Optimum Route Design for Paper Waste Transportation using Sequential Insertion: Waste Bank in Grobogan

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Abstract

Increasing the volume of waste will be a source of problems if it is not managed properly. The scattered waste requires challenges in the optimal collecting system and route design. Large volumes of waste paper are more valuable when sold to manufacturers. This study intends to design an optimal route for transporting waste. The model used is capacitated vehicle routing problem with a waste bank as an intermediate facility. Problem-solving is done by using the Sequential Insertion algorithm with the help of Mahlab software. The object of research was carried out on the transportation of paper waste at a waste bank in Grobogan. The transportation of waste from the waste bank has not been systematic, where the schedule has not been regular and has not considered the distance between the waste banks, the amount of waste and the capacity of the fleet. Transportation costs are sometimes more expensive than the profit margins from selling waste paper. This study has designed an optimal route with 2 scenarios. The first scenario is based on the current depot. Scenario 2 by designing depots in three regions using a Gravity Model. The research recommends the optimal route using scenario 2.

Keywords
Optimal Route, Vehicle Routing Problem, Sequential Insertion, Paper Waste, and Waste Bank.

1. Introduction
Waste and natural resource management should aim to reduce resource consumption and protect the environment and human health (Van Ewijk et al. 2018, Hartini et al. 2021, Hartini et al. 2020). Paper is one of the most important necessities in the world and becomes one of the most wasteful after being used. Paper waste comes from households, schools and offices. Paper production and consumption generates solid waste including industrial waste (206 Mt) and post-use waste (363 Mt) (Van Ewijk et al. 2018). Recycling paper waste means saving trees, energy, oil and water. Recycling paper can help governments tackle waste. Indonesia's paper consumption per capita is around 27 kg / person / year, which is equivalent to 11 reams / 11 trees. The discarded paper will produce methane which is worse for global warming than carbon dioxide. Saving 1 ton of paper by recycling will save 13 trees, 400 liters of oil, 4100 Kwh of electricity and 31,780 liters of water (Arfah 2017). Efforts to maintain the value of products, materials and resources in the economy as long as possible so that waste disposal can be minimized is a circular economy approach (Charonis 2013) which has become one of Indonesia's agendas until 2025 (Ministry of Environment and Forestry 2017).

In practice, paper waste occurs at scattered points, such as from schools, offices and communities. Thus, recycling paper waste requires an optimal collection point and route to collect it so that the utilization of paper waste can also be realized (Vinyes et al. 2013). The problem of paper waste includes operational technical aspects, institutional, financing and retribution, regulation/law, and community participation (Soemargono 1977). Meanwhile, operational and maintenance costs for waste transportation become a heavy burden due to the volume of waste that must be transported and the distance from the waste source to the TPA (Wahyono 2001).

The Ministry of Environment developed the Waste Bank as an initial collection point before recycling. Grobogan Regency has 213 waste banks at the village, school, and even office levels. The district government continues to encourage all villages to have waste banks. This study intends to design a route for transporting paper waste as the largest waste in a waste bank using the Vehicle Routing Problem (VRP) model. The research objective is to determine the optimal route by considering the location of the depot, the waste bank and the capacity of the transport vehicles used so as to minimize transportation costs.

2. Literature Review

2.1. Sequential Insertion

Determining the optimal route to minimize costs based on the total distance or travel time with the capacity limitation of the vehicle is known as the vehicle routing problem (Pillay and Qu 2018, Bernal et al. 2017, Du and Yi 2013). Several characteristics of VRP problems (Osaba et al. 2020) include vehicle trips starting and ending at the depot, there are a number of places that all have to be visited and fulfilled the request exactly once, if the vehicle capacity is used up and cannot serve the next point, the vehicle can return to the depot to meet the vehicle capacity and serve the next point. The Sequence Insertion method is popularly used in VRP because it is fast in providing solutions, easy to implement, and easy to develop to deal with vehicle scheduling route problems. Informing a route solution, there are two kinds of routes, namely combining existing routes with savings criteria and trying sequentially which customers must be served with the cost of insertion criteria.

Several studies on sequential insertion have been carried out by several previous researchers. Vecchi et al. (2016) solve the problem of optimal solid waste collection truck routes. The results lead to a reduction in the distance travelled by trucks, cost savings, and a reduction in carbon dioxide emissions. Arvianto et al. (2019) used sequential insertion algorithms to obtain optimal solutions and computer simulation techniques to determine the ability of solutions to address probabilistic demands. Arvianto et al. (2015) also develop a Vehicle Routing Problem (VRP) model with a heterogeneous vehicle fleet size and mix vehicle routing (HFSMVR) using a sequential insertion approach. This model is applied to solve the problem of fuel oil distribution in East Nusa Tenggara. The Vehicle Routing Problem (VRP) and sequential insertion algorithm model for delivering products to customers were carried out by Nugrahani et al. (2018) by implementing this method were able to shorten the time and mileage, so as to save 75% of distribution costs.

2.2. Center of Gravity

The Center of Gravity method is a mathematical technique for finding the location of the depot that minimizes transportation costs. This method generally gives an important value in facility location where it only relates cost to distance (Kudláčková and Chocholáč 2017). This method assumes that the cost is directly proportional to the distance and the volume of goods transported. The formula used to calculate the Center of Gravity method can be seen as follows (Heizer and Render 2014).

$$\bar{X} = \frac{\sum x_i d_i}{\sum d_i} \quad (1)$$

$$\bar{Y} = \frac{\sum y_i d_i}{\sum d_i} \quad (2)$$

Where:
$d_i =$ volume in unit i
$x_i =$ The x-coordinate of unit i
$y_i =$ y coordinate point on unit i
$\bar{X}, \bar{Y} =$ Coordinate point for facility location

3. Methods

3.1 Model

This research uses primary and secondary data. Secondary data is in the form of data on the number of units and locations of waste banks in the Grobogan Regency. The location of the truck station as a depot, waste bank and waste collection warehouse is determined by using Google Maps. The goal of modelling is to minimize the total travel distance of transporting waste.

Objective function:

$$\text{Min } Z = \sum_{i\in v} \sum_{j\in v} \sum_{t\in T} \sum_{k\in K} c_{i,j} X^t_{i,j,k} \quad (3)$$

Decision variable:

$$X^t_{i,j,k} = \begin{cases} 1, if\ there\ is\ a\ trip\ from\ i\ to\ j\ on\ t\ on\ route\ k \\ 0, other \end{cases}$$

$$Y_{i,j,k}^{t} = \begin{cases} 1, if\ there\ is\ a\ load\ on\ i\ that\ is\ on\ trip\ t\ on\ route\ k \\ 0, if\ other \end{cases}$$

Notation:
$V = \{0, 1, \dots, n, n+1\} = The\ set\ of\ all\ nodes\ or\ waste\ banks, where\ 0\ represents\ the\ depot\ and$
= The set of all nodes or waste banks, where 0 represents the depot and n + 1 represents the intermediate facility
C = {1,2,…, n} = the collection of waste banks served,
E = ((i, j) | i, j∈V, i ≠ J} = Set of directed sides,
T = {1,2, ..., t} = The set number of trips,
K = {1,2, ..., k} = The set of routes represented by vehicles with identical capacities,
T = Total distance traveled,
Cij = Distance from point i to j,
$X_{i,j,k}^{t}$ = Whether or not there is a trip from point i to point j on trip t,
d_i = capacity of waste in waste bank i,
Q = Load capacity on one route = 5.1 tones,

$$Q = \sum_{1\in C} d_i Y_{i,k}^{t} \tag{4}$$

$$Tij = \frac{Cij}{v} = \frac{Cij}{40\ km/hour} \tag{5}$$

Tij = Travel time from i to j,
v = 40 km/hour =speed rate of truck,
$S_k^t = Service\ time\ (loading - unloading)$ on trip *t*, Route *k*

$$S_k^t = \sum_{i=1}^{C} d_i Y_{i,k}^{t} \tag{6}$$

Constraint:

- Each route to serve customers starts from the depot
$$\sum_{j\in c} x_{0.j,k}^{1} = 1 \forall k \in K \tag{7}$$
- Each Waste Bank is served exactly once on one route
$$\sum_{j\in v} \sum_{t\in T} \sum_{k\in K} X_{i,j,k}^{t} = 1\ \forall j \in C, j \neq i \tag{8}$$
$$\sum_{j\in v} \sum_{t\in T} \sum_{k\in K} X_{i,j,k}^{t} = 1\ \forall i \in C, i \neq j \tag{9}$$
- The load capacity in the truck on a trip is the accumulation of the capacity of the waste bank that has been served.
$$Q \geq \sum_{1\in C} Q_{max,}\ \ d_i Y_{i,k}^{t} \forall t, \forall k \in K \tag{10}$$
- Trucks go to the depot for unloading
$$\sum_{i\in C} X_{i,0,k}^{t} = 1\ \ \forall t \in T, \forall k \in K \tag{11}$$
- The route completion time is calculated from the total travel time of the truck including the loading-unloading time *:*
$$CT = \sum_{i\in v} \sum_{j\in v} \sum_{t\in T} T_{i,j} X_{i,j,k}^{t} + \sum_{t\in T}^{t=t} S_k^t, \forall k \in K \tag{12}$$
- The route completion time does not exceed the maximum time allotted for the route
$$CT \leq T_{maks} \tag{13}$$
$$CT \leq 420\ menit \tag{14}$$
- Routes can be started from the depot on the following trips if the maximum time is sufficient
$$\sum_{i\in C} X_{i,j,k}^{t} = 1\ \ \forall t \in T, \forall k \in K \tag{15}$$
- Each route ends at an empty (unloaded) depot
$$\sum_{i\in C} X_{i,0,k}^{t} = 1\ \ \ \ \forall t \in T, \forall k \in K \tag{16}$$
- The decision variable used is a binary number
$$X_{i,j,k}^{t} \in \{0,1\},\ \forall k \in K, \forall i,j \in V, i \neq j. \tag{17}$$
$$Y_{i,j,k}^{t} \in \{0,1\},\ \forall k \in K, \forall i,j \in V, i \neq j \tag{18}$$

3.2 Depot determination
Scenario 1, depot according to current conditions Scenario 1 uses a depot at the Environmental Service of Grobogan Regency. When the load on the vehicle has reached the maximum limit, the vehicle will go to the depot for unloading. The route illustration can be seen in Figure 1.

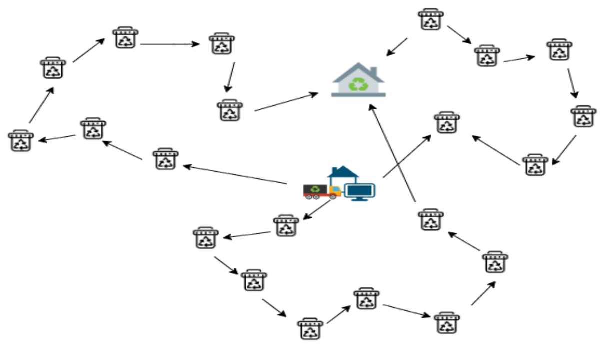

Figure 1. The route illustration of scenario 1

Scenario 2, adding a depot in each region by using the Center of Gravity Model. Waste collection starts from the main depot, when the vehicle load has reached the maximum limit, the vehicle will go to the regional depot. The depot is determined using equations 1 and 2. The route illustration can be seen in Figure 2.

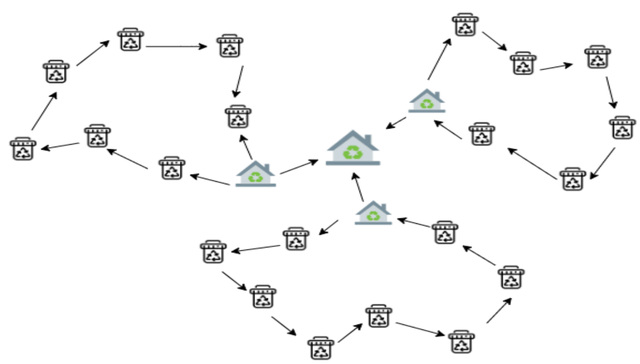

Figure 2. The route illustration of scenario 2.

4. Data Collection
There are 213 waste bank units in Grobogan Regency spread over 9 sub-districts. Waste bank locations are spread out in residential areas which are usually at least one per village, Islamic boarding schools, schools and strategic locations to reach. The Environment Agency is actively providing guidance and direction regarding waste management so as to increase public awareness in implementing the 3Rs (reduce, reuse and recycle) from the source. The distribution of Waste Banks in Grobogan can be seen in Figure 3.

Route formation is formed in each sub-district. The distance data between waste banks is obtained from Google Maps with the assumption that the distance from i to j is the same as the distance from j to i. The unit of distance used is km. Table 1 is an example of the distance matrix between waste bank units for Klambu sub-district, 0 is a depot, namely the Environmental Service of Grobogan Regency, and numbers 1, 2, 3, ,…, 12 are waste bank points.

Completion time (CT) is obtained from travel time and loading-unloading time (LU). The unit of time is minutes. Travel time is calculated based on the distance traveled and the speed of the vehicle. Assuming the average speed of the fleet is 40 km/hour, the value of travel time between waste banks will be obtained.

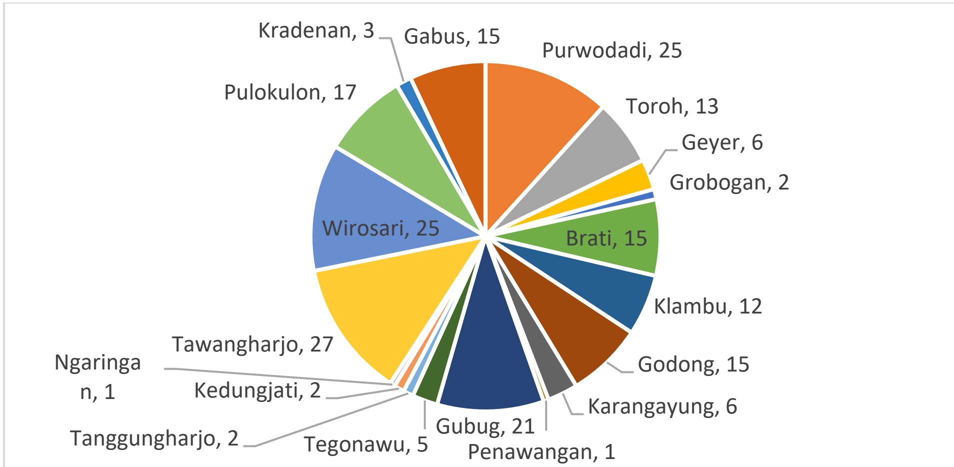

Figure 3. The distribution of waste banks in Grobogan

Table 1. The distance matrix between waste bank units for Klambu sub-district (km)

No	Village	The name of waste bank	0	1	2	3	4	5	6	7	8	9	10	11	12
0	DLH (Depot)			22.3	15.1	17.8	24.5	25.4	24.6	24.5	24.2	24.5	25.2	26.7	26.9
1	Klambu Krajan	Sekar Wangi	22.3		8.2	6.7	3.5	4.4	3.8	3.8	1.9	3	3.7	5.7	5.9
2	Selojari	Arto Moro	15.1	8.2		2.7	10.6	11.6	11	10.6	10.3	10.7	11.3	17.7	13
3	Taruman	Yasa Wangsa	17.8	6.7	2.7		9.1	10.1	9.5	9.1	8.8	10.1	9.8	11.4	11.5
4	Menawan	Menawan Hati 1	24.5	3.5	10.6	9.1		1.2	0.55	1.4	4.6	5.6	5.4	3.6	3.8
5	Menawan pesantren	Menawan Hati 2	25.4	4.4	11.6	10.1	1.2		0.9	2.4	5.5	5.9	6.3	4.6	4.7
6	Menawan sambung	Menawan Hati 3	24.6	3.8	11	9.5	0.55	0.9		1.7	4.9	5.3	5.7	3.9	4.1
7	Menawan kayumas	Menawan Hati 4	24.5	3.8	10.6	9.1	1.4	2.4	1.7		4.6	4.9	4.1	2.4	2.5
8	South Terkesi	Melati	24.2	1.9	10.3	8.8	4.6	5.5	4.9	4.6		0.75	2.1	6.8	3.5
9	North Terkesi	Dahlia	24.5	3	10.7	10.1	5.6	5.9	5.3	4.9	0.75		1.7	3.6	2.7
10	Terkesi beran	Kenanga	25.2	3.7	11.3	9.8	5.4	6.3	5.7	4.1	2.1	1.7		2.5	1.6
11	East Terkesi brakas	Teratai	26.7	5.7	17.7	11.4	3.6	4.6	3.9	2.4	6.8	3.6	2.5		0.9
12	Terkesi goleng	Mawar	26.9	5.9	13	11.5	3.8	4.7	4.1	2.5	3.5	2.7	1.6	0.9	

5. Results and Discussion

5.1 Collection Route using Sequential Insertion

Completion of the transportation model using the Sequential Insertion Method is done using MATLAB software. Scenario 1 produces 11 routes while scenario 2 produces 4 routes. Table 2 is a recapitulation of the routes in scenario 1 using existing depot. The route details in scenario 1 are described in Table 3.

Table 2. Paper waste collection route in scenario 1

No	Distric	Cycle Time	Quantity	Distance
1	Purwodadi	223	4.783	73
2	Toroh and Geyer	229	3.635	95
3	Brati and Grobogan	173	3.252	65
4	Klambu	155	2.295	67
5	Godong	172	2.870	69
6	Karangayung, Penawangan,	352	1.722	208
7	Gubug, Tegowanu,	558	5.356	287
8	Tawangharjo	291	5.165	112
9	Wirosari, Ngaringan	375	4.974	171
10	Pulokulon, Kradenan	269	3.826	119
11	Gabus	290	2.870	148

Table 3. Details of paper waste collection route in scenario 1

Route	District	Collecting Route
1	Purwodadi	Depot-Purwodadi – Danyang – Kalongan – Purwodadi– Kuripan - Ngembak – Genuksuran – Ngraji – Kedungrejo – Nglobar – Nambuhan – Cingkrong – Pulorejo – Putat – Candisari - Depot
2	Toroh and Geyer	Depot- Krangganharjo- Sugihan – Pilang – Kantong – Sindurejo – Tambirejo – Boloh – Dimoro – Geyer – Sobo – Kalangbancar – Depot
3	Brati and Grobogan	Depot- Menduran– Jangkungharjo- Temon – Lemah Putih – Karangsari – Grobogan – Kronggen - Depot
4	Klambu	Depot- Selojari- Taruman – Klambu Krajan – Terkesi - Menawan – East Terkesi Brakas - Terata - Depot
5	Godang	Depot- Bringin – Sumberagung – Godong – Klampok – Ketitang – Rajek Tegalrejo – Rajek – Harjowinangun - Depot
6	Karangrayung, Penawangan, Kedungjati	Depot - Penawangan- Dempel- Termas- Putatnganten- Temurejo - Ketro- Dumpel Krajan – Wates - Panimbo- Depot
7	Gubug, Tegowanu, Tanggungharjo	Depot- Trisari – Gelapan – Saban – Ketro – Panadaran – Trisari Kuniran – Kuwaron – Pranten – Jatipecaron – Tambakan – Baturagung – East Gubug – Kunjeng – Milir – Kemiri – Gubug – Gebangan – Kejawan – Tanggirejo – Sukorejo – Sugihmanik – Padang- Pepe- Tlogomulyo - Depot
8	Tawangharjo	Depot – Mayahan Kayen – Jono – Ledokdawan – Selo - Tarub – Godan - Depot
9	Wirosari, Ngaringan	Depot- Gedangan– Tambak Selo - Kunden – Kalirejo – Kropak – Dapurno – Mojorebo – Tambakrejo – Tambakselo– Dokoro – Karangasem – Ngaringan Belor – Tegalrejo – Depot
10	Pulokulon, Kradenan	Depot – Pulokulon – Tuko – Grabagan – Kuwu – Mlowokarangtalun – Bago - Depot
11	Gabus	Depot- Pandanharum - Tunggulrejo – Banjarejo – Bendoharjo – Pelem – Tlogotirto – Pandanharum – Gabus – Nglinduk – Keyongan - Depot

In scenario 2, the cluster formed is the first step in establishing the location and number of depots using the Center Gravity method. Table 4 is the location point of the intermediately facility for each region and its coverage area. Table 5 is the collection route in scenario 2.

Table 4. Scenario 2: Location point of intermediately facility and coverage area

Area	Latitude Coordinate	Longitude Coordinate	Coverage Area
Central	7° 5'25.137"S	110° 52'50.635"E	Purwodadi (25), Grobogan (2), Gayer (6), Toroh (13), Brati (15), Klambu (12)
West	7° 3'46.663"S	110° 42'35.054"E	Districts of Godong (15), Penawangan (1), Karangrayung (6), Gubug (21), Tegowanu (5), Responsiharjo (2), Kedungjati (2).
East	7° 5'49.568"S	111° 4'32.873"E	Districts of Tawangharjo (27), Ngaringan (1), Wirosari (25), Pulokulon (17), Kradenan (3), Gabus (15).

Table 5. Paper waste collection route in scenario 2

Region	Route	Cycle Time	Quantity	Distance
Middle	Route 1	204,35	5100	303,3
	Route 2	299,15	5100	
	Route 3	286,34	3764,9	
West	Route 1	248,15	5100	259,9
	Route 2	375,75	4847,6	
East	Route 1	251	5100	498
	Route 2	261,41	5100	
	Route 3	344,15	5100	
	Route 4	294,79	1534,4	

The transportation routes design for each region is carried out using the same method. Details of the waste bank in scenario 2 are described in Table 6.

Table 6. Details of paper waste collection route in scenario 2

Area	Route	
Middle	Route 1	Depot (Kuripan) – Kuripan - Ngembak - Genuksuran - Danyang - Purwodadi - Kalongan - Ngraji - Tambirejo - Sugihan - Candisari - Cingkrong - Pulorejo - Putat - Menduran - Depot (Kuripan)
	Route 2	Depot (Kuripan)-Menduran Pedak- Lemah Putih - Ds. Temon - Jangkungharjo - Grobogan Pancan - Kedungrejo - Nglobar - Nambuhan - Boloh-Pilang-Katong-Ds Dimoro–Sindurejo-Ds Sobo-Kalangbancar- Depot (Kuripan)
	Route 3	Depot (Kuripan)-Karangsari-Kronggen-Selojari-Taruman-Klambu Krajan-Terkesi-Menawan-Grobogan pucang-kalangbancar - Depot (Kuripan)
West	Route 1	Depot (Saban)-Saban-Milir-Desa Kemiri-Gubug-Desa Kuwaron-Trasari-Gelapan-Temurejo-Putatnganten- Termas-Dempel-Ketro-Panadaran-Wates-Kunjeng-Pranten-Jatipecaron-Tambakan-Baturagung-Pepe-Depot
	Route 2	Depot (Saban)-Harjowinangun-Rajek Tegalrejo-Ketitang-Godong-Klampok-Bringin-Gundi-Sumberagung- Dempel Kraja - Penawangan-Dusun Rajek-Tanggirejo-Gebangan-Kejawan-Pepe-Tlogomulyo-Sukorejo- Sugihmanik-Padang-Panimbo-Depot (Saban)
East	Route 1	Depot (Kunden) -Kalirejo - Kropak - Tuko-Pulokulon Kembangan-Pulokulon - Tarub trisik - Tarub Srondong -Tarub - Gedangan Ngaronan - Tambak – Tambak rejo - Depot
	Route 2	Depot - Mojorebo – Tambak Selo Jati - Karangasem - Godan - Selo - Jono - Depot
	Route 3	Depot - Tegalrejo - Dokoro - Godan Pojok - Jono Jangkung - Mayahan - Godan Nanjungan - Godan Sedah - Godan Karanggetas - Pojok Pulokulon - Tuko Ben Berkah - Tunggulrejo - Pandanharum - Gabus - Pandanharum - Tlogotirto - Pelem - Bendoharjo - Depot
	Route 4	Depot - Mlowokarangtalun - Bago - Keyongan - Nglinduk - Bendoharjo - Banjarejo - Ngaringan Belor - Karangrejo - Ledokdawan - Depot

5.2 Discussion

5.2.1 The comparison between scenario 1 and scenario 2: operational performance and cost

The route design in scenario 1 formed 11 routes with 11 trips. The transportation of waste paper in each unit of the waste bank can be done for 7 days in a month. Scenario 2 transportation routes have 9 routes consisting of 3 routes for the Central region, 2 routes for the West Region and 4 routes for the East region. In this case, the transportation of waste paper for all waste banks can be completed in 6 days a month.

The difference between scenario 1 and 2 lies in the number of depots. Scenario 1 only uses 1 depot for all districts. While scenario 2 uses 3 depots with three areas determined by the gravity model. The existence of depots in each region makes transportation distances shorter. This benefits the managers because the distance they have to travel to collect waste to each unit of the waste bank is shorter. A shorter range will shorten transport time. In the end, if the transportation distance is shorter, it will save fuel costs. A comparison of operational performance and cost can be seen in Table 7.

Table 7. Comparison of operational performance

No	Indicator	Unit	Scenario 1	Scenario 2
1	The number of Bank	Unit	213	213
2	The number of routes	Route	13	9
3	The number of depots	Depot	1	3
4	Total distance	Km	1.411,23	1.058,64
5	The number of vehicles	Unit	1	1
6	Time consumption	Minute	3.085,668	2.558,124
7	Fuel consumption	Liter	141,12	105,86
8	Fuel cost	IDR	1.079.596,65	809.859,60

The transportation of paper waste by buying or renting a fleet can affect the profit margins obtained by the waste bank manager. Operational costs incurred include truck costs, drivers and fuel costs. The comparison of costs incurred when using bought and rented trucks is described in the Table 8 and Table 9.

Table 8. Comparison of cost performance between scenario 1 and 2 (buy a truck)

Component	Unit	Unit cost (IDR)	Scenario 1		Scenario 2	
			Volume	Cost (IDR)	Volume	Cost (IDR)
Depreciation of vehicle	Unit	3.366.666	1	3.366.666	1	3.366.666
Maintenance of vehicle		977	1	977	1	977
Operator	Man-month	1.830.000	2	3.660.000	2	3.660.000
Fuel	Liter	7.650	141,123	1.079.596	105,86	809.859
Total				8.107.234		7.837.472

Table 9. Comparison of cost performance between scenario 1 and 2 (rent a truck)

Component	Unit	Unit cost (IDR)	Scenario 1		Scenario 2	
			Volume	Cost (IDR)	Volume	Cost (IDR)
Rent cost	Unit-days	350.000	7	2.450.000	6	2.100.000
Operator	Man-days	150.000	7	1.050.000	6	900.000
Fuel	Liter	7.650	141,123	1.079.591	105,86	809.829
Total				4.579.591		3.809.829

5.2.2 Sensitivity Analysis

The parameter analyzed is the volume of waste paper taken on the route to the destination of the unit i waste bank (d_i). The d_i parameter affects the number of fleets because the service time is affected by the amount of paper waste in the waste bank unit. Sensitivity analysis was carried out by increasing the volume of waste by 5%, 10%, and 20%. This is done to see changes in the resulting solution when there is a change in one parameter. The results of the comparison can be seen in Table 10.

The increase in the volume of waste can change the destination route formed and the value of the destination function. The difference in the value of the objective function is also caused by the difference in the number of vehicle routes and the completion time for each route. With the increase in waste in each unit served, it is directly proportional to the number of routes formed.

Table 10. Comparison due to changes in waste volume

	Scenario 1				Scenario 2			
	Change	**5%**	**10%**	**20%**	**Change**	**5%**	**10%**	**20%**
The number of route	13	14	14	14	9	9	10	11
Total Distance (Km)	1411,24	1482,24	1411,94	1569,50	1058,64	1063,84	1037,49	1093,57
Completion Time (Minute)	3085,67	3241,36	3487,05	3106,85	2558,12	2615,12	2719,10	2688,81

6. Conclusion

The design of paper waste transportation routes with sequential insertion resulted in 2 scenarios, namely based on sub-districts and regional grouping. The recommended transportation route is scenario 2 with the distribution of transportation in the West, Central, and East regions. The addition of regional-based depots can reduce the total distance to 352.59 km, reduce the number of routes, fuel requirements and operational costs. Analysis of operational costs in 2 scenarios concludes that renting a fleet is more economical than buying.

This study has several limitations. Loading and unloading time and travel time are deterministic so it will be more representative if the model is developed by considering time variations. The development of the application for determining the shortest route based on real-time waste will facilitate more optimal management. Applications can help develop routes based on waste data in real-time.

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