

# Designing Clusters of Distribution Area and Delivery Route for Maximizing the Vehicle Utilization and Minimizing the Workload Gap and Transportation Cost

**Amelia Santoso**

Department of Industrial Engineering, Faculty of Engineering  
University of Surabaya, Indonesia

Email: amelia@staff.ubaya.ac.id (*Corresponding Author*)

**Joniarto Parung**

Department of Industrial Engineering, Faculty of Engineering  
University of Surabaya, Indonesia

**Dina Natalia Prayogo**

Department of Industrial Engineering, Faculty of Engineering  
University of Surabaya, Indonesia

**Winardi**

Department of Industrial Engineering, Faculty of Engineering  
University of Surabaya, Indonesia

## ABSTRACT

This paper deals with determining vehicle routes in product distribution from a distributor to a large number of retailers in a vast distribution area. To determine the vehicle routes in a vast distribution area and a large number of retailers that have to be served causes the VRP model to become complicated. Therefore, this paper applies the cluster first-route second concept to design a distribution system in two stages. The first stage is to cluster the distribution area based on the distance between retailers. The second stage is to determine a vehicle route for each cluster using the multi-objective vehicle routing problem with time window and balanced driver workload (VRPTWBW) approach. The proposed VRPTWBW model has three objectives, i.e., (i) to minimize the number of assigned vehicles, (ii) to minimize the total delivery time, and (iii) to balance the driver workload. This second stage starts once the clusters of the distribution area are set. Contrasted with the current practice in the company, this proposed model offers the significant impacts: (i) the reduction of workload gap among driver about 29% (from 2.59 hours to 1.83 hours); (ii) the increased of vehicle utility by 44% (from 30% to 43%), and (iii) the increase savings of two-week course fees of IDR. 11 million (about 23.84%).

**Keywords:** *cluster first – route second, VRP time windows balance workload, distribution systems, workload balance*

## 1. INTRODUCTION

The distributor and retailers are intermediaries in the distribution concept that have a role to distribute the products

from the manufacturer to end customers (Chopra, 2019). A distributor can achieve high performance if the distributor delivers all retailer orders quickly (Das *et al.*, 2021) or on time with minimum total costs (Goetschalckx, 2011). Therefore, transportation is one of the critical success key factors of the distribution system to ensure the delivery is on time (Ravindran and Warsing Jr, 2013). According to Neves-Moreira *et al.* (2016), there are two types of transportation, i.e., long-haul transportation and short-haul transportation. Generally, long-haul transportation is used to deliver the products from manufacturer to distributor when short-haul transportation for delivering the products from distributor to retailers (Ghani *et al.*, 2004). This paper focuses on short-haul transportation.

According to Ghani *et al.* (2013), short-haul transportation is usually used to deliver products to many retailers in a relatively small-sized geographic area. Generally, the demand size of each retailer is less than truckload capacity so the distributor will deliver several retailers' demand using sharing shipping concepts. In sharing shipping. In the sharing shipping, the demand of multiple retailers is often delivered using LTL (less than truckload) or TL (truckload) carrier with multi stops (Cortes and Suzuki, 2020). The vehicle can load the demand of multi retailers as long as the vehicle capacity is still sufficient. Thus, the vehicle will visit several places to deliver the demand of retailers (Neves-Moreira *et al.*, 2016). Hence, the sharing shipment problem in the product distribution focuses on optimizing the vehicle route (Braekers *et al.*, 2016). The purpose of this paper is to determine the optimal routes of

assigned vehicles in distributing products from one distributor to geographically dispersed retailers.

The optimal routes of assigned vehicles to distribute products from one or multiple distributors to geographically dispersed retailers can be determined by applying the concepts of the vehicle routing problem (VRP) (Laporte *et al.*, 1988). According to Daneshzand (2011), Chen (2018) and Liao *et al.* (2017), the VRP determines a set of routes that starts and ends at the distributor minimizing the transportation cost and fulfilling the customer demands and operational constraints. As stated by Goetschalckx (2011), the simplest of the vehicle routing problems (VRP) is the traveling salesman problem (TSP) that determines the route of a single vehicle without vehicle capacity constraint. In reality, we can only load products less than or equal to the vehicle capacity. In research growth, many researchers such as Toth and Vigo (2002), Lei *et al.* (2011), and Jin *et al.* (2014) have considered the vehicle capacity constraint in the developed model called capacitated VRP (CVRP). In CVRP, a distributor delivers homogeneous products to several customers geographically separated using identical vehicles with limited capacity.

Besides CVRP, there are many kinds of VRP researched. One of other VRP variants is VRP that considers time window (Baldacci *et al.*, 2012; Braekers *et al.*, 2016; Pérez-rodríguez, and Hernández-aguirre, 2019). According to Miranda and Conceição (2016), in the vehicle routing problem with time windows (VRPTW), the vehicles are only allowed to start serving each retailer at the earliest time windows. Each vehicle has to return to the distributor before the latest time windows (El-Sherbeny, 2010). Due to the imbalanced load of each vehicle, Lee and Ueng (1999) considered the balanced load of each vehicle in the VRP model. Nevertheless, the VRP model did not consider the time window constraint. According to Mancini *et al.* (2021) and Matl *et al.* (2017), the workload can be measured by the number of customers visited by the driver or vehicle, the amount of delivered load, or the tour length. Kriticos and Ioannou (2010) developed the VRPTW model by considering the balance of loads carried by each vehicle. Even though Kriticos and Ioannou (2010) have balanced a load of vehicles carried, they cannot guarantee that the workload of each driver is balanced. If the number of consumers visited by vehicles is not the same, each vehicle has different travel times. It causes an imbalanced driver workload for each vehicle. Therefore, this paper uses the tour time length to balance driver workload.

The VRP model will be more complicated when a distributor has to distribute products to many serving retailers that are separated geographically. It needs more time to solve the complicated VRP model. Generally, a distributor has a large number of retailers, thus Cormet *et al.* (2016) suggest classifying the retailers into several clusters of the distribution area. The clustering retailers' purpose is to simplify a complicated VRP model and reduce the completion time of solving the VRP model (Rautela, *et al.*, 2019). Dondo (2007) also states that in designing a distribution system with a vast distribution area and many retailers, the cluster first-route second algorithm is an appropriate heuristic approach to minimize total distribution cost.

Hiquebran *et al.* (2010) stated there are two heuristic methods for clustering the distribution area, namely route-

first cluster second (RFCS) and cluster-first route-second (CFRS). Similar to Dondo and Cerda (2007), Cormet *et al.* (2016), and Hiquebran *et al.* (2010), this paper deals with the cluster first-route second concept to design a distribution system. After clusters are formed in the CFRS concepts, vehicle routes are determined for each cluster independent of each other.

Although Hiquebran *et al.* (2010), Dondo and Cerda (2007), and also Cormet *et al.* (2016) apply the CFRS concepts but to determine vehicle routes, they apply different VRP variants. Hiquebran *et al.* (2010) use the classic vehicle routing problem that have no constraint, while Dondo and Cerda (2007) and also Cormet *et al.* (2016) use the capacitated vehicle routing problem (CVRP) that consider vehicle capacity constraint. In reality, each retailer has a different time to be able to receive their delivered order or has a different operating time, but whether Hiquebran *et al.* (2010), Dondo and Cerda (2007), and Cormet *et al.* (2016) did not consider it in their VRP model. Pérez-rodríguez and Hernández-aguirre (2019) have considered time window (duration time to be able to receive its order) in their VRP model (VRPTW) even though they did not apply CFRS. This paper applies the CFRS and also VRPTW to obtain the optimal vehicle routes.

On the other side, each cluster has many retailers that their order should be fulfilled. It impacts the distributor who will assign several vehicles to fulfill retailers' orders in that cluster. When the distributor usually uses more than one vehicle in a cluster, it is necessary to pay attention to balance the workload among drivers in one cluster. Hiquebran (2010), Cormet *et al.* (2016), Dondo and Cerda (2007) did not consider it. Therefore, besides applying the cluster first-route second concept, this paper deals with determining vehicle routes by applying the VRP model that considers time window and a balanced driver's workload. The vehicle route will be determined to maximize the vehicle utility, balance each driver's workload, and minimize the total delivery time. According to the literature review above, the contribution of this study can be briefly shown as proposed model (see Table 1).

**Table 1** The contribution of this study

	Kriticos and Ioannou (2010)	Hiquebran <i>et al.</i> (2010)	Dondo and Cerda (2007)	Cormet <i>et al.</i> (2016)	Pérez-rodríguez and Hernández-aguirre (2019)	Proposed model
To apply CFRS		√	√	√		√
To consider Time window	√				√	√
To consider balanced workload	√ (delivery load)					√ (tour time length)

## 2. RESEARCH FRAMEWORK

The research framework is to provide a guideline conducting this research systematically. This research framework consists of two stages, the first stage is to develop

the cluster first route second algorithm, and the second one is to validate the proposed algorithm using a case study. In the first stage, there are two steps of developing the proposed cluster first – route second algorithm, as shown in **Figure 1**. The first step is to develop a clustering heuristic algorithm to form clusters of distribution. The heuristic algorithm of clustering distribution area is developed based on Comert *et al.* (2018). Meanwhile, the second step is to develop a vehicle routing problem model by considering the time window and balanced workload (VRPTWBW) for determining the vehicle route in each cluster independent of each other. The VRPTWBW model is developed based on

the model VRPTW of Pérez-Rodríguez and Hernández-Aguirre (2019).

In the second stage, the proposed clustering heuristic algorithm and vehicle routing problem model are applied using numerical data of a distributor of a multi-national company located in East Java. Using the distributor's data, we form the cluster of retailers every day. After forming clusters, we determine each cluster's vehicle route independently for each cluster. In the last part of this research, we compare the company method result (current condition) and the proposed method one.

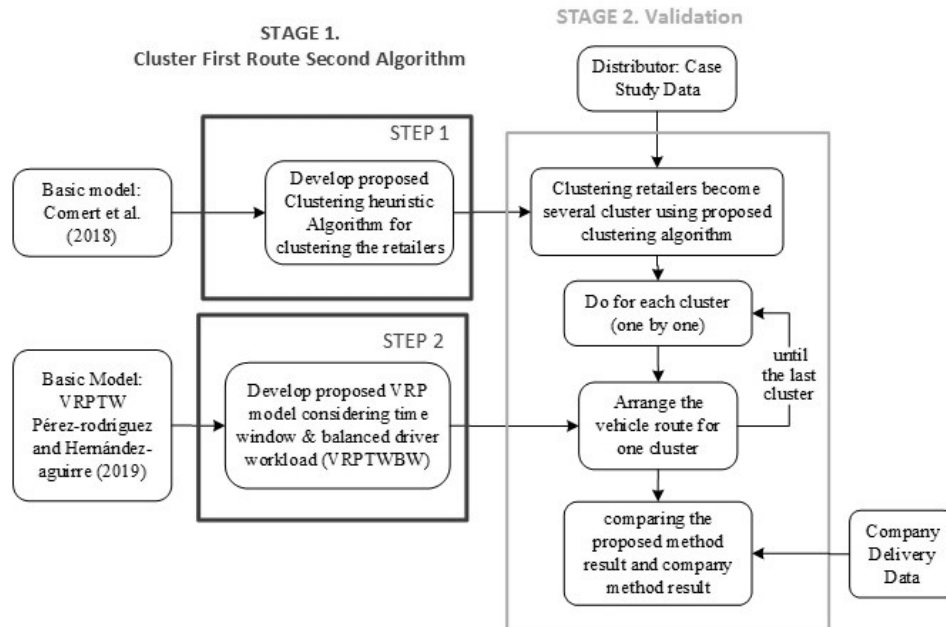


Figure 1 Research framework

### 3. DISTRIBUTION SYSTEM DESIGN

The distribution system in this paper only has one distributor. It distributes its products to a large number of retailers. The location of retailers is separated geographically in a vast distribution area. The conditions cause the VRP model used to become more complicated. Therefore, the

cluster first route second concept will be applied to design the distribution system (**Figure 2**). The first step is to develop heuristic clustering method for clustering the retailers into some clusters. The clustering retailers is to simplify the VRP model and to be able to solve the distribution problem easier. After we classify all retailers becomes several clusters, the next step we develop a vehicle routing problem (VRP) model with considering the time window and balanced driver workload (VRPTWBW).

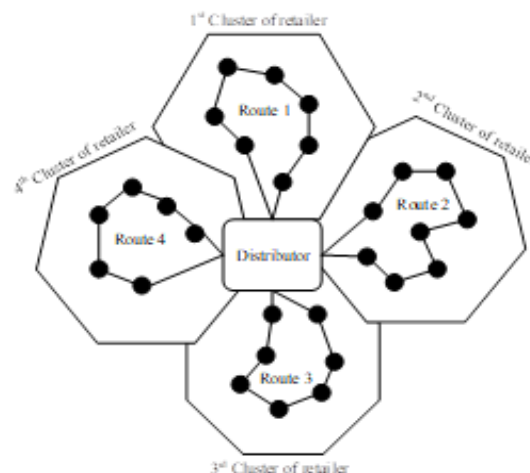


Figure 2 Illustration of retailers clustering and vehicle routing concepts

### 3.1 Retailer Clustering

In this paper, the retailer's clustering algorithm is developed based on a random clustering algorithm (Comert *et al.*, 2018). Like the random clustering algorithm (Comert *et al.*, 2018), the proposed retailers clustering algorithm aims to maximize the similarity inside the set and minimize the similarity between data sets. The similarity inside and between sets of data can be calculated from the average distance between two retailers. **Table 2** contents of the proposed retailers clustering algorithm.

**Table 2** Proposed algorithm of retailers clustering

Step	Activities
1	Collect and determine the latitude and longitude of distributor and retailers that will be served at a particular day
2	Calculate the distance between retailers and between the retailer – distributor
3	Generate cluster by determining which set retailers belong to according to the shortest distances <ol style="list-style-type: none"> <li>Choose <math>k</math> retailers having the shortest distance to the distributor</li> <li>Classify all retailers that belong to a cluster according to the shortest distance</li> </ol>
4	Check whether any retailer has a shorter distance to another cluster, adjust the cluster until no retailer having a shorter distance to another cluster

### 3.2 Vehicle Routes in Each Cluster of Distribution Area

After developing the clustering algorithm in the first step, the next step is to develop a VRP model for determining the vehicle route in each cluster. The vehicle route model is developed, taking into account the duration of each retailer's operating time, and balancing the driver's workload. The distributor distributes all products to its retailers in each cluster using its vehicles. The vehicles of each cluster are different. Each retailer has a different duration of operation time and only can be visited by a vehicle. The proposed vehicle routing problem model is developed by considering the balance of each driver workload, the minimum number of vehicles and the total delivery time. The VRPTWBW model is developed based on the VRPTW model developed by Pérez-Rodríguez and Hernández-Aguirre (2019) with the differences as shown in **Table 3**.

**Table 3** Comparison between BRPTW and proposed model

	VRPTW model of Pérez-Rodríguez and Hernández-Aguirre (2019)	Proposed model
Objective function	<ul style="list-style-type: none"> <li>Minimize total transportation distance</li> </ul>	<ul style="list-style-type: none"> <li>Minimize number of assigned vehicles</li> <li>Minimize total delivery time</li> <li>Balancing the driver's workload</li> </ul>
Constraint	Time window	Time window of retailers  The total delivery time of each vehicle has to be less than the maximum delivery duration for ensuring workload balancing of each vehicle (driver)

#### 3.2.1 Mathematical notation

The mathematical notations that are used in the developing VRPTW model that balancing all of the driver workload (VRPTWBW) consists of Index, parameters/intermediate variable, and decision variables as follows.

Index:

- $i, j$  : distribution/retailer location;  
 $i, j = 1$  is distributor and  $i, j > 1$  are retailers  
 $v$  : vehicle  
 $n$  : total number of retailers  
 $H$  : total number of vehicles

Parameters/intermediate variables:

- $K_v$  : the capacity of vehicle  $v$   
 $D_{ij}$  : the distance from distributor/retailer location  $i$  to retailer/ distributor location  $j$   
 $W_{iv}$  : the total delivery time of distributor/retailer location  $i$  using vehicle  $v$   
 $D_i$  : the demand of retailer location  $i$ ;  $i > 1$   
 $A_i$  : the earliest time that retailer  $i$  is able to receive the load;  $i > 1$   
 $B_i$  : the latest time that retailer  $i$  is able to receive the load  $i > 1$  or vehicle return to distributor ( $i=1$ )  
 $S_i$  : the service time at retailer  $i$ ;  $i > 1$   
 $T_{ij}$  : the transportation time from distributor/retailer  $i$  to distributor/retailer  $j$   
 $T_{max}$  : the maximum delivery duration

Decision variables:

- $Z_v$  = 1 if vehicle  $v$  is used and 0 otherwise  
 $X_{ijv}$  = 1 if vehicle  $v$  is used to deliver from distributor/retailer  $i$  to distributor/retailer  $j$  and 0 otherwise

#### 3.2.2 Mathematical Formulation

This proposed VRPTWBW model developed based on the VRPTW model of Pérez-rodríguez and Hernández-aguirre (2019) has three objectives. The first objective is to minimize the number of assigned vehicles to deliver the product from a distributor to many retailers ( $TV$ ). It is formulated by vehicle capacity multiply by  $Z_v$ .  $K_v$  is a parameter for vehicle capacity  $v$  that is different for every vehicle. Meanwhile,  $Z_v$  is a binary variable, a decision variable to indicate whether the vehicle is being used. Thus, when we combine the first objective function and constraint (6), it will maximize the vehicle utility. The second objective is to minimize the total delivery time ( $TT$ ). The total delivery time is the accumulation of service time and transportation time of all assigned vehicles. The third objective is to balance the workload of all drivers ( $TN$ ).  $TN$  is the workload of all

drivers driving an assigned vehicle, so the total working time maximum multiply by  $Z_v$ . The objective functions are as follows.

$$\text{Minimize } TV = \sum_{v=1}^H K_v Z_v \quad (1)$$

$$\text{Minimize } TT = \sum_{v=1}^H W_{1v} \quad (2)$$

$$\text{Minimize } TN = (\sum_{v=1}^H Z_v) T_{max} \quad (3)$$

Several constraints are used to ensure the suitability of the proposed VRPTWBW model and the condition of distribution systems. Constraint (4) ensures that each retailer can only be served by one vehicle. This constraint does not apply to vehicles start from the distributor, so the constraint formula is applied for  $i > 1$ . Meanwhile, each vehicle that arrived from another retailer or distributor is guaranteed by constraint (5) will continue to visit another retailer return to the distributor. The total loads of a vehicle have to be less than its capacity is stated by constraint (6).

$$\sum_{j=1}^n \sum_{v=1}^H X_{ijv} = 1; \forall i, i \neq 1, j \neq i \quad (4)$$

$$\sum_{i=1}^n X_{ijv} - \sum_{i=1}^n X_{jiv} = 0 \quad ; \forall j, v \quad j \geq 1 \quad (5)$$

$$\sum_{i=1}^n \sum_{j=1}^n D_i X_{ijv} \leq K_v Z_v \quad ; \forall v \quad (6)$$

Constraint (7) and (8) guarantee that a vehicle always starts from the distributor and returns to the distributor after completing product delivery, where  $i, j = 1$  is distributor, otherwise retailers.

$$\sum_{i=2}^n X_{i1v} = Z_v \quad ; \forall v \quad (7)$$

$$\sum_{j=2}^n X_{1jv} = Z_v \quad ; \forall v \quad (8)$$

Constraint (9) deals with time window concepts, where a vehicle can only serve retailers during their working or operation time. Operation or working time of retailer  $i$  starts at time  $A_i$  and ends at time  $B_i$ . Constraint (10) states the total time needed in the shipping process until vehicle  $v$  arrive at retailer  $j$  is summation of time at vehicle  $v$  comes at retailer  $i$  and transportation time from retailer  $i$  to retailer  $j$ .  $M$  is a big number. Meanwhile, if vehicle  $v$  starts from distributor  $i=1$ , so there is no service time at distributor. Therefore, constraint (11) state the total delivery time at retailer  $j$  when the vehicle  $v$  starts from distributor equal to the transportation time from distributor to retailer  $j$ . Constraint (13) ensures each vehicle has to be returned to the distributor before the distributor closed. Distributor will be closed at  $B_1$ . Constraint (14) ensures each vehicle's total delivery time has to be less than the maximum delivery duration for ensuring workload balancing of each vehicle.

$$A_i \sum_{j=1}^n X_{ijv} \leq W_{iv} \leq B_i \sum_{j=1}^n X_{ijv} \quad ; \forall i, v \quad (9)$$

$$W_{jv} \geq W_{iv} + S_i + T_{ij} - M(1 - X_{ijv}) \quad ; \forall i, j, v \quad i > 1, j > 1 \quad (10)$$

$$W_{jv} \geq T_{1j} Z_v - M(1 - X_{1jv}) \quad ; \forall j, v \quad j > 1 \quad (11)$$

$$W_{1v} \geq W_{iv} + S_i + T_{i1} Z_v - M(1 - X_{i1v}) \quad ; \forall i, v, i > 1 \quad (12)$$

$$W_{1v} \leq B_1 Z_v \quad ; \forall v \quad (13)$$

$$W_{1v} \leq T_{max} \quad ; \forall v \quad (14)$$

Constraint (15) and (16) deal with the binary decision variables

$$Z_v \in 0,1 \quad ; \forall v \quad (15)$$

$$X_{ijv} \in 0,1 \quad ; \forall i, j, v \quad (16)$$

## 4. RESULTS AND DISCUSSION

The proposed clustering heuristic algorithms and VRPTWBW model are applied in one of the multi-national company distributors located in East Java, Indonesia. The distributor distributes various products to a large number of various types of retailers. The distributor classifies its retailers into three types (segments) based on service time duration, and the number of orders. The first type consists of traditional market, retailer and store, the second one is minimarkets, and the last one is supermarkets. **Table 4** shows operating time and service time of each type of retailers.

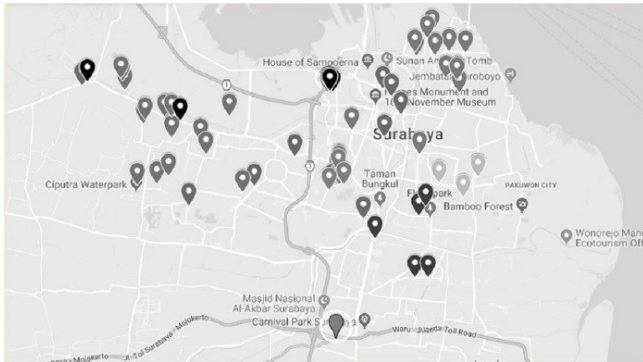
**Table 4** Operating and service time of each type of retailers

Types		Operating time	Service time
1	Traditional market, retailer, store	08.00 AM – 13.00 PM	15 minutes
2	Minimarket	09.00 AM – 14.00 PM	25 minutes
3	Supermarket	09.00 AM – 14.00 PM	0.7 minutes/0.1465m <sup>3</sup>

The distributor has 21 vehicles for delivering products to 646 retailers. The twenty-one vehicles can be classified into three types of vehicles. Two vehicles (type 1) have a capacity of 12m<sup>3</sup> per vehicle, and two vehicles (type 2) have a capacity of 6m<sup>3</sup> per vehicle. Meanwhile, 17 vehicles (type 3) have a capacity of 3m<sup>3</sup> per vehicle. Delivering products has to be completed within the duration of retailer operation time. The distributor conducts the clustering and route arrangement every day.

Currently, the distributor forms distribution areas (clusters) based on the retailer type (top priority) and region. With this current clustering method, two retailers of various types are sent in two different vehicles even though their locations are very close. All drivers only receive a list of retailers that must be served, so drivers make their route arrangements without considering the retailers' operation hours. It causes drivers to visit the retailer twice or wait for the store to open to send retailer orders so shipping is inefficient. The current clustering and routing method causes an imbalanced workload of each driver and low vehicle utility. **Figure 3** shows the result of clustering on March 5th, 2019.





**Figure 3** Clusters of distribution area using the current practice

As discussed above, the proposed method consists of two steps, i.e., the clustering method and the routing arrangement. The proposed clustering method is applying to data of retailer's order to the distributor in one day, such as on March 5<sup>th</sup>, 2019. The result of applying the proposed clustering methods is that all retailers that have an order to distributor are classified into three clusters, as shown in **Figure 4**. The detail of the district area in each cluster as shown in **Table 5**.



**Figure 4** Clusters of distribution area using the proposed method

**Table 5** The district area of members in each cluster

Cluster	Distribution area
1	Genteng district, Pabean Cantian district, Kenjeran district and Tambak Sari district
2	Mulyorejo district, Gubeng district, Sawahan district, Wonokromo district and Tenggilis Mejoyo district
3	Tandes district, Dukuh Pakis district, Sambikerep district, Pakal district and Benowo district

For every day, we form the clusters of distribution area using the proposed clustering algorithm. After forming the distribution area cluster on a particular day, we have to arrange routes in each cluster one by one by implementing the proposed VRPTWBW model. **Table 6** shows an example of the outcome of the proposed VRPTWBW model at each cluster on March 5<sup>th</sup>, 2019. We get the number of assigned vehicles and vehicle routes for each cluster every day as well as the number of the served retailer. There are indirect results, i.e., the total loading that a vehicle delivers in one route as well as the vehicle utility, the total delivery distance, and total delivery time ( $W_{ij}$ ). With 1 litre of fuel (bio solar), a vehicle can travel an average distance of 6.34 km. The price of 1 litre fuel is amount IDR 5,150, so that the cost of fuel is IDR 812.5 per km. Therefore, we can calculate the total fuel cost for every vehicle on 5/3/2019, as shown in **Table 6**.

The workload of each vehicle driver is measured from their total delivery time. For every day, after we have the delivery time of each vehicle, we can get the fastest and the longest delivery time. Based on the fastest and the longest delivery time on a day, we can calculate each vehicle driver's workload gap. **Table 7** compares of the delivery time gap, which also means the workload gap between the current practice and the proposed method.

**Table 6.** The outcome of the proposed VRPTWBW model at each cluster on March 5<sup>th</sup>, 2019

Cluster	Number of Retailer	Number of Assigned Vehicle	Vehicle Number:	Route	Number Served Retailer	Total Loading (m3)	Total Delivery Distance (km)	Total Delivery Time (minutes)	Total Fuel Cost (IDR)
1	28	3	1	L1-L206-L177-L8-L227-L484-L127-L464-L119-L616-L1	9	2.35	48	321	38,722.94
			2	L1-L150-L483-L223-L119-L255-L550-L410-L433-L203-L1	9	2.54	45	276	36,890.75
			3	L1-L149-L60-L528-L345-L531-L198-L548-L526-L629-L589-L1	10	1.46	54	318	43,901.00
2	20	2	4	L1-L458-L204-L452-L328-L181-L175-L449-L360-L627-L257-L642-L1	11	0.56	66	311	53,847.63
			5	L1-L518-L213-L130-L522-L314-L362-L344-L418-L415-L1	9	1.30	68	338	55,235.38
3	14	1	6	L1-L438-L299-L417-L200-L634-L461-L447-L474-L129-L39-L195-L432-L412-L520-L1	14	0.99	70	376	57,096.81

**Table 7** Comparing the gap of workload

Date (year 2019)	Gap of workload						Reduction (%)
	Current Practice			Proposed			
	The fastest time (hours)	The longest time (hours)	Gap (hours)	The fastest time (hours)	The longest time (hours)	Gap (hours)	
March 5 <sup>th</sup> ,	4.83	6.85	2.02	4.6	6.27	1.67	17%
March 6 <sup>th</sup>	4.08	6.83	2.75	4.25	6.35	2.1	24%
March 8 <sup>th</sup>	4.92	6.92	2	5.67	7.02	1.35	33%
March 9 <sup>th</sup>	3.67	6.33	2.67	5.24	6.22	0.98	63%
March 11 <sup>th</sup>	4	7.17	3.17	3.82	5.66	1.84	42%
March 12 <sup>th</sup>	4.33	6.25	1.92	4.73	6.21	1.48	23%
March 13 <sup>th</sup>	4.67	7.33	2.67	4.95	5.91	0.96	64%
March 14 <sup>th</sup>	4.67	7.67	3	4.09	6.83	2.75	8%
March 15 <sup>th</sup>	4.5	7.87	3.37	4	7.27	3.26	3%
March 16 <sup>th</sup>	4.17	6.5	2.33	4.28	6.18	1.9	18%
Average			2.59			1.83	29%

**Table 7** shows that the proposed clustering algorithm and VRPTWBW model can reduce the average driver workload gap by around 29%. The company routing methods result in the average driver workload amount of 2.59 hours, while the proposed VRPTWBW results in 1.83 hours. It means the proposed clustering algorithm and routing method results in a more balanced workload.

Although the average workload of drivers using the proposed method is 1.83, if we analyze the driver workload gap per day in more detail, the driver workload gap is measured by the difference of the longest and fastest delivery time. The driver workload gap ranges from 0.96 hours to 3.26 hours. There were two days where the workload gap was more than 2.5 hours or 50% greater than the average. If we look again at **Table 5**, each vehicle's total delivery time is not in line with the vehicle's load carried (vehicle utility) but in line with the total delivery distance. Thus, we can conclude that the total vehicle delivery distance is not only influenced by the number of retailers served by a vehicle but also the retail distribution area (**Table 5**). Therefore, future research needs to be carried out by developing the clustering retailer algorithm that considers the retailers' distance and the number of served retailers, so the driver workload is more balanced.

Vehicle utility is calculated from the ratio of total loading of the vehicle and the vehicle capacity. **Table 8** shows the average vehicle utility per day using both the company method and the proposed method. The average vehicle utility using current practice is 30%, while the average vehicle utility using the proposed method becomes 43%. The proposed methods consisted of the clustering algorithm, and the VRPTWBW model can increase vehicle utility by around 44%. Although the increase in vehicle utility using the proposed method is around 44%, the average vehicle utility is still low. We pay attention to the average total delivery time per day ranging between 4 hours until 6

hours. It is still able to make an improvement to increase vehicle utility in the future.

**Table 8** Comparing the vehicle utility

Date (year 2019)	Average vehicle utility		Increment (%)
	Current practice	Proposed	
March 5 <sup>th</sup> ,	37%	51%	38%
March 6 <sup>th</sup>	30%	51%	67%
March 8 <sup>th</sup>	23%	35%	50%
March 9 <sup>th</sup>	37%	53%	42%
March 11 <sup>th</sup>	15%	22%	50%
March 12 <sup>th</sup>	43%	49%	14%
March 13 <sup>th</sup>	33%	49%	50%
March 14 <sup>th</sup>	21%	31%	50%
March 15 <sup>th</sup>	23%	34%	50%
March 16 <sup>th</sup>	35%	51%	46%
Average	30%	43%	44%

**Table 9** shows the comparison between the total transportation cost of current practice and the proposed method and the cost saving. The total transportation cost consists of the total fuel cost and the fixed cost of the vehicle. Transportation cost is driven by assigned vehicles. In contrast, the assigned vehicle is driven by fulfilling retailer order (demand) that have to be delivered, vehicle utility, time window (range of retailer operating time), and the balanced driver workload. Due to the reduced number of assigned vehicles, the proposed methods can reduce the transportation cost by around 23.84%. In this paper, reducing the transportation cost is the impact of minimizing the assigned vehicles. For the future study, the transportation cost can be considered to become the objective function.

**Table 9** Comparing the total transportation cost and the cost saving

Date (year 2019)	Current			Proposed			(IDR)	Cost saving
	Type vehicle		Total cost	Type Vehicle		Total cost		(%)
	C	B		C	B			
March 5 <sup>th</sup> ,	7	1	4,890,221.50	6	0	3,553,816.50	1,336,405.00	27.33%
March 6 <sup>th</sup>	6	2	4,915,134.50	6	0	3,560,687.81	1,354,446.69	27.56%
March 8 <sup>th</sup>	7	1	4,869,096.50	6	0	3,575,758.88	1,293,337.63	26.56%
March 9 <sup>th</sup>	8	1	5,265,908.50	7	0	4,134,827.13	1,131,081.38	21.48%
March 11 <sup>th</sup>	7	1	4,782,971.50	6	0	3,532,596.44	1,250,375.06	26.14%
March 12 <sup>th</sup>	6	1	4,186,284.50	7	0	4,148,382.06	37,902.44	0.91%
March 13 <sup>th</sup>	7	1	4,895,909.00	6	0	3,558,353.50	1,337,555.50	27.32%
March 14 <sup>th</sup>	7	1	4,838,221.50	6	0	3,537,369.88	1,300,851.63	26.89%
March 15 <sup>th</sup>	7	1	4,730,159.00	6	0	3,547,487.13	1,182,671.88	25.00%
March 16 <sup>th</sup>	7	1	4,813,846.50	6	0	3,549,463.13	1,264,383.38	26.27%
Total			48,187,753.00			36,698,742.44	11,489,010.56	23.84%

## 5. CONCLUSION

The proposed method is developed based on the concepts of cluster first - route second. Therefore, the proposed method consists of two steps, and the first is to develop clustering algorithm based on the distance of retailers for classifying all retailers into several clusters. The second step is to develop VRPTWBW model for determining the vehicle routes in each cluster formed in step one.

The results of applying the proposed methods in a distributor are as follow. There are three clusters formed, the proposed method can reduce the average of driver workload gap around 29%, increase the average of vehicle utility around 44% and reduce the total transportation cost around 23.84%.

Although the proposed methods have increased the distribution performance, there are some potentials for future research. It is to develop the clustering retailer algorithm that considers the retailers' distance and the number of served retailers in each cluster to establish a more balanced workload. We will also consider the minimum utility vehicle used to improve vehicle utility and to consider transportation cost to become an objective function.

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**Amelia Santoso** is an Associate Professor of Industrial Engineering at the University of Surabaya, Indonesia. She received her Master's and Ph.D. degree in Industrial Engineering from Institut Teknologi Bandung (ITB), Bandung, Indonesia, and her Bachelor's degree in Statistics from Institut Teknologi Sepuluh Nopember (ITS) Surabaya, Indonesia. Her research interests are production, distribution, transportation systems; supply chain engineering; and humanitarian logistics in disaster operations and management.

**Joniarto Parung** is currently a Professor of Supply Chain Management at the Department of Industrial Engineering, University of Surabaya, Indonesia. He received his Ph.D. from Design Manufacture and Engineering Management, University of Strathclyde, Glasgow, UK. His research interests include supply chain management, smart supply chain, sustainable supply chain, and humanitarian logistics.

**Dina Natalia** is an Associate Professor of Industrial Engineering at the University of Surabaya, Indonesia. She received her Master's degree in Industrial Engineering from the National University of Singapore and her Bachelor's degree in Physics Engineering from Institut Teknologi Sepuluh Nopember (ITS) Surabaya, Indonesia. Her research interests are in container terminal operations, supply chain engineering, and disaster operations and management.

**Winardi** is an industrial practitioner, and he obtained a bachelor's degree in Industrial Engineering from the University of Surabaya, Indonesia. His research interests include transportation and distribution systems, Vehicle routing optimization, and modeling.

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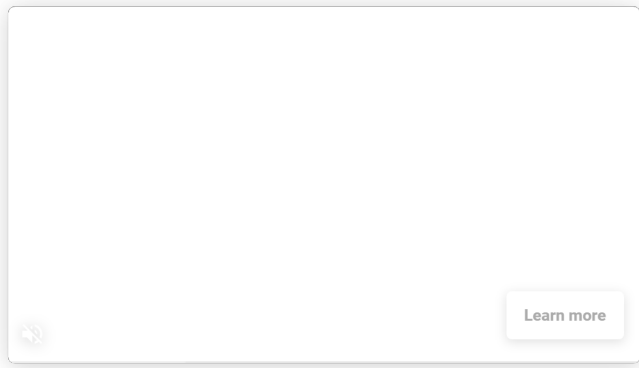
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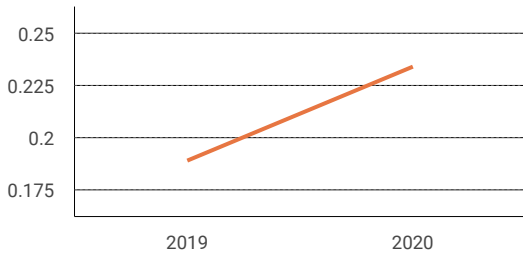
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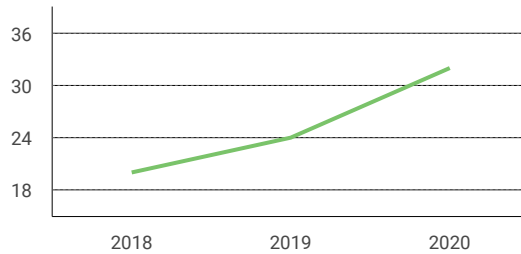
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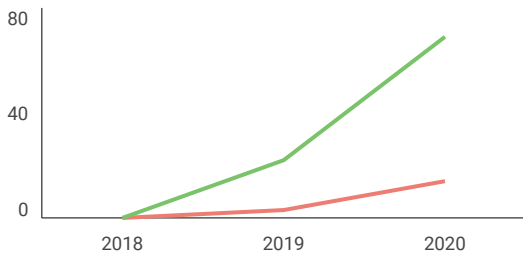
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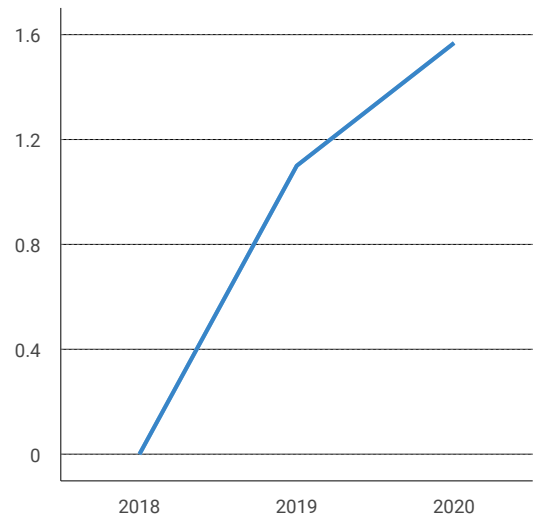
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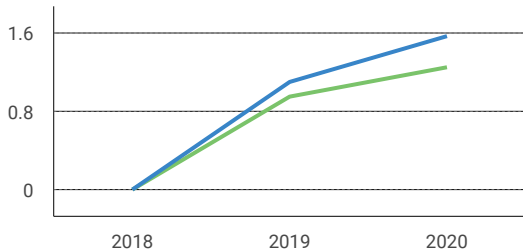
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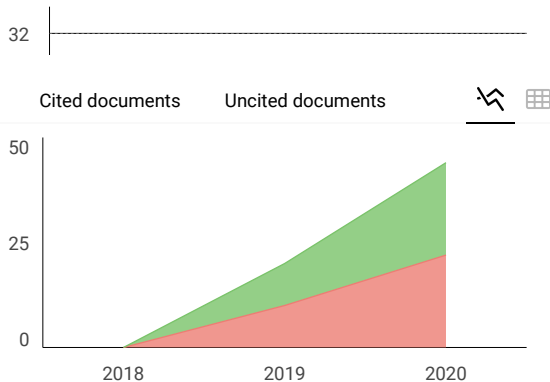
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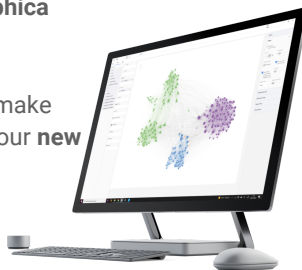
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S **Sugeng** 4 weeks ago

Sorry to ask? Do all journals have to be in English? How do I create an account?

reply



**Melanie Ortiz** 4 weeks ago

SCImago Team

Dear Sugeng,  
Thank you for contacting us.  
Unfortunately, we cannot help you with your request, we suggest you visit the journal's homepage or contact the journals editorial staffs , so they could inform you more deeply.  
Best Regards, SCImago Team

R **Ramakrishna** 7 months ago

Dear Admin,

Greetings of the Day!

Can you please update whether this journal is still listed in SCOPUS or not?

reply



**Melanie Ortiz** 7 months ago

SCImago Team

Dear Ramakrishna,

Thank you very much for your comment.

All the metadata have been provided by Scopus /Elsevier in their last update sent to SCImago, including the Coverage's period data. The SJR for 2019 was released on 11 June 2020. We suggest you consult the Scopus database directly to see the current index status as SJR is a static image of Scopus, which is changing every day.

Best Regards, SCImago Team

A **ANUSHA A** 11 months ago

could you tell me that the coverage mentioned above says 2019 but we are in 2020 now can we still publish paper.

reply



**Melanie Ortiz** 11 months ago

SCImago Team

Dear Anusha,

Thank you for contacting us. The Coverage data shown above indicates the period in which the journal has been indexed in Scopus database. For further information about the journal's submission guidelines, please visit the journal's website or contact the editorial staff.

Best Regards, SCImago Team

S **Sigit Susanto** 12 months ago

How long usually takes time from submitted to accepted of a Journal?what about the cost of publication?thanks very much

reply



**Melanie Ortiz** 12 months ago

SCImago Team

Dear Sigit,

thank you for contacting us.

Unfortunately, we cannot help you with your request, we suggest you visit the journal's homepage or contact the journal's editorial staff , so they could inform you more deeply.

Best Regards, SCImago Team

T **Trinoto** 1 year ago

Dear Scimago admin,

could you please send the homepage of this journal.

thanks

reply



**Melanie Ortiz** 12 months ago

SCImago Team

Dear Trinoto, thank you for contacting us. We will proceed to update the journal's website information as soon as possible. Greetings from Spain and thank you for using the SCImago products, SCImago Team

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Horatio (Satire 1,1,106)