the situation, the Vehicle Routing Problem (VRP) is addressed to determine a set of vehicle routes to execute transportation requests at minimum cost [5]. Over the years of its development, VRP has been applied with several aspects being considered, such as time windows, pickup and delivery problems, backhauls, etc. In other words, the VRP can be tailored based on the situation encountered by the planner. Thus, to suit the implementation of last mile deliveries of Siklus, the Heterogeneous Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows (HVRPSPDTW) is carried out in this research to tackle the ongoing issues faced by Siklus. The term *Heterogeneous* represent the existence of different types

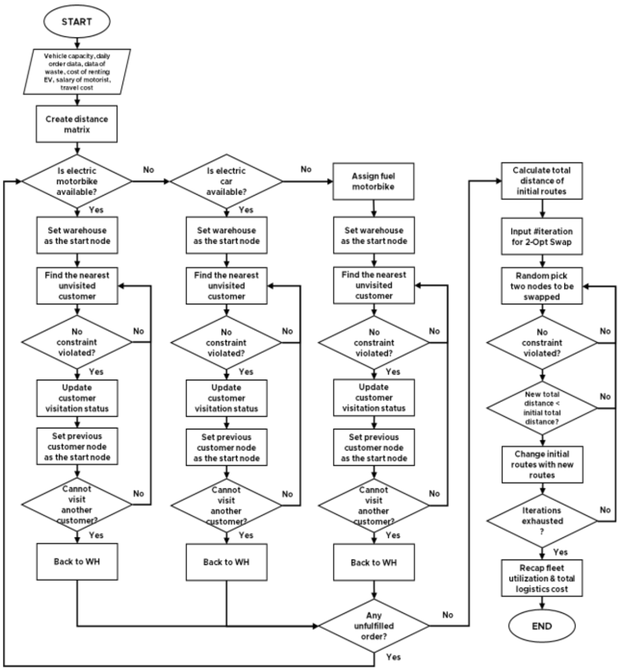

Figure 1 Conceptual Model

of vehicles used by Siklus, *Simultaneous Pickup and Delivery* to represent the activities related to both delivering orders and collecting waste, and *Time Windows* to represent certain time of deliveries requested by the customers, if any.

Several research As the HVRPSPDTW model is a generalization of VRP, it is considered as NP-hard problem. Although mathematical programming or exact algorithms generate global optimum solution, this approach has proven to be inefficient to solve large instances due to high computational time. Thus, heuristics are commonly preferred due to much shorter computational time despite its optimality [7]. One of the most applied heuristics to construct the initial route of VRP is the Nearest Neighbor algorithm [8]. The algorithm works by searching for the nearest unvisited customer. Yet, as a constructive heuristic, the Nearest Neighbor may lack routing quality, hence the so-called improvement heuristics is applied to improve the solution. Almost all improvement heuristics work by modifying solutions within the neighborhood [9]. One example of improvement heuristics is the 2-Opt algorithm, which intended to improve a route by exchanging two edges by two other edges iteratively [10].

Therefore, in this research, the Nearest Neighbor (NN) and 2-Opt algorithm are employed to solve the HVRPSPDTW model. With the development of this model, it determines the optimal routes and number of required vehicles and motorists. At the end, the model carried out in this research acts as a decision-making tool for Siklus to manage its fleet utilization for daily last mile deliveries efficiently, hence leading to minimum logistics cost incurred.

PAST LITERATURES

Several research has been conducted like the Vehicle Routing Problem carried out in this research. Ref [11] developed a VRPSPD (Vehicle Routing Problem with Simultaneous Pickup and Delivery) for milk collection process, in which empty milk containers are unloaded, and full containers are loaded simultaneously. It is aimed to reduce the total cost of distributing 17 milk productive units and 2 milk processing enterprises, with three vehicles that are heterogeneous in capacity for deliveries. It is solved using the exact method, obtaining an optimal solution within eight minutes which leads to 7% decrease of the total cost.

Ref [12] developed a Heterogeneous Fixed Fleet Vehicle Routing Problem with Simultaneous Pickup and Delivery, solved using hybrid metaheuristic algorithm, combining simulated annealing and local search, called as the SA-LS. A computational study is conducted with three stages – first is evaluating the SA-LS on small and medium instances of HVRPSPD. The second stage of it is evaluating the SA-LS on a large HVRPSPD instances. The third stage is evaluating the SA-LS on HVRP instances as a special case of HVRPSPD. Based on the results, it generates a good quality solution within a reasonable computational time of six seconds.

Ref [13] developed a Capacitated Heterogeneous Vehicle Routing Problem for pharmaceutical products delivery across the city of Medan, Indonesia. The Mixed Integer Programming (MIP) is used to solve the problem, along with heuristic neighborhood search. The objective of the proposed model is to minimize the travel cost, respecting the capacity and time constraints. A sample dataset consisting of four consumers to be delivered with two vehicles, and it incurred Rp500,000 of minimum travel cost.

PROBLEM DESCRIPTION

A. *Last Mile Deliveries of Siklus*

Siklus delivers the customer orders right into the customers' place. To perform the deliveries, currently there are up to three types of vehicles to be assigned with

Table 5 Comparison Fleet and Motorist Utilization

Condition	Vehicle Units (#)			Motorist (#)	
	EC[a]	EM[b]	FM[c]	Internal	Outsourced
Existing	1	3	2	3	3
Improved	0	5	0	3	2

[a]EC – *Electric Car*, [b]EM – *Electric Motorbike*, [c]FM – *Fuel Motorbike*

Table 6 Comparison of Total Distance Travelled

Condition	Travelled Distance (km)			Total Travelled Distance (km)
	EC[a]	EM[b]	FM[c]	
Existing	125.6	125	232	482.6
Improved	0	332.6	0	332.6
Differences (%)				31.08%

[a]EC – *Electric Car*, [b]EM – *Electric Motorbike*, [c]FM – *Fuel Motorbike*

Table 7 Comparison of Total Logistics Cost

Condition	Traveling Cost	Cost of Motorist (Internal + Outsourced)	Cost of Rent EV	Total Logistics Cost
Existing	Rp21,011	Rp906,000	Rp621,472	Rp1,548,483
Improved	Rp12,013	Rp720,000	Rp332,083	Rp1,064,096
Differences (%)				31.28%

each of its available units, namely one electric car, five electric motorbikes, and three fuel motorbikes. The fuel motorbikes are borrowed from the Outsourced motorist and are used whenever the EVs are not capable of handling the deliveries yet there are remaining unfulfilled orders. The electric vehicles are rented daily, with the rent cost per unit of electric car and electric motorbike are Rp422,222 and Rp66,417 respectively. Furthermore, the electric car can carry up to 300 kg load, while the electric motorbike is able to carry up to 80 kg load, and the fuel motorbike is able to carry up t0 110 kg load. Finally, the electricity cost per kilometer of electric car and electric motorbike are Rp131 and Rp44 respectively.

Regarding the motorists, there are two types of motorists available, namely three Internal motorists, and five Outsourced motorists. The Outsourced motorist is utilized whenever the Internal motorists are not capable of handling the deliveries yet there are remaining unfulfilled orders. The daily salary of Internal motorist and Outsourced motorist are Rp140,000 and Rp150,000 respectively. Regarding the salary of Outsourced motorist, there is an allowance pay for them if their fuel motorbike is used by Siklus, as much as Rp36,000, which intended to accommodate the fuel cost.

Furthermore, due to data limitations, several assumptions are made as the following:

a. Load capacity of fuel motorbikes are set to be the same despite differences in any attribute
b. Service time of motorist is set within 15-30 minutes
c. Events that may disturb delivery activities are ignored, e.g., rain, blocked road, etc.
d. Average speed of all vehicles is the same and constant despite the traffic.

B. *HVRPSPDTW Description*

The VRP with Simultaneous Pickup and Delivery is a variant of the VRP which covers two transportation requests for each customer, including delivery from depot to customer, and pickup from customer to depot, with both activities performed by one vehicle in a single visit. Such events occur, for instance, bus transportation of newly arriving and leaving hotel guests [5]. Furthermore, the VRP with Time Windows is a variant of VRP in which the service of customer must start within certain time interval, or later known as time window. The time window is divided into two, namely hard time windows, in which a vehicle that arrives too early must wait before performing service, and soft time windows, in which a vehicle that violates the time window is incurred a penalty cost. Meanwhile, the heterogeneous VRP is a variant of VRP in which there are vehicles with different properties, such as capacity and cost, available for distribution [7]. Therefore, with these definitions, the HVRPSPDTW can be defined as a Vehicle Routing Problem with heterogeneous vehicles available for distribution, where each allocated vehicle performs delivery and pickup activities in a single visit with respect to the customer time window.

C. *HVRPSPDTW Mathematical Model*

The HVRPSPDTW mathematical model is needed to describe the constraints faced by Siklus for its last mile deliveries, as well as the guideline for later construction of the heuristic algorithm. The HVRPSPDTW model carried out in this research is developed by adopting the VRP mathematical models carried out in [11]-[12]. The HVRPSPDTW model is defined over a graph $G = (V, A)$ where $V = \{0, 1, 2, \ldots, n\}$ is the node set and $A = \{(i, j): i, j \in V, i \neq j\}$ is the set of arcs, with node 0 is the depot, hence the customer node set is $V' = V \backslash \{0\}$. A fleet of vehicles K consisting of k types, each with mk available unit, load capacity Qk, fixed renting cost CVk, and variable routing cost cijk. Each customer $i \in V'$ have delivery load di and pickup load pi, and delivery time windows [ei, μi]. Yet, if a certain customer does not request certain delivery time windows, then the corresponding customer time window is the same as the depot time window [e0, μ0]. The total load of delivery yijk and pickup zijk, carried by each vehicle k must not exceed its load capacity. The following are notations and formulations of the mathematical model:

1) Notations

a. Indices

i, j = Index of nodes
k = Index of vehicles
e = Index of motorists

b. Parameters

V = Set of nodes
V' = Set of customer nodes
K = Set of vehicles {1,2,3...k}
E = Set of motorists {1,2...e}
m_k = Number of vehicle k available
c_{ij}^k = Traveling cost of vehicle k from node i to j
FC_k = Fixed renting cost of vehicle k
e_i = Earliest time window of node i
μ_i = Latest time window of node i
l_i^k = Arrival time of vehicle k at node i
s_i = Service time at node i
t_{ij} = Traveling time from node i to node j
Q_k = Load capacity of vehicle k
d_i = Delivery load to be unloaded at node i
p_i = Pickup load to be loaded at node i

c. Decision Variables

x_{ij}^k = 1 if vehicle k travels from node i to j, 0 otherwise
y_{ij}^k = Delivery load carried by vehicle k from node i to node j
z_{ij}^k = Pickup load carried by vehicle k from node i to node j

2) Formulations

$$\min Z = \sum_{k\in K}\sum_{i,j\in V: i\neq j} c_{ij}^k x_{ij}^k + \sum_{k\in K}\sum_{i,j\in V'} FC_k x_{0j}^k \quad (1)$$

$$FC_k = CV_k + CS_e \qquad \forall k \in K, \forall e \in E \quad (2)$$

$$\sum_{j\in V'} x_{ij}^k = 1 \qquad \forall i \in V, \forall k \in K \quad (3)$$

$$\sum_{i\in V': i\neq j} x_{ij}^k = \sum_{j\in V': i\neq j} x_{ji}^k \qquad \forall k \in K \quad (4)$$

$$\sum_{j\in V'} x_{0j}^k \leq m_k \qquad \forall k \in K \quad (5)$$

$$\sum_{i\in V'} x_{i0}^k \leq m_k \qquad \forall k \in K \quad (6)$$

$$e_i \leq l_i^k \leq u_i \qquad \forall i \in V', \forall k \in K \quad (7)$$

$$l_i^k + s_i + t_{ij} - M\left(1 - x_{ij}^k\right) \leq l_j^k \qquad \forall (i,j) \in V', \forall k \in K \quad (8)$$

$$y_{ij}^k + z_{ij}^k \leq Q_k x_{ij}^k \qquad \forall (i,j) \in V, \forall k \in K \quad (9)$$

$$z_{0j}^k = 0 \qquad \forall j \in V' \quad (10)$$

$$y_{i0}^k = 0 \qquad \forall i \in V' \quad (11)$$

$$\sum_{i\in V} y_{ij}^k - \sum_{j\in V} y_{ji}^k = d_j \qquad \forall j \in V' \quad (12)$$

$$\sum_{i\in V} z_{ij}^k - \sum_{j\in V} z_{ji}^k = p_j \qquad \forall j \in V' \quad (13)$$

$$y_{ij}^k \geq 0 \qquad \forall (i,j) \in V, i \neq j, \forall k \in K \quad (14)$$

$$z_{ij}^k \geq 0 \qquad \forall (i,j) \in V, i \neq j, \forall k \in K \quad (15)$$

$$x_{ij}^k \in \{0, 1\} \qquad \forall (i,j) \in V, i \neq j, \forall k \in K \quad (16)$$

The HVRPSPDTW model carried out in this research has an objective as presented by Eq. (1), which is to minimize the total cost which comprised of two components, namely traveling cost and fixed cost respectively. The traveling cost is calculated based on the electricity cost per kilometer for electric car and electric motorbike, with respect to the assignation of each vehicle. While for the fixed cost of renting vehicle k, it is as shown by Eq. (2), which comprised of two sub-components including the cost of renting vehicle k (CV_k) and the salary of motorist (CS_e).

Eq. (3) is the constraint of the HVRPSPDTW model, which is nessecary to ensure that each customer is visited exactly once by the allocated vehicle. Eq (4) ensures that when the allocated vehicle enters a node, it will leave the respective node. Eq. (5) and (6) ensure that the allocated vehicle which leaves from and arrives at the depot do not exceed the available units of each vehicle. Eq. (7) ensures that the vehicle must arrive at the customers' place within the time windows restriction. Eq. (8) ensures that allocated vehicle must complete service at customers' place which begins, has a service time, and travel from node i to j before performing service at another customers' place

Eq. (9) ensure that the total carried load of delivery and pickup does not exceed the load capacity of the allocated vehicle. Eq. (10) and (11) ensure that zero pickup load is carried at the beginning of the route (leave depot), and zero delivery load carried at the end of the route (back to depot). Eq. (12) and (13) ensure that the carried load of both delivery and pickup when the vehicle enters and leaves the customers' place is equal to the customers' demand. Finally, Eq. (14) and (15) represent that the carried load of vehicle is nonnegative, and Eq. (16) indicates the allocation of vehicle from node i to node j.

METHODOLOGY

A. Conceptual Model

After the mathematical model has been constructed, the Nearest Neighbour and 2-Opt heuristics are developed with respect to the mathematical model in Visual Basic Applications (VBA) Excel. Thus, the conceptual model is necessary to depict how the model should work. First, regarding the objective of the HVRPSPDTW model, which is to minimize logistics cost, a prioritization of allocating which vehicle to perform the deliveries is made. The electric vehicle is prioritized first than the fuel vehicle to align with sustainability that cycle upholds. Then, the electric motorbike is prioritized first rather than the electric car due to flexibility and cheaper renting cost. In other words, the algorithm is going to allocate electric motorbike first, and if there are still any unfulfilled order, then the electric car is allocated, and if there are still any unfulfilled order, the fuel motorbike is allocated for deliveries.

The flowchart of the conceptual model is as shown in Figure 2. The first step to solve the problem is to create the distance matrix. The distance matrix is constructed with the help of Haversine Formula to estimate the distance between two locations given the longitude and latitude [14]. Then, for each vehicle type with respect to the prioritization, the availability is tested. If available, then the Nearest Neighbor algorithm is employed to build the initial route. First thing is to set the depot as the start node. Next is to search for the nearest unvisited customer from the depot and evaluate whether visiting the respective customer violates any constraints. If not, it is visited and it is set as the next start node. Then, it is evaluated whether visiting the nearest unvisited customer is feasible, if yes, repeat the previous task, and if not, command the vehicle to go back to the depot. These procedures are done until no unfulfilled order is left, which when this happens, the Nearest Neighbor is terminated. For that, the total distance travelled by the allocated vehicles is calculated – called the initial total distance.

The process is continued by employing the 2-Opt algorithm to improve the routing solution. First is to set the number of iterations to be done. Larger iterations lead to a greater chance of getting better routing solutions as more combinations are explored yet requiring more computational time. After setting the iterations, random two nodes are swapped. Then, it is evaluated whether any constraint is violated, if yes, then move to next iteration, and if otherwise, the new total distance is checked whether it is less than the initial total distance. If yes, the initial routes are replaced with the new routes. These tasks are done until the iteration is exhausted, indicating the termination of the 2-Opt algorithm. At last, the fleet utilization (along with the motorist) and total logistics cost are recapitulated.

B. *Model Verification*

After constructing the model through VBA Excel, model verification is done to ensure the generated solution has no errors and most important, does not violate the constraints. Thus, a comparison between manual and VBA Excel routing is conducted. The model verification is done using a sample dataset as shown in Table 1.

Furthermore, the manual routing result is as shown in Table 2, and the VBA Excel routing result is shown in existing condition. As have been discussed previously, less distance travelled leads to the reduction of the travel cost in the improved condition. Furthermore, as less vehicles are needed, one TLH motorist which used to be hired, along with the allowance for fuel motorbike in the existing condition is eliminated in the improvement condition, leading to less cost incurred for the motorists. Then, as no electric car is needed in the improvement condition, there is no renting cost of electric car incurred. Yet, the renting cost of electric motorbikes is incurred greater than it used to in the existing condition, as more electric motorbikes are needed. Despite of it, the renting cost of electric motorbike is much less than the renting

Table 3. Based on the results comparison, the VBA Excel routing result builds the exact same route along with other details compared to the manual one. Most importantly, no constraints are violated. Thus, the model is verified and is eligible for further use with actual data.

C. *Model Verification*

The actual data used in this research is collected based on the March 7, 2023, order data. There are 38 customers involved, spread within the Jabodetabek area. The routing result is as shown in Table 4. Based on the result, it is found that according to the proposed model, the delivery for orders of March 7, 2023, are performed using five electric motorbikes with three Internal motorists and two Outsourced motorists, and the total distance travelled of all vehicles is 332.6 km.

RESULTS AND ANALYSIS

A. *Recapitulation of Existing and Improvement Condition*

1) Fleet and Motorist Utilization

Recapitulation of the existing and improvement condition based on the fleet and motorist utilization is conducted, as shown in Table 5. As can be seen from Table 5, it is inferred that as more electric motorbikes are utilized, there is a reduction on the utilization of electric cars and fuel motorbikes. Such an event occurs due to the vehicle prioritization as have been previously discussed. Turns out, electric motorbikes can perform the deliveries if their capacity is utilized optimally as done by the proposed model, as it travelled more.

Distance as it carries more orders. While in the existing condition, the capacity of electric motorbikes is somewhat underestimated, hence leading to the allocation of electric cars and fuel motorbikes. Furthermore, the travelled distance decreases as well in the improvement condition as shown in Table 6, as much as 150 km or 31.08%, leading to less vehicles needed to perform the deliveries.

2) Total Logistics Cost

Recapitulation of the existing and improvement condition based on the total logistics cost is conducted, as shown in Table 4. As can be seen from Table 7, there is a reduction as much as Rp484,386.75 or 31.28% in the total logistics cost in the improvement condition from the

cost of electric car, leading to a cost-saving in the total logistics cost of Siklus.

CONCLUSION AND SUGESTIONS

In this research, a Heterogeneous Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows is developed regarding improving the routing arrangement for daily last mile deliveries of PT Siklus Refil Indonesia. The order data of March 7, 2023, is used as an instance for implementing the proposed model. Based on the results, it is found that the proposed model carried out in this research has led to optimal arrangement of the vehicle for the last mile deliveries, proven by cost-saving to the total logistics cost as much as Rp484,386.75 or 31.28%. Such thing occurs due to the improvement towards the fleet utilization for last mile deliveries of Siklus, proven by maximizing the utilization of electric motorbikes hence fewer total vehicles are needed along with the reduction in less distance travelled for as much as 150 km or 31.08%. Furthermore, as this research involves the use of Electric Vehicle (EV), it is suggested for future research to put in consideration of further constraints related to the EV battery. The EV battery degrades gradually as time goes on under several driving conditions, which then affects the EV electricity consumption hence leading to, for instance, reduced driving range capacity, thus battery replacement needs to be done, especially when its capacity drops until the battery degradation limit is reached [15]. Finally, as society becomes more aware of sustainable living [16], an increase in demand of Siklus which may occur in the future should be considered, as it eventually leads to an increase in the resource needs (vehicle, motorist, etc.) to perform the last mile deliveries.

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