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Optimalization of Management System of Municipal Solid Waste Transportation (Case Study: Jakarta, Indonesia)

Nova Ulhasanah*, Muhamad Hisyam Dhiya Ulhaq, Nurulbaiti Listyendah Zahra
Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina,
Jl. Teuku Nyak Arief, RT. 7/RW. 8, Simprug, Kec. Keby. Lama, South Jakarta City, Special Capital Region of Jakarta, 12220
*Correspondence: nova.u@universitaspertamina.ac.id

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Abstrak

Jakarta Barat memiliki jarak terjauh dalam proses pengangkutan sampah dibandingkan dengan kota lainnya di DKI Jakarta. Jumlah penduduk dan sampah yang selalu meningkat setiap tahunnya dapat menyebabkan wilayah Jakarta Barat mengalami masalah baru dalam sistem pengangkutan sampah. Pada kondisi eksisting, terdapat 68 dari 195 truk di 174 tempat penampungan sementara yang tidak memiliki volume sampah yang dapat langsung mengisi kontainer dalam 1 hari pengumpulan sampah. Truk-truk tersebut harus menunggu pengumpulan lebih lanjut hingga kontainer truk terisi penuh. Selain itu, terdapat 31 truk yang mengangkut sampah di tempat penampungan sementara dengan jumlah sampah yang melebihi kapasitas truk. Hal ini dapat menyebabkan sampah mengendap di tempat penampungan sementara atau truk akan mengangkut lebih banyak sampah dari kapasitasnya. Oleh karena itu, tujuan yang ingin dicapai dalam perancangan ini adalah mengoptimalkan sistem pengangkutan sampah di Jakarta Barat dengan SCS dari segi teknis dan ekonomis. Setelah mengevaluasi kondisi eksisting dan menganalisis alternatif pilihan yang dibuat, ditemukan bahwa sistem dapat dioptimalkan menggunakan Sistem Kontainer Terangkut (HCS) dan Sistem Kontainer Stasioner (SCS) dengan 1 dan 2 rit transportasi per hari. Jumlah truk dapat dikurangi dari 195 menjadi 73, dengan 70 truk melakukan 2 rit per hari dan 3 truk melakukan 1 rit per hari. Jumlah pengemudi dapat dikurangi dari 195 menjadi 143 pengemudi, dengan setiap pengemudi hanya bekerja untuk 1 rit. Terdapat penurunan biaya bahan bakar solar per bulan dari Rp873.158.589 menjadi Rp853.612.500 dan dapat mengurangi upah pengemudi dari Rp711.366.825 menjadi Rp521.669.005 setiap bulannya. Total biaya transportasi untuk bahan bakar solar dan upah karyawan dalam satu bulan adalah Rp1.375.281.505 atau Rp209.243.909 lebih murah daripada kondisi eksisting.

Kata kunci: Transportasi, HCS, SCS, Sampah, Jakarta Barat

Abstract

West Jakarta has the farthest distance for the waste transportation process compared to other municipalities in DKI Jakarta. The number of population and garbage which always increases every year can make the West Jakarta area experience new problems with the waste transportation system. In existing conditions, there are 68 out of 195 trucks in 174 temporary trash shelter that do not have a volume of waste that can immediately fill containers in 1 day of garbage collection. The trucks have to wait for further collection until the truck containers are filled. In addition, there are 31 trucks which transports waste in temporary waste shelter with a generated amount that exceeds the capacity of the truck. This can cause the waste to settle at the temporary trash shelter or the truck will carry more waste than it's capacity. Therefore, the goal to be achieved in this design is to optimizing the waste transportation system in West Jakarta with SCS from a technical and economic point of view. After evaluating the existing conditions and analyzing the alternative choices made, it was found that the system can be optimized using the Hauled Container System (HCS) and the Stationary Container System (SCS) with 1 and 2 transportation rit / day. The number of trucks could be reduced from 195 to 73, with 70 trucks doing 2 rit / day and 3 trucks doing 1 rit / day. The number of drivers can be reduced from 195 to 143 drivers, with each driver only working for 1 rit. There was a decrease in the cost of diesel fuel / month from Rp873,158,589 to Rp853,612,500 and could reduce the driver's wages from Rp711,366,825 to Rp521,669,005 each month. The total transportation cost for diesel fuel and employee wages in a month is Rp1,375,281,505 or Rp209,243,909 cheaper than the existing conditions.

Keywords: Transportation, HCS, SCS, Waste, West Jakarta

Introduction

Linear with population growth increasing by 1.43% every year, the city of Jakarta produces waste of 7,702 tons/day, and always increases by an average of 600 tons/year (BPS, 2019). The city of West Jakarta alone contributes 41,555 tonnes/month of waste to the landfill. West Jakarta is the administrative city of Jakarta Province which is located farthest from the Bantargebang landfill. Therefore, this city faces the most problems transporting municipal waste to the landfill (DLH DKI Jakarta, 2015, 2018a; UPST, 2019; Suryawan and Lee, 2023a,b; 2024a, b; Suhardono et al., 2024).

Waste transportation is a waste management sub-system which aims to carry waste from sources or temporary waste disposal sites to the landfill

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(Damanhuri & Padmi, 2015). Jakarta Province has the only landfill in Bantargebang, Bekasi. The waste transportation system is the most expensive part compared to other parts in the city's waste management system, reaching 70% of the total planned budget (Ambariski, 2016). The high cost of transporting waste is a major problem faced by developing countries (Ambariski, 2016). Another problem that can occur due to the transportation system is the comfort and aesthetics of the temporary waste collection area which occurs due to the accumulation of untransported waste, delays in waste transportation which will create nests for disease vectors, and excess truck capacity in the waste transportation process (Ambariski, 2016).

Currently, West Jakarta's waste transportation system uses a Hauled Container System (HCS). HCS is a waste transportation system where the transportation container can be moved and transported to a processing site (Damanhuri & Padmi, 2015). In this system, if the waste collection process can immediately fill the container capacity in one go, the truck can immediately go to transport the waste to the landfill. However, this can also make the truck transportation process less efficient and disrupt the aesthetic value of the area. In existing conditions in West Jakarta, there are 68 out of 195 trucks in 174 TPS that do not have the volume of waste that can immediately fill the container in 1 day of waste collection. The truck also has to wait for the next collection until the truck container is filled. Apart from that, there were 31 trucks transporting waste at the temporary dump site with the amount generated exceeding the capacity of the trucks. This can cause waste to settle in Temporary dump site or trucks can carry waste that exceeds its capacity. Therefore, it is necessary to optimize the waste transportation system in the West Jakarta area.

Optimizing the transportation system in West Jakarta is important to increase the effectiveness and efficiency of the system, optimize the number of trucks used, optimize the number of drivers and fuel costs in the waste transportation system. Apart from HCS, there are other waste transportation systems, namely the Stationary Container System (SCS) or fixed container system. SCS is a waste transportation system whose collection containers are static (Damanhuri & Padmi, 2015). This system will reduce the waiting time for transportation from each TPS caused by the truck's container capacity not being fulfilled, because the truck will move to the next TPS to fulfill the truck's container capacity. This research aims to design an optimal waste transportation system in West Jakarta, in terms of technical and economic aspects. SCS is the recommended system for analysis.

Methods

This research began by conducting a literature study regarding waste problems in West Jakarta. Primary data (in the form of field surveys for existing conditions) and secondary (in the form of the number of Temporary Dump Site and trucks operating in West Jakarta, related regulations, previous studies, and other supporting data from various sources) are processed using the Vehicle Routing Problem method to obtain the most efficient routes and number of trucks. From the 2 proposed scenarios, the best scenario will be selected using the Decision Matrix (Khandani, 2005).

Vehicle Routing Problem (VRP) is a method for finding the most efficient way to use several vehicles that have to travel to reach several places to drop off and/or pick up customers (Hendrawan, 2007). The term customer is used to indicate a stop to drop off and/or pick up people/goods. Each customer must be served by one vehicle. Determining vehicle pairs with customers is carried out by considering the capacity of the vehicle in one transport, this is done in order to obtain the minimum travel costs.

The West Jakarta area was taken as the boundary because it has the furthest distance from the Bantargebang landfill compared to other areas of Jakarta (DLH DKI Jakarta, 2015). West Jakarta also has 41,555 tons of waste transported to the Bantargebang TPST in a month (DLH DKI Jakarta, 2018b). The economic aspect is seen from the use of the least petrol and the fewest number of drivers. In calculating economic aspects, a savings algorithm is used to estimate the costs incurred by each vehicle. This algorithm is designed to solve problems on routes and capacities that have been determined according to the goods to be transported (Salipadang, 2011). The technical aspect looks at compliance with regulations, the effectiveness of the system to be designed, and the number of trucks.

Results

1. Existing Condition of Solid Waste Management in Jakarta Province

Based on Governor Regulation no. 284 of 2016, the DKI Jakarta Environmental Service (DLH) is the implementing element for administering government affairs in the environmental sector. In carrying out its duties, DLH Jakarta Province is assisted by the city

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administrative environmental department, which has the task of carrying out environmental protection and management activities; cleanliness management, supervision and control of environmental and cleanliness impacts; management of cleanliness and hazardous waste; community participation and increasing legal compliance; as well as environmental and cleanliness infrastructure and facilities in the administrative city. In the West Jakarta area, DLH Jakarta Province is assisted by the West Jakarta City Administration Environmental Service.

The waste management system in Jakarta Province begins with the process of containing waste originating from waste sources. Then, the waste thrown into the container will be collected by local cleaning staff to be delivered to the Temporary Dump Site. Then, the process of moving the waste into the garbage truck which is already at the Temporary Dump Site is carried out. The waste will be transported to the Bantargebang landfill for further processing. Finally, after leaving the Bantargebang landfill, the garbage truck will return to the initial Temporary Dump Site to wait for the next transportation cycle.

In the 1987 Master Plan, Jakarta Province planned to create 2 landfill, namely in Ciangir, Tangerang and in Bantargebang, Bekasi (DLH DKI Jakarta, 2015). The Ciangir landfill is planned to accommodate waste from the West Jakarta and South Jakarta areas, while the Bantargebang landfill is planned to accommodate waste from the North Jakarta, Central Jakarta and East Jakarta areas (DLH DKI Jakarta, 2015). Apart from that, in the 1987 Master Plan it was planned to create a large and small Intermediate Transition System (ITS) which is useful as a means of transferring from smaller transport equipment to larger transport equipment from each Temporary Dump Site in Jakarta before being transported to Ciangir and Bantargebang TPST, so that waste transportation costs can be streamlined (DLH, 2015). In reality, the Ciangir landfill cannot operate due to changes to the Tangerang Regency General Spatial Planning Plan, which changed the designation of the landfill area to a residential area and was rejected by local residents (DLH, 2015). Therefore, until now all waste from DKI Jakarta has only been managed at the Bantargebang landfill.

The waste transportation process in West Jakarta use several types of trucks (DLH DKI Jakarta, 2018a). namely tow truck (volume 24m3, fuel (diesel) 40 liter/rit/vehicle), large typers (volume 22 m3, fuel (diesel) 40 liter/rit/vehicle), small typers (volume 14m3, fuel 35 liter/rit/vehicle), large arm roll (volume 22m3, fuel 40 liter/rit/vehicle), small arm rolls (volume 14 m3, fuel 35 liter/rit/vehicle), large compactor (volume 18m3, fuel 40 liter/rit/vehicle), small compactors (volume 12m3, fuel 35 liter/rit/vehicle), and dump trucks (volume 22m3, fuel 40 liter/rit/vehicle). The trucks can be seen in Figure 1.

Based on Governor's Instruction no. 160 of 2015, there are 2 routes that can be passed by the garbage trucks, namely via the Transyogi Route (Cibubur) and West Bekasi. On the Transyogi route, trucks can use this route from 09.00 in the morning until 03.00 in the morning. Meanwhile, for the West Bekasi route, trucks can use this route from 21.00 to 05.00 in the morning. In this transportation process, garbage trucks cannot pass through toll roads.

In transportation activities, each garbage truck has 1 driver who drives the truck. Truck drivers' wages are determined through Governor Decree No. 1887 of 2017, namely the wage standard for Individual Other Service Providers is determined by multiplying the cost coefficient value by the Provincial Minimum Wage for the current year. The coefficient value set for truck drivers is 1.00. In 2018, Jakarta Province's Provincial Minimum Wage was IDR 3,648,035 (Kompas, 2018).

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(a)

(b)

(c)

Figure 1. (a) Typer Truck, (b) Arm Roll Truck, (c) Compactor Truck

2. Evaluation toward Existing Condition

The waste transportation system in Jakarta Province is carried out using the Hauled Container System (HCS) method. In this method, trucks will transport waste that has filled the truck's capacity from Temporary Dump Site (TDS) A, then go to Bantargebang landfill via the Tranyogi or West Bekasi routes to carry out the unloading process. Waste in the active landfill zone, after which the truck will return to TDS A to wait until the next waste collection time or wait until the truck's container capacity is filled. Garbage that has been collected by local officers from waste sources will be collected at the TDS. The West Jakarta region has 187 TDS in 8 sub-districts, however, there are 13 TDS that do not have data on average daily waste generation. Therefore, the number of TDS included in this design is only 174 TPS (DLH DKI Jakarta, 2018a). Table 1 dan Figure 2 can show detail transportation route from Kamal Sub-Distric.

Table 1. Waste Transportation Detail from Kamal Sub-Distric to Bantargebang Landfill

Route	Truck Type	Volume of Waste Transported (m3)	Pencent Occupancy (%)	Waiting Time (Day)	Track	Distance (Km)	Travel Duration	Diesel Cost (IDR/day)
1-x-1	Small Typer (14m3)	6	43	2	Transyogi	131	4 hour 29 minutes	Rp90,125.00
2-x-2	Big Tiper (22m3)	20	91	1	Transyogi	133	4 hours 34 minutes	Rp206,000.00
3-x-3	Big Typer (22m3)	20	91	1	Transyogi	133	4 hours 35 minutes	Rp206,000.00
4-x-4	Small Typer (14m3)	10	71	1	Transyogi	132	4 hours 32 minutes	Rp180,250.00

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Note:
1: Market in RW02, 2: TDS in RW08, 3: TDS in RW03, 4: TDS in RW05, X: Bantargebang Landfill

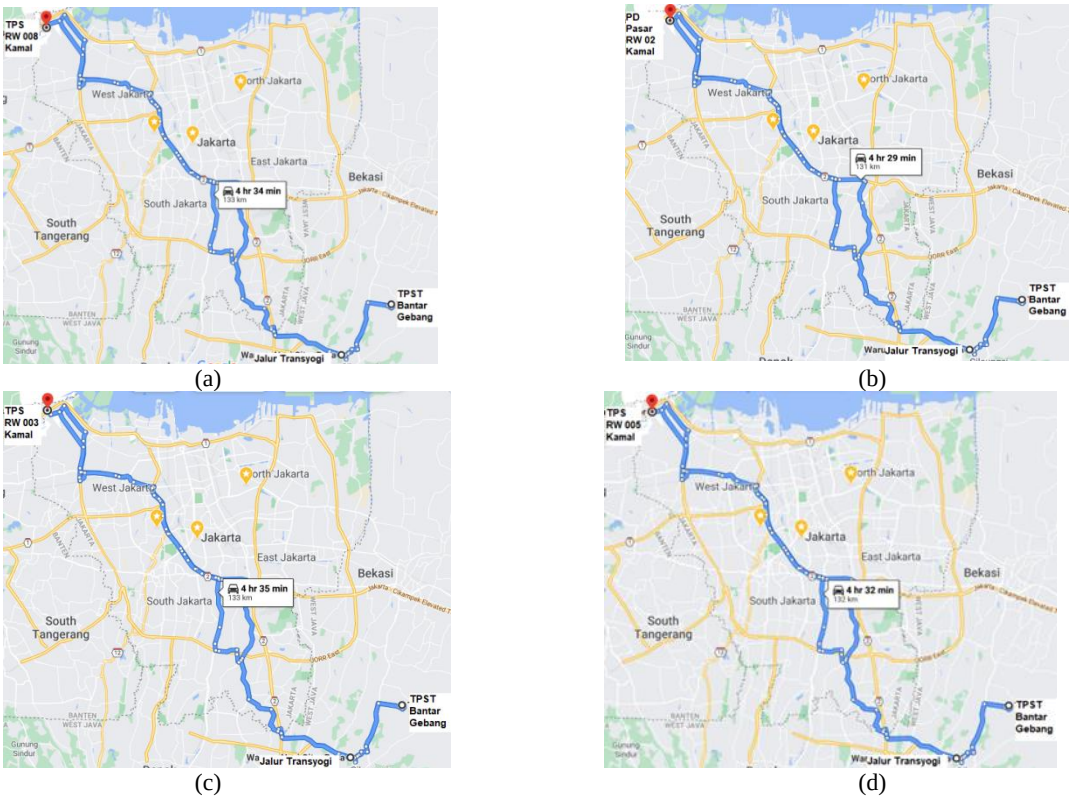

Figure 2. (a) 1-x-1, (b) 2-x-2, (c) 3-x-3, (d) 4-x-4

Under these conditions, of the 195 trucks at 174 TDS, there are 68 trucks that are not immediately filled to capacity every day and have to wait for further waste collection at the TDS. This violates Public Works Government Regulation no. 3/PRT/M/2013 which contains transport vehicles that must be able to maximize the transport capacity used. The average waiting time is 2 days. Apart from that, 31 trucks cannot accommodate all the daily waste produced because the amount of waste exceeds the capacity of the trucks, this causes waste to settle in TDS or trucks can transport waste that exceeds its capacity. In existing conditions, the large typer truck being the most widely used truck (69 units), follow by small typer truck (45 units), big arm roll truck (34 units), small arm roll truck (25 units), big compactor truck (12 units), tow truck (6 units), small compactor truck (3 units), and the least used truck being the large dump truck, namely 1 unit. Apart from that, not every waste at a TDS will only be transported by 1 truck, it can be transported using more than 1 trash truck, depending on the amount of waste collected at that TDS.

Each truck has a different departure time, because it has different waste collection time. So, waste transportation activities are via 2 available routes, namely 171 trucks via the Transyogi route and 24 trucks via West Bekasi. Of the 171 trucks passing through the Transyogi Route, there were 27 trucks whose departure times did not comply with Jakarta Governor's Instruction No. 160 of 2015, because it departs between 05.00-09.00 in the morning (The maximum departure schedule for garbage trucks from TDS to the landfill is 05.00 am). In addition, the average duration time and distance used to travel from the initial TDS to the Bantargebang landfill and back again to the initial

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TDS with travel conditions without traffic jams, namely 3 hours 39 minutes and 107,769 km.

Each truck has 1 driver who drives the dump truck. So the total wages that will be paid each month is IDR 711,366,825. In term of fuel cost, the total cost of diesel fuel needed each day is IDR 29,105,286 (873,158,589/month). Therefore, total cost is IDR 1,584,525,414. Based on those evaluations, there are some mismanagement of the system that is needed to be redesign, not only for the better system, but also for operational cost savings of government. In this paper, 2 scenarios were designed to propose better route of waste transportation. Those scenarios then were compared to decide the best system to be suggested.

2. Scenario 1

In existing conditions, not all TDS locations can meet truck capacity with 1 day of waste collection time, therefore 2 alternatives have been created, one of which will be chosen to overcome this. In alternative 1, the waste transportation system will be planned to be supplemented with a fixed container system method (Stationary Collection System), namely trucks that have not yet met their capacity can carry out transportation to several other TDSs, until the truck capacity is sufficient. Then, trucks can depart via the Transyogi Route or West Bekasi to the Bantargebang landfill for unloading the waste and will return to the initial TDS to wait for further transportation. In this alternative, transportation is only carried out with 1 rotation/day.

TDSs that have daily waste generation greater than or equal to truck capacity will still use the HCS system. At TDS that have a smaller amount of waste generation compared to truck capacity, they will use the Stationary Container System (SCS). This is done to reduce waiting time caused by the lack of waste generation at the TPS to maximize truck capacity and any waste produced every day will be directly transported to the Bantargebang landfill. The example of scenario 1 route can be seen in Table 2.

Table 2. Example of Scenario 1 transportation Route Detail in Kamal Sub-District

Route	Truck Type	Volume of Waste Transported (m3)	Pencent Occupancy (%)	Waiting Time (Day)	Track	Distance (Km)	Travel Duration	Diesel Cost (IDR/day)
2-3-x-2	Big Arm Roll (22m3)	20 + 2 = 22	100%	1	West Bekasi	121	4 hours 5 minutes	Rp206.000
3'-1-x-3'	Big Arm Roll (22m3)	20 + 2 = 22	100%	1	West Bekasi	119	4 hours 2 minutes	Rp206.000
1'-4-x-1'	Small Arm Roll (14m3)	2 + 10 = 12	86%	1	West Bekasi	118	3 hours 59 minutes	Rp180.250

Note:
1 = Market in RW02 Kamal (truck capacity: 6m3), 2 = TDS in RW08 Kamal (truck capacity: 20m3), 3 = TDS RW03 Kamal (truck capacity 20m3), 4 = TDS RW05 (truck capacity: 10m3), X = Bantargebang Landfill, ' = The second pickup in TDS

By using this system, there are still 3 trucks that cannot immediately meet the available truck capacity, because they experience a shortage of more than 50% of the total truck capacity. So, the truck had to wait at the TDS until the next day. The trucks that will be used in scenario 1 are 149 garbage trucks or 24% less than the existing condition. The large typer truck are the most widely used truck (48 units), followed by big arm roll truck (34 units), small typer truck (28 units), small arm roll truck (25 units), tow truck (5 units), and the smallest truck used is the small compactor truck, namely 1 unit. Not all TDS are only transported by 1 truck, but there are also TDS that can be transported using more than 1 waste truck, depending on the amount of waste produced.

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Arm roll trucks are trucks that are practical and fast to operate (Damanhuri & Padmi, 2015). The use of large and small arm roll trucks is prioritized in Kalideres District and Cengkareng District as the furthest area from the Bantargebang landfill and TDS that use a fixed container system. The use of tow trucks, typers and compactors is adjusted to the waste generation from each TDS to be transported.

The trucks were planned to leave between 2 times, namely 09.00 or 21.00. This was chosen because the road conditions in Jakarta have begun to experience a decrease in traffic jams (Tomtom, 2018). Another reason is to fulfill Governor's Instruction no. 160 of 2015. A total of 66 trucks using the HCS system will pass through the transyogi route at 09.00. A total of 83 trucks that use SCS and/or are in Kalideres and Cengkareng Districts, will go through the West Bekasi route at 21.00, where the congestion value is lower (Tomtom, 2018). This was chosen because SCS and/or Kalideres and Cengkareng Districts have longer transportation times and longer distances compared to the HCS system. In this transportation activity, the SCS system was planned to be used at polling stations in 1 sub-district or with the nearest sub-district. By the difference in departure time and distance traveled for each truck, the average time and distance used for transportation activities with travel conditions that do not experience traffic jams is 3 hours 28 minutes and 103,248 km.

Based on 149 drivers, the multiplier coefficient value of 1.00 and employee wages of IDR 3,648,035, total wages that will be paid each month is IDR 543,557,215. Then, the total cost of diesel fuel needed each day is IDR 29,033,125 (IDR 870,993,750/month). Total cost from wage and fuel cost will be IDR 1,414,545,965.

3. Scenario 2

In alternative 2, because in the existing condition not all TDS locations can meet the truck capacity with 1 time of waste collection. To overcome this, in alternative 2, the waste transportation system will be planned to use the HCS method and SCS, namely trucks that have insufficient capacity can transport to the next TDS until the truck capacity is met, then the truck can leave for Bantargebang landfill, and the truck will leave for the next TDS to carry out further transportation. In this alternative, transportation will be carried out with 1 and 2 trips/day.

By using this system, all trucks can transport their waste in 1 collection trip and no truck transports waste beyond its capacity. The trucks that will be used are 73 garbage trucks, 63% less than the existing conditions. By 70 trucks making 2 trips per day and 3 trucks making 1 trip per day. This is determined based on the amount of daily waste collected by each TDS and the capacity of the trucks used. Large arm roll trucks are the most widely used truck (34 units), followed by small arm roll truck (21 units), big typer truck (10 units), and large compactors and trontons (4 units each).

The use of arm roll trucks is prioritized compared to typer trucks, because arm roll trucks are practical and fast in operation (Damanhuri & Padmi, 2015). The use of tronton, typer, and compactor trucks is adjusted to the capacity of each TDS to be transported. Each truck is planned to depart 2 times, namely at 09.00 and 21.00. This was chosen because at 09.00 and 21.00, road conditions in Jakarta province have begun to experience a decrease congestion (Tomtom, 2018). A total of 72 trucks will pass through the Transyogi Route at 09.00 and a total of 71 trucks will pass through the West Bekasi Route at 21.00. Trucks using SCS that will transport waste from several TPS will be prioritized to use the West Bekasi Route, because this route has a shorter travel time compared to the Transyogi Route. In this transportation activity, the SCS system is planned to be used at TDS in 1 sub-district or with the nearest sub-district. The average time and distance used for the trip from the initial TDS to the Bantargebang landfill and back to the initial TDS with travel conditions that

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do not experience congestion, namely for 3 hours 29 minutes and a distance of 103.469 km.

In this alternative 2, 1 driver only works for one trip. Therefore, from a total of 143 trips carried out in a day, 143 drivers are needed to drive garbage trucks. Based on the multiplier coefficient value of 1.00 and employee wages of Rp3,648,035. Then the total wages that will be issued each month is IDR 521,669,005. Meanwhile, in terms of fuel costs, the total cost of diesel fuel needed each day is IDR 28,453,750. If multiplied in one month or 30 days, the cost of fulfilling diesel fuel for all trucks in West Jakarta is IDR 1,375,281,505. Comparison of detail route of the two scenarios can be seen in Figure 3.

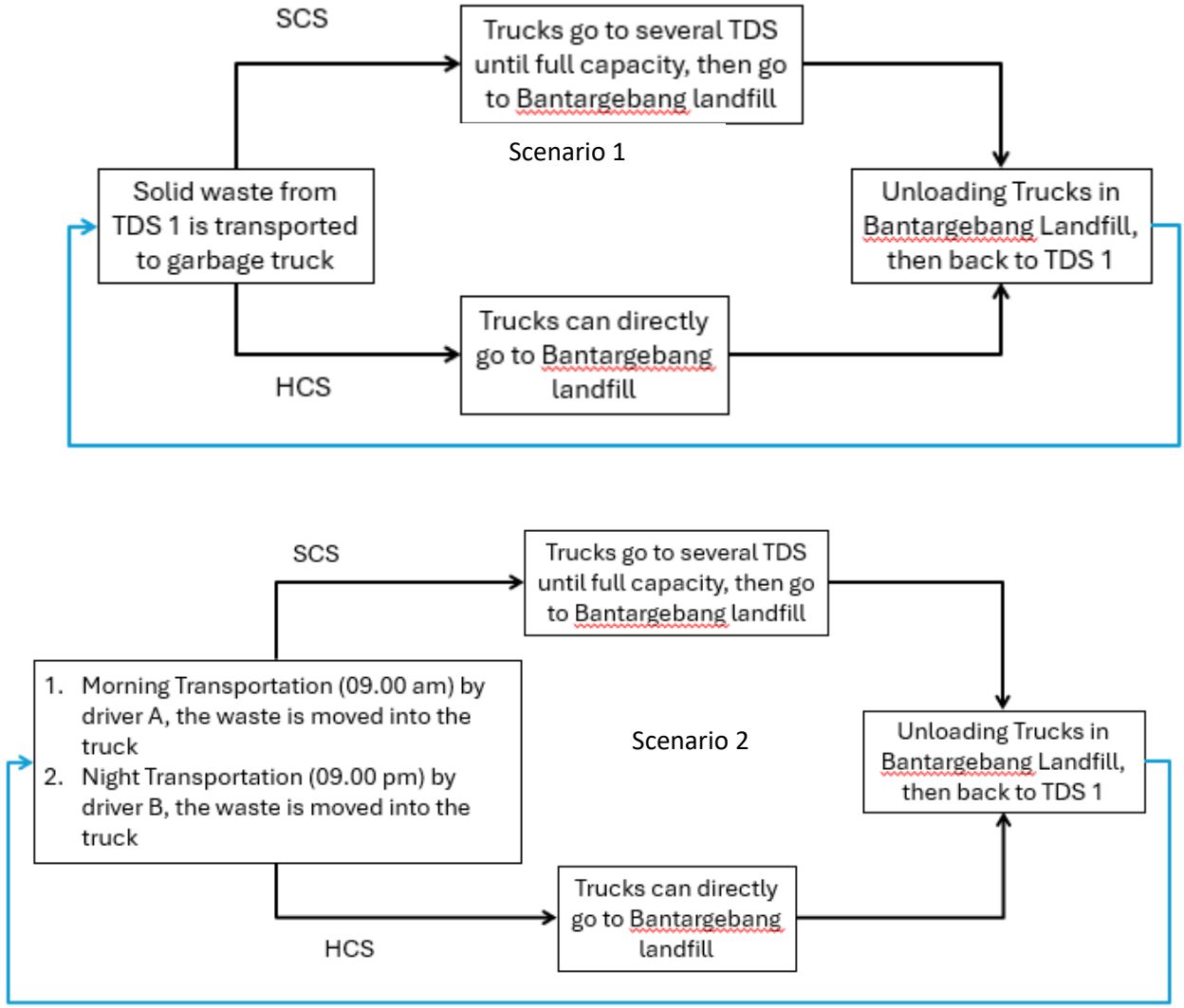

Figure 3. Comparison of System of Scenario 1 and 2

4. The Best Scenario Selection

After analyzing 2 alternatives that may be implemented in West Jakarta as a waste transportation system, the Khandani method will be used to determine the best system to be implemented in West Jakarta. Determination of alternatives is determined based on the weight value determined based on the criteria multiplied

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by the rating value that has been determined based on the provisions that have been set. The rating division based on the criteria for total waste transported per day, criteria for the number of trucks, criteria for fuel cost, and criteria for driver wages is determined in **Table 3**. Therefore, the decision matrix Khandani can be described by **Table 4**.

Table 3. Detail of Criterions Rating Division

Rating	Criteria for Transported Waste/day	Criteria for Amount of Truck	Criteria of Fuel Cost	Criteria for Driver Wages
0 - 2	0 - 20% transported waste/day	use 195-168 of trucks	Lower 1-3% of existing condition	Lower 1-8% of existing condition
3 - 4	21 - 40% transported waste/day	use 167-141 of trucks	Lower 4-6% of existing condition	Lower 9-16% of existing condition
5 - 6	41 - 60% transported waste/day	use 140-114 of trucks	Lower 7-9% of existing condition	Lower 17-24% of existing condition
7 - 8	61 - 80% transported waste/day	use 114-87 of trucks	Lower 10-12% of existing condition	Lower 25-32% of existing condition
9 - 10	81- 100% transported waste/day	use 86-60 of trucks	Lower 13-15% of existing condition	Lower 33-40% of existing condition

Note: 0-2: unsatisfactory, 3-4: bad, 5-6: enough, 7-8: good, 9-10: excellent

Table 4. Decision Matrix Khandani

No.	Criterion	Weight	Scenario 1		Scenario 2	
			Rating	Total	*Rating*	Total
1	Total of transported waste/day	35	10	350	10	350
2	Amount of truck	30	4	120	9	270
3	Fuel Cost/month	20	1	20	2	40
4	Driver wages/month	15	6	90	7	105
	Total	100		580		765

The criteria considered are the total waste transported, the number of trucks, the cost of diesel fuel/month, and wages for each driver/month. The total waste transported per day was chosen and has the largest weight, which is 35%, because this is the main objective in waste transportation activities. Another reason is that the composition of Jakarta waste for food waste is 43% (UPST, 2019). This means that the waste transported must be taken directly to the landfill to prevent problems with the comfort and aesthetics of the TDS area which occurs due to the odor produced by the pile of waste that is not transported and will cause the growth of disease vector nests in the TDS (Ambariski, 2016).

The waste transportation system is the most expensive waste management method compared to other management methods, namely containerization, collection, transfer, processing, and landfill, the budget spent on the waste transportation system can reach 70% of the total planned budget (Ambariski, 2016). The number of trucks is selected and has the second largest weight, which is 25%, because the number of trucks is what affects the effectiveness of the system and the cost efficiency that will be used. Therefore, the number of trucks must be optimized as much as possible.

There are several factors that can affect the amount of fuel consumption, namely the distance of the transportation route, road gradient, vehicle weight, rolling resistance and aerodynamics, vehicle speed and acceleration, driving style, and vehicle maintenance (Setiadi et al., 2019) The waste transportation process in West Jakarta has the farthest distance and the longest time to get to the Bantargebang landfill compared to other cities. This causes fuel to be an important factor in

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calculating the cost for each transport vehicle (Setiadi et al., 2019). In addition, the cost of diesel/month has a higher value compared to the driver's wages. Therefore, the cost of diesel/month is chosen and has a weight of 20%. Wages are important in employment relationships, because wages are the rights of workers/laborers for the work and dedication that workers/laborers have done to the company(Safira, 2015). From the perspective of the wage provider, the more workers/laborers you have, the greater the costs that must be incurred. The average cost of driver wages is included in the two largest of the average total transportation costs, along with diesel costs (Hooper & Murray, 2017). Driver wages were chosen and have a weight of 15%, because the total driver wages are one of the things that significantly affect transportation costs and have a lower value compared to the amount of diesel costs/month.

For criteria of transported waste/day, scenario 1 has 3 trucks out of 149 trucks that cannot transport their waste in a day, because they have a volume of less than 50%. In scenario 2, all waste can be transported and can avoid waste sedimentation caused by delayed waste transportation caused by low daily waste generation at a TDS. Therefore, both scenarios got the same rating which is 10. In another criteria, which is amount of truck, scenario 1 was rated as 4 because of using 149 trucks or 24% less than existing condition (existing condition uses 195 trucks). Then scenario 2 was rated as 9 because of using 73 trucks or 63% less than existing condition.

For the fuel cost criteria, the scenario 1 used IDR 870,993,750/month (1% cheaper than the existing condition), and the scenario 2 used IDR 853,612,500/month (2% cheaper than the existing condition) Therefore, scenario 1 was rated as 1 and scenario 2 was rated as 2. While the driver wages criteria, scenario 1 was rated as 6 because of 24% less cost than the existing condition (IDR 543,557,215/month). Then scenario 2 was rated as 7 because of 27% less cost than the existing condition. Eventually, based on the Khandani Decision Matrix table, by multiplying the weights on the criteria with the values given to each scenario, scenario 2 was selected as the optimum system in West Jakarta because the higher value than scenario 1.

Conclusion

The scenario 2 has been proposed to better transportation system for West Jakarta, which uses combination of the Hauled Container System (HCS) and Stationary Container System (SCS) with 1 and 2 transportation trips. By using this scenario, the number of trucks can be reduced from 195 to 73, with 70 trucks doing 2 trips/day and 3 trucks doing 1 trip/day. The number of drivers can be reduced from 195 to 143 drivers, with each driver only working for 1 trip. There is a decrease in the cost of diesel fuel/month from Rp873,158,589 to Rp853,612,500 and can reduce driver wages from Rp711,366,825 to Rp521,669,005 for each month. The total transportation cost for diesel and employee wages in a month becomes Rp1,375,281,505 or Rp209,243,909 cheaper compared to the existing condition.(Mahlil et al., 2020)

References

Ambariski, P. P. D. (2016). *Optimasi Sistem Pengangkutan Sampah Berdasarkan Kapasitas Kendaraan Pengangkut dan Kondisi Kontainer Sampah di Surabaya Barat*. ITS.

BPS. (2019). *Statistik Daerah Kota Jakarta Barat 2019*.

Damanhuri, E., & Padmi, T. (2015). *Pengelolaan Sampah Terpadu (Edisi Kedua)*. ITB.

DLH DKI Jakarta. (2015). *Master Plan dan Kajian Akademis Persampahan Provinsi DKI Jakarta*.

DLH DKI Jakarta. (2018a). *Tempat Penampungan Sementara (TPS) di Wilayah DKI Jakarta Tahun 2018*.

DLH DKI Jakarta. (2018b). *Timbangan Sampah di TPST Bantargebang Juli 2018*.

Hendrawan, B. E. (2007). *Implementasi Algoritma Paralel Genetic Algorithm Untuk Penyelesaian Heterogeneous Fleet Vehicle Routing Problem*. ITS.

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Hooper, A., & Murray, D. (2017). *An Analysis of the Operational Costs of Trucking: 2017 Update*.

Khandani, S. (2005). *Engineering Design Process*.

Kompas. (2018). *UMP DKI 2019 Ditetapkan 3,9 Juta. Accessed*. https://megapolitan.kompas.com/read/2018/11/01/14033561/ump-dki-2019-ditetapkan-rp-39-juta

Mahlil, T., Inoue, T., & Yokota, K. (2020). Evaluation of Phytoplankton Growth in Atsumi Bay as an Effect of Nutrient Input during Rainfall. *Journal of Water and Environment Technology*, *18*(2), 95–104. https://doi.org/10.2965/jwet.19-025

Safira. (2015). *Sistem pengupahan atas dasar satuan hasil / borongan bagi pengemudi truk (pekerja) PT Varia Usaha*. Universitas Airlangga.

Salipadang, J. C. (2011). *Analisis Sistem Pengangkutan Sampah Kota Makassar Dengan Metode Penyelesaian Vehicle Routing Problem (VRP) (Studi kasus: Kecamatan Mamajang)*. Universitas Hasanuddin.

Setiadi, A., Gundoro, D., & Yuliadi. (2019). *Perhitungan Rencana Kebutuhan Bahan Bakar Solar Dumptruck Nissan Diesel CWA 260MX di Tambang Andesit PT Gunung Lagadar Abadi di Desa Lagadar, Kecamatan Marga Asih Kabupaten Bandung, Provinsi Jawa Barat*. Universitas Islam Bandung.

Suryawan, I. W. K., & Lee, C. H. (2023a). Citizens' willingness to pay for adaptive municipal solid waste management services in Jakarta, Indonesia. Sustainable Cities and Society, 97, 104765.

Suryawan, I. W. K., & Lee, C. H. (2023b). Community preferences in carbon reduction: Unveiling the importance of adaptive capacity for solid waste management. Ecological Indicators, 157, 111226.

Suryawan, I. W. K., & Lee, C. H. (2024a). Achieving zero waste for landfills by employing adaptive municipal solid waste management services. Ecological Indicators, 165, 112191.

Suryawan, I. W. K., & Lee, C. H. (2024). Exploring citizens' cluster attitudes and importance-performance policy for adopting sustainable waste management practices. Waste Management Bulletin.

Suhardono, S., Fitria, L., Suryawan, I. W. K., Ulhasanah, N., Sari, M. M., Septiariva, I. Y., & Prayogo, W. (2024). Multidimensional factors of community behavioral responses and implications to landfill closures: A case study in Yogyakarta, Indonesia. Environmental Advances, 16, 100533.

Tomtom. (2018). *Jakarta Traffic 2018*. https://www.tomtom.com/en_gb/traffic-index/jakarta-traffic/

UPST. (2019). *Data-Data TPST Bantargebang. Accessed on 4th of March 2020* . https://upst.dlh.jakarta.go.id/tpst/data