Inkalindo Environmental Journal (IEJ)
ISSN: 2745-651X (p), 2746-2757 (e)
Website: inkalindo-journal.or.id

Vol. 1, no. 2 (2020), pp. 122-134

Optimization of Waste Transportation Systems in Semarang Selatan District, Semarang City

Optimasi Sistem Pengangkutan Sampah Kecamatan Semarang Selatan, Kota Semarang

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Abstract

South Semarang District is one of the Districts in the urban area of Semarang City, with a population of 72789 in 2019 based on population projections and service levels based on the percentage of waste generation of 64.37%. In the existing condition, Semarang Selatan District serves 22 waste shelters (TPS) and uses two vehicles, namely Arm Roll Truck, Dump Truck from TPS to the Jatibarang landfill (TPA) location. Traffic congestion is a factor in the occurrence of work operational delays, which causes additional operational costs incurred. The purpose of this planning is to get the optimum time based on several alternatives from the results of the analysis using the Network Analyst method in a GIS-based application, and to choose the optimum operational costs using the PIC method. The results of the optimization in this plan are recommended to the relevant office during the planning period for the next five years. Variable cost in the existing condition of USD 76,372 (IDR 1,091,497,300.83). Fixed cost in the existing condition of USD 33,359 (IDR 476.830.000). So that the total operational cost of the vehicle for transporting garbage in South Semarang District is USD 109,736.93 (IDR 1,568,327,300.83). Based on the results of Network Analysis and operational calculations, it is known that alternative I is the most optimum alternative, which consists of time segments I and II with an operational time of 05.30 a.m-13.00 p.m.

[*Kabupaten Semarang Selatan merupakan salah satu Kecamatan di kawasan perkotaan Kota Semarang, dengan jumlah penduduk 72789 pada tahun 2019 berdasarkan proyeksi penduduk dan tingkat pelayanan berdasarkan persentase timbulan sampah sebesar 64.37%. Pada kondisi eksisting Kabupaten Semarang Selatan melayani 22 waste shelters (TPS) dan menggunakan dua kendaraan yaitu Arm Roll Truck, Dump Truck dari TPS menuju lokasi TPA Jatibarang. Kemacetan lalu lintas merupakan salah satu faktor terjadinya keterlambatan operasional pekerjaan, yang menyebabkan timbulnya biaya operasional tambahan. Perencanaan ini bertujuan untuk mendapatkan waktu yang optimal berdasarkan beberapa alternatif dari hasil analisis dengan menggunakan metode Network Analyst pada aplikasi berbasis SIG, dan untuk memilih biaya operasional yang optimal dengan menggunakan metode PIC. Hasil optimasi dalam rencana ini direkomendasikan kepada Dinas terkait selama periode perencanaan untuk lima tahun ke depan. Biaya variabel pada kondisi eksisting sebesar Rp. 1.091.497.300,83. Biaya tetap pada kondisi eksisting sebesar Rp. 476.830.000,00. Sehingga total biaya operasional kendaraan pengangkut sampah di Kecamatan Semarang Selatan sebesar Rp. 1.568.327.300,83. Berdasarkan hasil analisis Network Analysis dan perhitungan operasional diketahui bahwa alternatif I merupakan alternatif yang paling optimal, yang terdiri dari segmen waktu I dan II dengan waktu operasional 05.30-13.00 WIB.*]

Keywords: GIS, Network Analyst, Optimization, Transportation, Waste

I. Introduction

Waste management is a systematic, total, and sustainable work step, which has stopped waste management and handling. Waste reduction is the activity of managing waste generation, recycling waste, and reusing waste. Meanwhile, waste handling includes direction, transportation, management and final waste management (Law No. 18 of 2008).

According to Damanhuri and Padmi (2003), the cost of transporting waste is relatively greater than other stages of waste processing, this cost can reach 60% (or around 50-70%) of the total waste processing costs. To reduce waste transportation costs, there are several steps that are carried out by optimizing the route of the transportation vehicle, determining the location of the landfill and placing the right trash can to minimize the vehicles used, modifying the transportation schedule, optimizing the fleet, combining information related to traffic conditions by using Waste Collection Vehicle Routing Problem model. In order to avoid traffic jams (Han & Ponce-Cueto, 2015; Adnani, 2010; Arnatha, 2017).

The administrative area of South Semarang District is located in Semarang City, Central Java, with an area of 5.93 Km2 of the total area of Semarang City. And the number of sub-districts of South Semarang Subdistrict is divided into 10 sub-districts. The population density level in South Semarang District reached 82,286

people in 2018 with a total population density of 12,869 people / km2 and a population growth of 7.49% in 2015-2018. South Semarang Subdistrict has 22 service TPS locations and has two types of garbage collection vehicles from the TPS location to the landfill (TPA) location, namely Arm Roll Trucks and Dump Trucks.

II. Literature Review

a. Waste Management

Waste can be interpreted as waste from the rest of the routine daily activities of the community or natural processes that are in the form of a solid form (Law 18 of 2008). The increase in population and changes in the consumption pattern of the people have resulted in an increase in the volume, amount and characteristics of the waste. So that garbage can cause environmental pollution if not managed properly (Wijanarko & Ridlo, 2017; Yunitasari, 2014). According to Law No. 18 of 2008 which discusses waste processing, waste processing is a systemized, comprehensive and sustainable activity consisting of reducing and handling waste. Waste reduction activities consist of limiting waste generation and recycling waste, or reusing waste. Meanwhile, waste handling includes the activities of selecting, collecting, transporting, processing and final processing of waste.

b. Waste Transport

The definition of waste transportation is a series of activities that are part of the processing, processing or handling of waste (Hutagaol et al., 2015; Indratmo, 2006). Meanwhile, waste transportation is the process of carrying waste from the collection location to an integrated waste processing facility or final processing site using a motorized vehicle that has been designed for waste transportation (Regulation of the Minister of Public Works No. 3 of 2013). According to the regulation, waste transportation has several provisions, namely maximizing the capacity of a transportation vehicle used, minimizing the distance and obstacles on the transportation route, the frequency of transportation from TPS, TPS 3R to TPA/TPST is carried out according to the existing number, and the ritation is carried out by considering efficiency. as well as the effectiveness of transportation (Meutia et al., 2017, Sugito & Sugandi, 2009).

III. Methods

This planning aims to determine the existing conditions in the garbage collection system in South Semarang District and the influence of the traffic conditions that are passed by the waste transport vehicles, as well as the optimum optimization

results from the analysis carried out (Direktorat Jenderal Bina Marga. 1997; Direktorat Jenderal Bina Marga. 2014). Following are the steps taken.

a. Data collection

1. Primary data

The primary data needed in optimizing the garbage transportation system in South Semarang District were obtained from measurements and sampling, among others:

- Traffic volume of Semarang City roads
- Road capacity in the city of Semarang
- Operational time for garbage collection in South Semarang District
- Travel speed of waste transport vehicles in existing conditions
- Percentage of work accident rate for garbage collectors in South Semarang District

2. Secondary Data

Secondary data were obtained from the Semarang City Transportation Agency, the Semarang City Environmental Service and the Semarang City Central Statistics Agency. The required data includes:

- Administrative map and road network for the city of Semarang
- Administrative map of South Semarang District
- The location of TPS and TPA in the service area of South Semarang District
- Patterns, routes and means of transporting waste in existing conditions
- Waste generation enters the TPA
- Total population of South Semarang District
- Vehicle operating costs in existing conditions
- Occupational safety and health (K3) data for garbage collection officers in South Semarang District (Padila et al., 2018; Lumintang, 2013).

b. Data Processing and Analysis

Data processing is carried out by double-checking the data that has been obtained from the relevant agencies or offices, then an analysis is carried out based on the required criteria by referring to the five aspects of waste management, namely operational technical aspects, legal and regulatory aspects, institutional aspects, financial aspects, and other aspects. community participation (Government Regulation No. 81 of 2012; Badan Standar Nasional, 2002). As for some of the data processed as follows:

a. Analysis of the degree of traffic saturation and Level of Service
b. Evaluation of waste transportation operations according to Minister of Public Works Regulation Number 3 of 2013 and Law Number 13 of 2003, as well as analysis of vehicle operating costs in existing conditions using the PCI (Pacific Consultant International) method.

c. Optimization of waste transportation routes with Network Analyst using ArcMap 10.3.1 software, Google Earth Pro, Global Mapper 18
d. Population projection for 2020-2024 for planning the waste transportation system
e. Budget plan
f. Application of K3 to garbage collection officers in the service area of South Semarang District.

IV. Results

a. Traffic Density Analysis

The analysis was carried out with the aim of knowing the typical roads traversed by garbage transport vehicles and knowing the level of congestion on these roads (Ridha et al., 2016; Suprapto, 2005). The analysis is carried out by performing time optimization by dividing into several time segments in order to obtain the degree of saturation on the road segment, the LOS value, and the travel speed on the road segment.

The time segments are determined by calculating the traffic density on weekdays and holidays for three samples of roads, namely Sriwijaya Road, Sultan Agung Road, Veteran Road by dividing it into three time segments, namely morning 05.30-08.00, afternoon 11.00-13.00 and afternoon 15.00-17.00 with an optimization time of 20 minutes for each sample seen using CCTV footage on these roads. Based on the results of the analysis carried out, it can be seen in Figures 1 and 2.

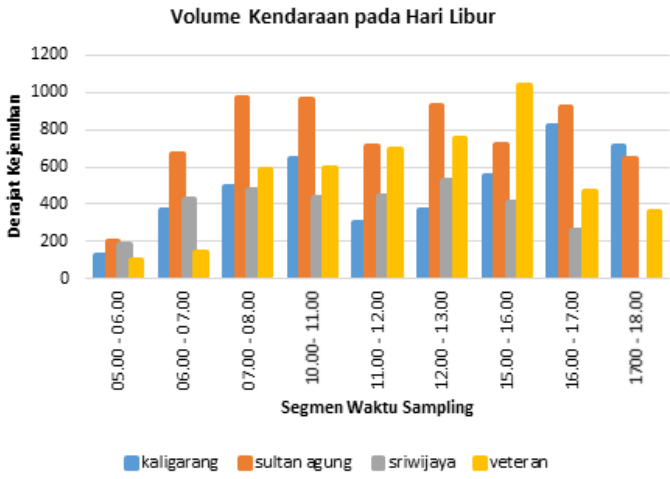

Figure 1. Traffic Density at Three Sampling Roads on Weekdays.

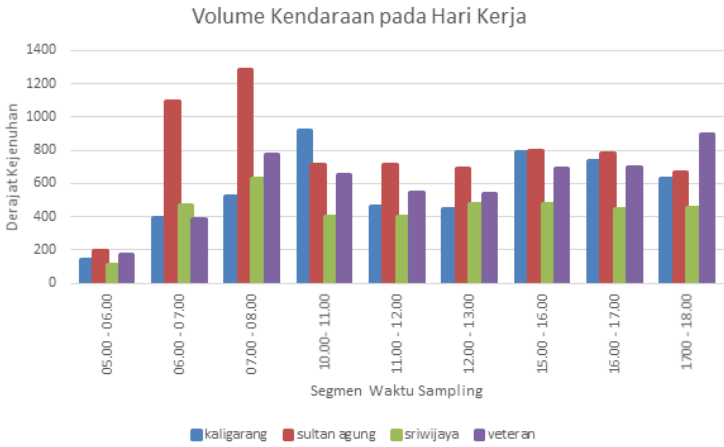

Figure 2. Traffic Density on Three Sampling Roads on Holidays.

b. Garbage Transport System in South Semarang Subdistrict in Existing Conditions

The operational system for transporting waste in the service area of South Semarang District is under the supervision of UPT 1 Semarang City Environmental Service. Semarang Selatan sub-district is one of the sub-districts of Semarang City which is directly adjacent to the urban center. The transportation system uses the Hauled Container System pattern using an Arm Roll Truck and a Stationary Container System using a Dump Truck, as well as mobile transportation using a Dump Truck to transport illegal garbage around the TPS. South Semarang Subdistrict, there are 22 TPS locations that are served by UPT 1 Semarang Environmental Service, while for several other locations this is done by the private sector. The number of vehicles in the existing condition is 9 Arm Roll vehicles and 1 Dump Truck vehicle. The results of the calculation of operational time for transporting waste in existing conditions can be seen in Tables 1 and 2.

The operational time for transporting waste is obtained based on the results of the routing of several arm roll trucks and dump trucks. The average travel speed of arm roll trucks based on the routing results is 28.09 km / hour, while the dump trucks have a travel speed of 26.01 km / hour. The results of the analysis on the existing conditions show that the operating time of the working hours exceeds the operational time stipulated in the regulation of Law No. 13 of 2003 which states that the working hours are 40 hours / week where this time does not include rest time.

Based on calculations using the PCI method in Burhamtoro (2016), the total vehicle operating costs in the existing conditions are USD 109,721 (IDR

1,568,327,300.83) with a service level of 64.37% (Badan Pusat Statistik Kota Semarang, 2019).

Table 1. Analysis of Operational Time for Garbage Transport in South Semarang District with the HCS System

Police Number	PHCS (h/week)	h (h/week)	s (h/week)	W (h/week)		T off (h/week)	THCS (h/week)
				T-ham (h/week)	t-fill fuel		
H 9534 TS	15,46	7,72	1,87	6,23	7,77	4,08	43,13
H 9533 TS	18,63	8,43	1,70	5,66	7,77	4,08	46,29
H 9530 YS	11,14	3,71	1,19	3,96	7,77	4,08	31,86
H 9562 RS	11,41	4,37	1,11	3,68	7,77	4,08	32,43
H 9586 PS	17,74	8,59	1,87	6,23	7,77	4,08	46,28
H 9564 RS	12,11	6,04	1,70	5,66	7,77	4,08	37,37
H 9531 YS	7,46	5,30	1,36	4,53	7,77	4,08	30,50
H 9563 RS	11,69	6,20	1,45	4,81	7,77	4,08	36,00
H 9535 US	8,89	6,19	1,70	5,66	7,77	4,08	34,31

Information:

PHCS: time needed to go to the next container location after placing an empty container at the previous location, time to collect a full container and time to return an empty container (Rit)

h: the time it takes to get to the location where the container will be transported

s: time spent waiting at the location

T-ham: time constraints in waste hauling operations

T off: rest time, THCS: total operational time per trip of the HCS system garbage collection vehicle

Table 2. Analysis of Operational Time for Garbage Transport in South Semarang District with the SCS System

Police Number	PSCS (h/week)	h (h/week)	s (h/week)	W (hours/week)		T off (h/week)	TSCS (h/week)
				T-ham	t-Fill fuel		
H 9646 SS	40.81	1,98	0,63	1,98	7,76	4,08	57,26

c. Optimization of the Waste Transport System in South Semarang District

Optimization is carried out based on the results of the average volume value of critical roads that have LOS E-F values on roads that are analyzed using the Network Analyst. From the results of the analysis, it was found that on Jl. Sriwijaya, Sultan Agung, Veteran have high potential for traffic jams on holidays and weekdays. These results conclude that there are three segments of the optimization time, namely morning, afternoon and evening. Based on these three segments, there are two alternatives to the optimization made, namely:

- Alternative I: Combined time segments I, II (05.30-13.00)
- Alternative II: Combined time segments II and III (06.00-17.00)

Based on the results of the analysis, it is found that the operational time for transporting waste in the District of South Semarang is optimal for alternative I, thus the alternative is used as a reference in planning the waste transportation system for a period of 5 years. The RAB of the planning results is shown in Table 8. Table 3 is a comparison of the two optimization alternatives according to the travel speed and vehicle mileage, while Table 4 is a comparison of the vehicle operating costs of the two optimization alternatives and the existing conditions. Table 5 is a comparison of the selected alternative operational time with the existing conditions. Tables 5 and 8 represent the waste transportation system planning for 2020-2024.

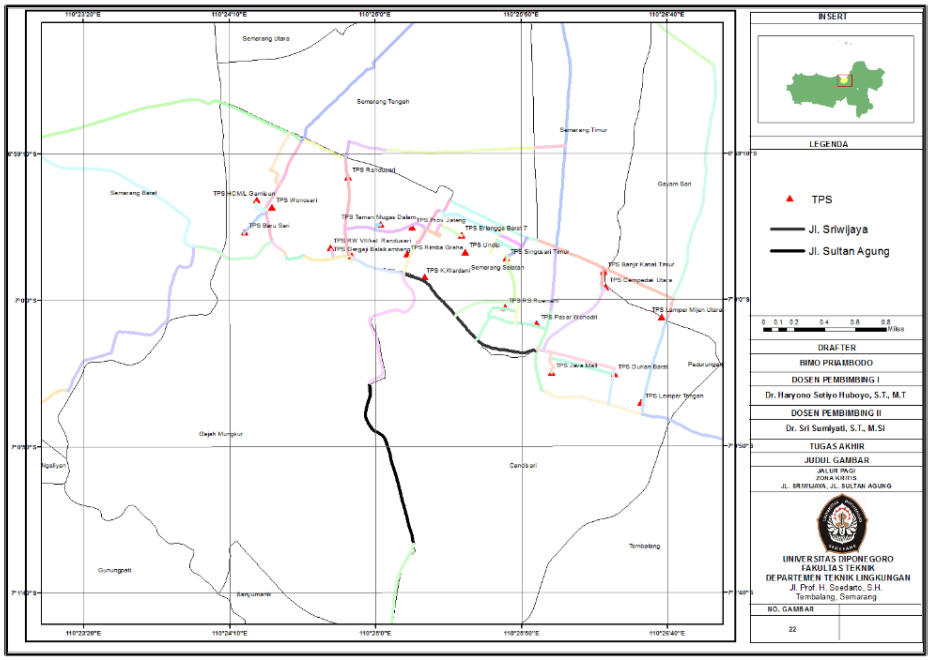

Figure 3. Segment I

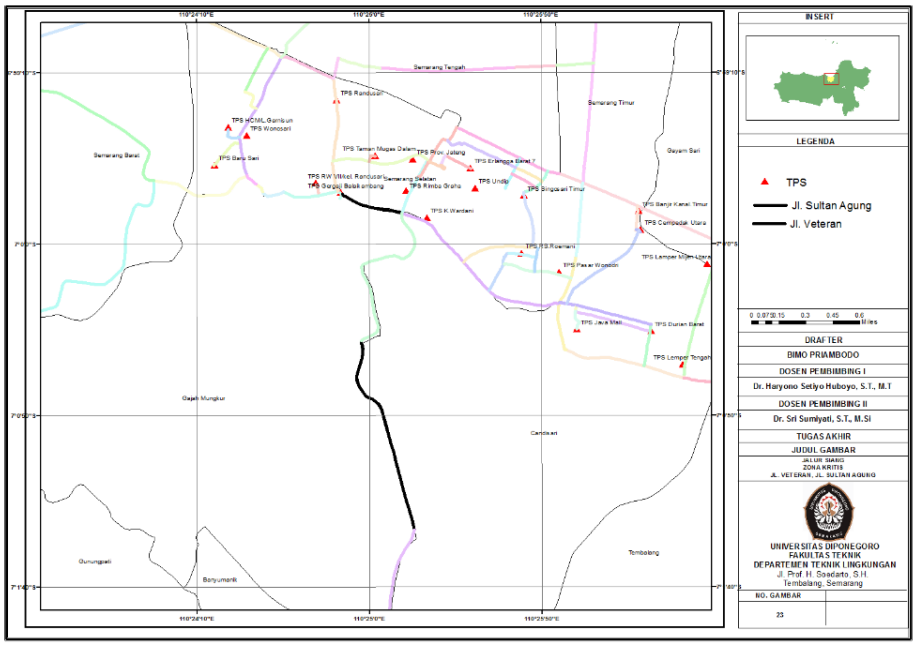

Figure 4. Segment II

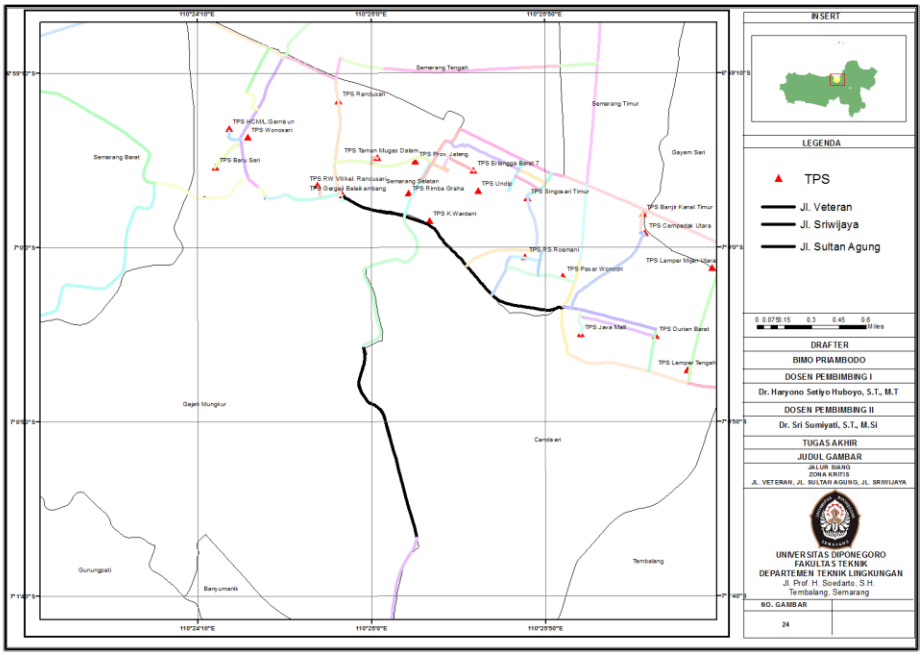

Figure 5. Segment III

Table 3. Comparison of Alternatives' Optimization

Transportation type	Parameter	Alternative I	Alternative II
Arm roll truck	Velocity (km/h)	31,48	24,20
	Distance (km/week)	3831,6	3829,2
Dump truck	Velocity (km/h)	28,65	21,10
	Distance (km/week)	175,56	179,34

Table 5. Comparison of Vehicle Operating Time Before and After Optimization

Vehicle	Transportation type	Alternative I	Existing
		(h/week)	*(h/week)*
1	*arm roll truck*	40,84	43,13
2	*arm roll truck*	41,69	46,29
3	*arm roll truck*	40,32	31,86
4	*arm roll truck*	41,52	32,43
5	*arm roll truck*	41,53	46,28
6	*arm roll truck*	41,91	37,37
7	*arm roll truck*	-	30,50
8	*arm roll truck*	-	36,00
9	*arm roll truck*	-	34,30
10	*dump truck*	46,87	57,26

d. Budget plan for Planning of Garbage Transportation System in South Semarang District

The value of the Budget Plan (RAB) for waste transportation in South Semarang District for 2020-2024 shows that the amount does not exceed the Regional Revenue and Expenditure Budget (APBD) contained in the Semarang City Solid Waste Master Plan (2013). The RAB for waste transportation for 2020-2024 is USD 103,579 (IDR 1,480,539,779.77); USD 101,781 (IDR 1,454,835,792.26); USD 95,812 (IDR 1,369,515,289.83); USD 94,538 (IDR 1,351. 309,599.71) and USD 90,427 (IDR 1,292,545,058.61). Meanwhile, the regional budget (APBD) in 2020 to 2024 is USD 152,483 (IDR 2,179,556,031.99); USD 159,909 (IDR 2,285,700,410.75); USD 167,696 (IDR 2,397,014,020.75); USD 175,863 (IDR 2,513,748,603.56) and USD 184,428 (IDR 2,636,168,160.56) in that year.

V. Conclusion

The conclusion of the optimization of the garbage transportation system in South Semarang District, Semarang City is as follows:

1. Traffic conditions that are passed by garbage transport vehicles in South Semarang Subdistrict. Based on the results of the analysis, there are roads that have a level of congestion which affects the travel speed of waste transport vehicles. As for the road, namely, Jl. Sriwijaya, Jl. Sultan Agung, Jl, Kaligarang and Jl. Veteran. And it is divided into three time segments, namely morning, afternoon and evening. For morning roads that have high traffic jams Jl. Sriwijaya, Jl. Sultan Agung. Siang, Jl. Veteran, Jl. Sultan Agung. And for the afternoon Jl. Veteran, Jl. Sriwijaya, Jl. Sultan Agung. Based on the results of the analysis, the optimization and planning of waste transportation in South Semarang District for the route vehicles that do not pass this road are based on the division of optimization time segments.
2. The waste transportation system in the existing conditions in South Semarang District in 2019 for a service level of 64.37% (Badan Pusat Statistik Kota Semarang, 2019). Average per capita waste generation in South Semarang Subdistrict is 1.41 kg / person / day or 4.72 L / person / day. There are 22 TPS locations served by 42 containers in 8 urban villages and there are two transportation systems, namely Arm Roll Trucks and Dump Trucks. The total operational cost of transporting waste from South Semarang Subdistrict in an exclusive condition is IDR 1,568,327,300.83.

Alternative I was chosen as the most optimal alternative, based on the results of the Network Analyst and the calculation of the most optimum vehicle operating costs from other alternatives. The optimal operational time for waste transportation is at 05.30 - 13.00 WIB. The results of the 2020-2024 planning show that the budget plan for waste transportation costs still reaches the Semarang City solid waste budget based on the Semarang City solid waste masterplan (2013). The percentage of financing efficiency in 2020-2024 is 31% respectively; 36%; 43%; 46% and 51%.

Disclosure and Conflicts of Interest

All authors state there is no conflict of interest.

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