Jurnal Presipitasi
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 19, No 3, 2022, 687-700
Article available at homepage presipitasi

Regional Case Study

Waste Collection and Transport Optimization of Pemalang District Service Area, Pemalang Regency

Adranandini Noor Anisa[1,2], Mochtar Hadiwidodo[2*], Sudarno[2], Sri Sumiyati[2]
[1] Master Program of Environmental Engineering, Universitas Diponegoro, Semarang, Indonesia
[2]Department of Environmental Engineering, Universitas Diponegoro, Semarang, Indonesia
* Corresponding author: E-mail: mch323@yahoo.com

Abstract

This study was prepared with the aim to plan the optimum transportation system in Pemalang sub-district based on traffic conditions in accordance with the desired target. The method used in this planning uses GIS-based applications, namely network analyst and google map. The operational cost of the vehicle in this planning is calculated by the PCI (Pacific Consultant International) method. Based on existing conditions, the operational costs of vehicles incurred reached Rp2,361,445,231.21 while in optimization conditions the operational costs incurred became more efficient at Rp2,913,093,684.31. The optimum time of transportation is done at 05.00 – 12.00 to avoid peak traffic hours at 13.00 – 17.00 with a vehicle travel speed of 47.42 km/h. Addition of freight after optimization so that it becomes 50 freight/day and the addition of containers to 9 containers. It was obtained for 2021 - 2025 as many as 17 containers as well as the addition of freight as many as 15 freight, and 6 fleets of armroll truck carriers.

Keywords: Waste management; rotation; transportation; optimization

1. Introduction

It's true that waste management has long been linked to environmental problems. In recent years, the effects of waste on the environment have become even more apparent, as the global population has continued to grow and produce more waste. This has led to a greater focus on waste reduction and management strategies that can help mitigate the environmental impacts of waste. One of the most significant environmental impacts of waste is climate change. The production and disposal of waste generates greenhouse gases, such as methane and carbon dioxide, which contribute to global warming. Landfills are a major source of methane emissions, as organic waste decomposes and produces the gas. Another major environmental impact of waste is toxicity (Bachanova et al., 2009). Many waste materials, such as electronic waste or hazardous waste, contain toxic substances that can be harmful to human health and the environment. When these materials are not properly managed, they can leach into the soil and water, contaminating both and potentially causing harm to plants, animals, and people (Dobrowolski et al., 2018).

Finally, waste can also lead to resource depletion. When materials are not recycled or repurposed, they are often discarded and sent to landfills, where they take up space and resources. This can lead to a depletion of natural resources, as new materials must be extracted to replace the ones that were wasted. Inefficient recycling processes can also lead to the waste of resources, as materials are not properly separated and processed (Bakas et al., 2018; Stentiford et al., 2011). Overall, waste management is an important issue with significant environmental impacts.

The city and trade center in Pemalang Regency is Pemalang District. Pemalang District, Pemalang Regency with an area of 101.93 km2 has a population of 204,370 (BPS, 2019). These human activities will cause quite a lot of waste generation. The availability of a waste handling system is a part that should be prioritized to meet the needs of the community. Increased economic activity in Pemalang District has resulted in an increase in the amount of waste that must be managed. Based on Damanhuri and Padmi (2010) it is estimated that at most only 60-70% of waste can be transported to the Final Disposal Site (Landfill) by responsible institutions, while the part that is not transported is handled by the community independently or it can be scattered and thrown away anywhere. To support the waste handling system, good handling is needed, one of which is the handling of waste transportation routes.

Waste transportation is one of the problems including making decisions regarding waste collection routes which will determine the total distance traveled by the fleet (Sri and Endah, 2014). In order to minimize the cost of transporting waste, there are several ways to do it, such as optimizing transport vehicle routes, determining the location of the landfill and placing the right trash cans to minimize the vehicles used, modifying transport schedules, optimizing fleets, combining information related to traffic conditions to avoid traffic jams. (Han, 2015).

Waste transportation is strongly influenced by the growth rate of the industrial, economic, agricultural and trade sectors. In waste transportation planning activities, selecting vehicle routes and transportation schedules are essential in determining the total distance travelled by the fleet (Han, 2015). A transport route/pattern can be optimal if designed as short as possible, and II-9 has the least resistance from Wast Collectition Site (WCS) to landfill points (Ridha et al., 2016). Problems related to waste transportation include making decisions regarding Waste collection routes which will determine the total distance travelled by the fleet (Sri & Endah, 2014).

Total waste generation in Pemalang District in 2019 was 124 m3/day (Sie. Waste Management and B3 Waste, 2019). As the population increases and human activity increases, the amount of waste generated also increases. This causes densely populated areas to find space such as WCS/Landfill (Wibowo, 2011). The level of service for waste transportation in Pemalang District is still relatively small, namely 40.05%. There are several WCS that have excess waste generation which results in scattered waste and not being transported directly on the day the waste collection takes place, one of which is WCS Pasar Paduraksa, WCS Kramat and WCS Sewaka. The waste will pile up and wait until the dump truck has a certain capacity, causing a quite pungent odor around WCS Paduraksa, WCS Kramat and WCS Sewaka. Transportation on dump trucks is carried out every day, but there is still residual waste that will continue to accumulate every day. Then the dump truck that carries the remaining waste at the WCS does not wait at the pool but waits at the WCS until the waste fills the dump truck and is ready to be transported to the landfill.

The waste transportation system cannot be separated from the transportation route from WCS to Landfill, where road conditions, route distance, vehicle speed and type of road traversed can affect transportation time (Ambariski, 2016). The absence of firmness from the relevant agencies regarding more optimal transportation times and transportation routes has resulted in the number of trips that can change every day according to road conditions. In addition to affecting transportation time, routes and road conditions also affect the costs incurred by the agency for management, these costs are mostly found in the operation of transport vehicles (Subandriyo et al, 2014). Vehicle operating costs are based on vehicle speed, the higher the vehicle speed, the smaller the vehicle operating costs (Burhamtoro, 2016). Meanwhile, the average speed of waste collection vehicles is relatively low due to the selection of transport times during rush hours on the main roads of Pemalang Regency, such as Jl. General Gatot Subroto, Jl. I-3 Ahmad Yani, Jl.Pemuda, and Jl. Dr. Wahidin. At the time of departure and when returning from work, there is a traffic jam at the Sirandu intersection that connects Jl. Dr. Wahidin, Jl. Dr. Ahmad Dahlan, Jl. Ahmad Yani and Jl. Jend. Gatot Subroto. This congestion is one of the obstacles

when transporting waste, coupled with the absence of regulations or fixed routes for waste transportation which results in waste truck drivers being careless.

Based on KBBI optimization is an effort or method to get the best results, so optimization is an action, process, or methodology to make something more effective and efficient. Optimization is adjusted to the facilities and infrastructure that are already owned by the local government and is also adjusted to the condition of the roads on the transportation route. Waste transportation routes must be made as effective and efficient as possible in terms of cost and time so as to get the most optimal route. Therefore, it is necessary to optimize the waste transportation system to improve services in the field of waste transportation in Pemalang District at this time

This research was conducted because no one has previously analyzed waste management in Pemalang District, and because the district is known to be a major producer of waste. By studying waste management in Pemalang District, this research can provide valuable insights into the current state of waste management in the area, and can serve as a model for other regions to improve their own waste management practices. This can help to protect the environment and reduce the negative impacts of waste on our planet.

2. Methods

2.1 Sampling Technique

Sampling was carried out using the "My Track" application to determine the speed of waste transport vehicles in existing conditions, both when loaded and empty. Vehicle samples for routing include 1 type of dump truck vehicle and 1 type of arm roll vehicle. Routing for each of these vehicles is carried out on weekdays and holidays. Road density is measured using traffic counting from road CCTV managed by the Traffic Department of the Transportation Service by paying attention to vehicle side activity and geometric characteristics.

2.2 Sample Collection Techniques

We obtained primary and secondary data collection from the Pemalang District Office, the Central Bureau of Statistics of Pemalang Regency, the Environmental Service of Pemalang Regency, the Public Works Office and the Transportation Office of Pemalang City. Primary data was obtained from direct observation and interviews. Secondary data was obtained from a documentation study with an inventory of data. The primary and secondary data needed in this plan are in the table.

Table 1. Data collection technique

No	Data Requirements	Data Source	Data collection technique	Data Collection Tool
1	Assess the existing condition of the area 1. Regional and socio-economic conditions a. Geographical Conditions b. Total population c. Administration Map	Badan Pusat Statistik	Documentation	Monograph Data
2	Assessing the existing condition of the waste transportation system 1. Waste service and transportation a. Waste transport routes b. Waste transport system c. Number of fleet, type of fleet, and fleet capacity d. Service area Waste generation at WCS and Landfill originating from Pemalang District	Dinas Lingkungan Hidup	Interview, Documentation, and observation	Operational Data of Pemalang Regency solid waste, notebook, camera, flashdisk

No	Data Requirements	Data Source	Data collection technique	Data Collection Tool
	2. Waste Operational Costs a. Maintenance costs b. Travel expense c. Employee salary d. Miscellaneous expense			
3	Assess the effect of traffic conditions on the transport route 1. The number of vehicles passing on the route 2. Type and path	Dinas Perhubungan, Dinas Pekerjaan Umum	Observation, study of documents, calculations	Observation sheet, inventory, Harddisk, Multiple Counting application
4	Optimization of the waste transportation system 1. The time it takes the truck to transport the filled container (pc) 2. Time taken by the truck to empty the container (uc) 3. Time needed to cover the distance between WCS (tdbc) 4. Time of loading and unloading at landfill(s) 5. Time required from WCS to landfill (h1) 6. Time taken from landfill to WCS (h2) 7. The time required from the pool to the WCS (t1) and from the landfill to the pool (t2) 8. Distance from WCS to landfill 9. Off route factor 10. The condition of the waste collection fleet	Waste Officer	Routing, Calculations, interviews, documentation, observation, study of documents	GPS, Stopwatch, Notebook, camera

2.3 Data Processing Techniques

Data processing techniques in this plan include editing and tabulation of data. Editing is done to evaluate the completeness of the data and suitability with the required data criteria. Analysis of the waste transportation system in Pemalang Sub-District in existing conditions was carried out to determine per capita waste generation, the level of service for waste transportation, the operational time for waste transportation in Pemalang District, and vehicle operating costs in existing conditions. Vehicle operating time is analyzed based on Permen PU No. 3 of 2013. Vehicle operating costs in existing conditions are calculated using the Pacific Consultant International (PCI) method, which can be seen in formulas 2.20 to 2.28. However, wages and mechanic costs are not calculated based on PCI because the Regional Government of Pemalang Regency has determined labour wages. In contrast, mechanical costs are based on the vehicle care and maintenance period.

Analysis of traffic conditions is to determine fluctuations in traffic density on roads in Pemalang Regency, which analysis of traffic conditions can then use to determine the time segment in waste transportation operations. In addition, The analysis can use to determine the Level of Service (road performance) and the travel speed of vehicles on that road section. This traffic density analysis includes vehicle volume analysis, road capacity analysis, III-6 degrees of saturation analysis, time segment analysis, and vehicle travel speed analysis.

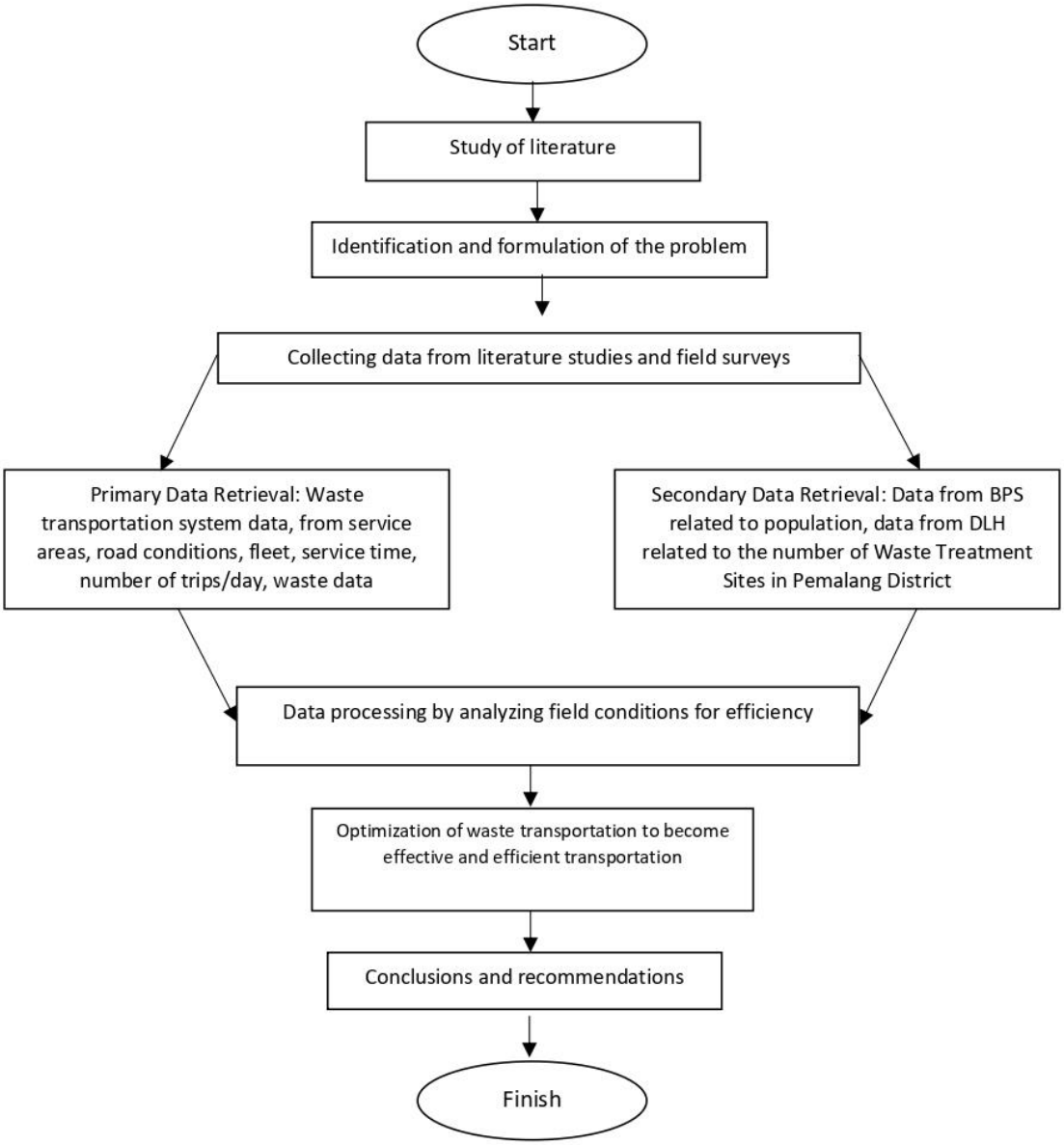

Figure. 1 Flowchart of this research

After the calculation obtained, vehicle volume from traffic counting on urban roads in Pemalang Regency included data on the number of light, medium and motorcycle vehicles. The road is obtained based on observations of the physical condition of the road in the form of type, width of the road, presence of a median, kerb or shoulder of the road, as well as roadside barriers which include the number of pedestrians, slow vehicles, vehicles going in and out and parked or stopped vehicles. Road capacity is calculated based on MKJI (1997). The degree of traffic saturation (DJ) is obtained from the analysis of vehicle volume and road capacity, which is the ratio of road volume and capacity.Optimization was carried out using the Network Analyst on ArcMap 10.4.1 software. Based on the results of road performance analysis at each time segment, road performance values are obtained, which are expressed in the Level of Service. Road sections with a value of D to F in each time segment are not recommended to be passed, so they are used as road barriers. However, it is still considered if the vehicle travel time is faster by going through these roads. The results of the Network Analyst are

then compared with transportation routes based on Google Maps. After obtaining the waste transportation route for each time segment, optimization is carried out with several alternatives based on the predetermined combination of time segments. The chosen alternative is an alternative with a suitable time and efficient operational costs. This alternative has been used for planning the waste transportation system in Pemalang District for five years.

3. Result and Discussion

3.1 Overview of the Area and Waste Transportation System in Pemalang District

Pemalang District is the center of Pemalang Regency, seen from the Administrative Map of Pemalang District, which can be seen from Figure Pemalang District is one of the sub-districts in Pemalang Regency with an area of 101.93km² (BPS, 2020), with the following area boundaries:

West Boundary : Tegal District
South Boundary : Bantarbolang District and Randudongkal District
East Boundary : Bantarbolang District and Taman District
North Boundary : Java Sea

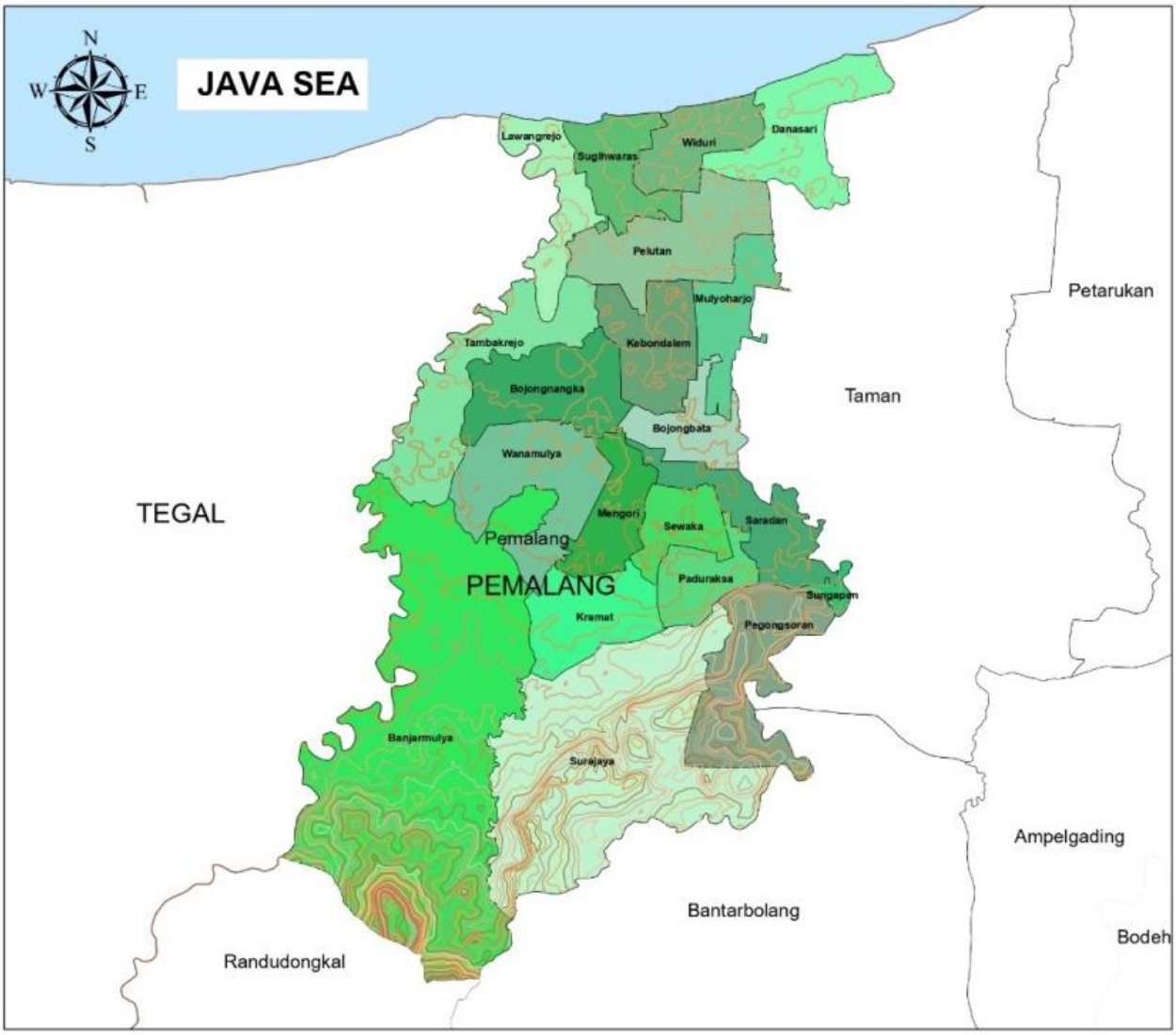

Figure 2. Administrative and geographical map of Pemalang sub-district

Pemalang District is one of the Districts in Pemalang District. The number of sub-districts owned is 13 villages and six sub-districts, 185 RW and 835 RT. Of the 13 towns and six sub-districts, the highest number of neighborhood associations (RT) is Mulyoharjo Sub-District, with 111 of 24 RWs (BPS, 2019).The waste transport system in Pemalang District is managed directly by the Cleanliness and Waste Unit of the DLH Kab. Pemalang. The UKP Kab governs Waste transportation. Pemalang from WCS is transported using arm roll trucks and dump trucks while riding along city roads using pickups and Tossa.

Waste in the WCS is transported daily to the Pesalakan Landfill using arm roll trucks and dump trucks. Officer will haul the trash with excess generation by adding it on certain days optionally, depending on the existing conditions. Waste transportation is carried out daily with a time range of 06.00 Western Indonesian Time (WIT) – 16.00 WIT with total working hours of 10 hours per day.

Pemalang District has 24 WCS serving seven sub-districts and nine villages. Four villages do not have WCS: Sungapan Village, Surajaya Village, Banjarmulya Village, and Pegongsoran Village. The number of WCS in Pemalang District Village can be seen in Table 2.

Table 2. Number of WCS in Pemalang district village

Village Name	**Number of WCS**
Banjarmulya	-
Surajaya	-
Pegongsoran	-
Sungapan	-
Paduraksa	1
Kramat	1
Wanamulya	2
Mengori	1
Sewaka	1
Saradan	1
Bojongbata	2
Bojongnangka	1
Tambakrejo	1
Kebondalem	1
Mulyoharjo	4
Pelutan	1
Lawangrejo	2
Sugihwaras	3
Widuri	1
Danasari	1
Total	**24**

Pemalang District in 2020 had three units of arm roll trucks and 12 units of dump trucks. Transport vehicles in Pemalang District have brands, colors, and years of operation. The following details of the trucks transporting Waste in Pemalang District can be seen in table 3.

Table 3. Waste transport truck in Pemalang district

Police number	Type	Merk	Year	Color
G 9553 M	Dump	Hino	2016	Green
B 9309 SOQ	Dump	Isuzu	1996	Yellow
G 9534 W	Dump	Hino	2016	Green
G 9550 D	Dump	Hino	2016	Green
G 9536 D	Dump	Hino	2016	Green
G 9532 M	Dump	Hino	2016	Green
G 9538 D	Dump	Mitshubisi	2004	Yellow
G 9533 W	Dump	Mitshubisi	2004	Yellow
G 9536 M	Dump	Mitshubisi	2004	Yellow
G 9549 D	Dump	Mitshubisi	2004	Yellow
G 9535 W	Dump	Hino	2016	Green
G 9533 D	Arm roll	Mitshubisi	2004	Yellow
G 9534 D	Arm roll	Mitshubisi	2004	Yellow
G 9598 W	Arm roll	Mitshubisi	2004	Yellow
G 9566 W	Dump	Hino	2016	Green

Sumber : UKP DLH Kab. Pemalang, 2020

The Cleaning and Waste Unit of the DLH Pemalang Regency manages funding for solid waste in Pemalang Regency. The funding provided by DLH covers the fuel needs of vehicles, maintenance, and maintenance of cars, the addition of Waste facilities and infrastructure, and labor wages. Pemalang District receives 14 L/trip for each dump truck vehicle, while for the arms roll, it is 11 L/trip. The material used for the transport trucks is diesel fuel with a price of Rp. 9400,-. Every year maintenance of vehicles is carried out under the policies of each driver. Details of the financing for waste management in Pemalang Regency can be seen in Table 4.

Table 4. Details of waste operational costs in Pemalang district

Type	Unit	Price
Labor Wages	Person/month	Rp1,400,000
Lubricant	L/6 month	Rp1,750,000
Fuel	Truck/month	Rp3,000,000
Mechanical Cost	Person/truck	Rp50,000
Tire	4 pieces/truck	Rp8,000,000
Arm roll truck	Unit	Rp4,500,000,000
Dump truck	Unit	Rp450,000,000
Container	Unit	Rp23,000,000

3.2 Road Conditions and Waste Transportation Traffic

The researcher obtained the width of the road passed by the Waste collection vehicles from the District Public Works Office documents. Malang. According to SNI 19-2454-2, during operation, waste transport vehicles are prohibited from obstructing other cars on the road so that the truck's minimum width of the road can pass four m. Waste transport vehicles with the brands Hino, Isuzu and Mitsubishi in Pemalang District have a width of 2 m and other vehicles with an average width of 1.6 m. The Pemalang District Public Works Office did not record several roads on the waste transportation

route in Pemalang District because they were in the process of being renovated. The width of the unrecorded path was obtained using observations from digitization using the Google Earth Pro application.

The saturation of the waste transportation route in the Pemalang sub-district was obtained from observations for four days of routing and the results of traffic-counting calculations using CCTV from the Pemalang Regency Transportation Agency by taking three-time segments for 1 hour with a sample of 20 minutes, namely morning (05.00-10.00), during the day (10.00-15.00) and evening (15.00-18.00) on roads that appear to have congestion points.

The volume of vehicles was increased on two roads, namely Jalan Gatot Subroto and Jalan Ahmad Yani, with a peak at 15.00-17.00. The increase was due to the high number of vehicles during lunchtime for the workers. The calculation of vehicle volume divided into three time segments can be seen in Table 5. Fluctuations in vehicle volume per time segment on Jl. Jend Gatot Subroto, Jl. KH Ahmad Dahlan and Jl. Ahmad Yani on weekdays and holidays can be seen in Figure 5.12 and Figure 5.13

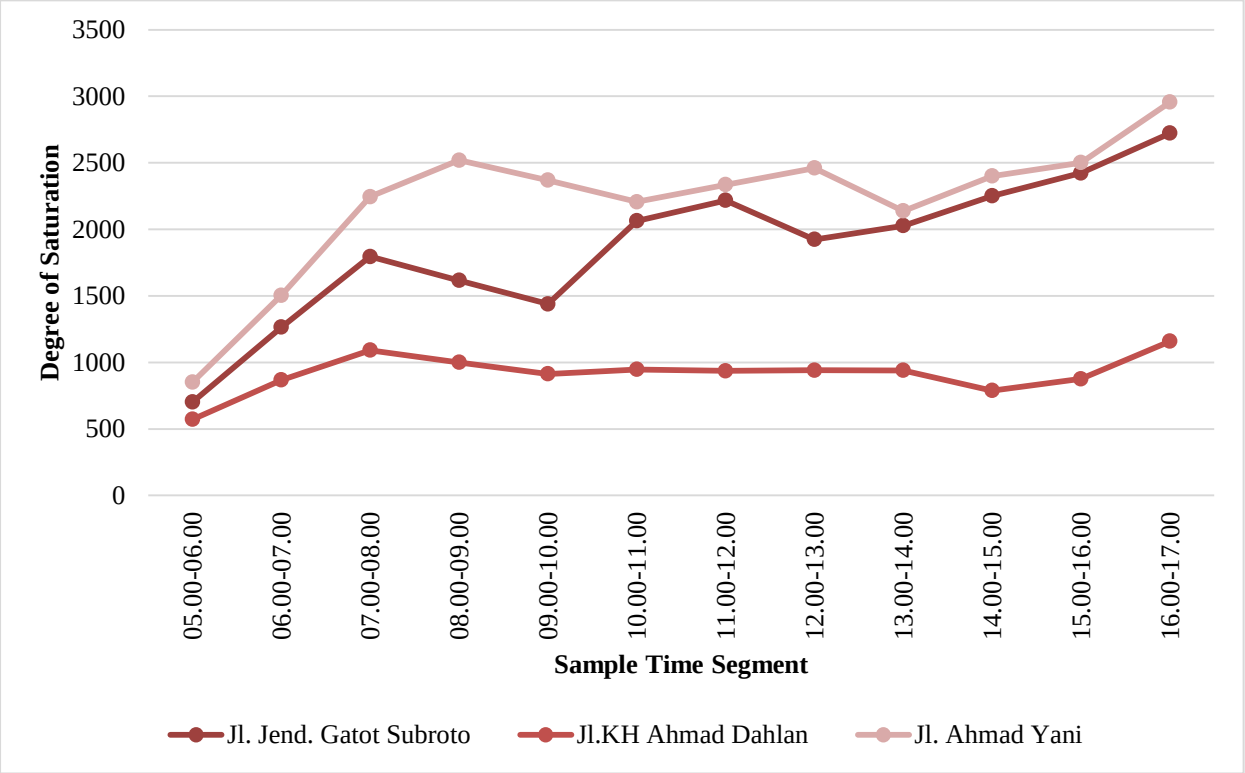

Figure 3. The volume of vehicles through the critical route from the Pemalang District Waste Transportation route on weekdays

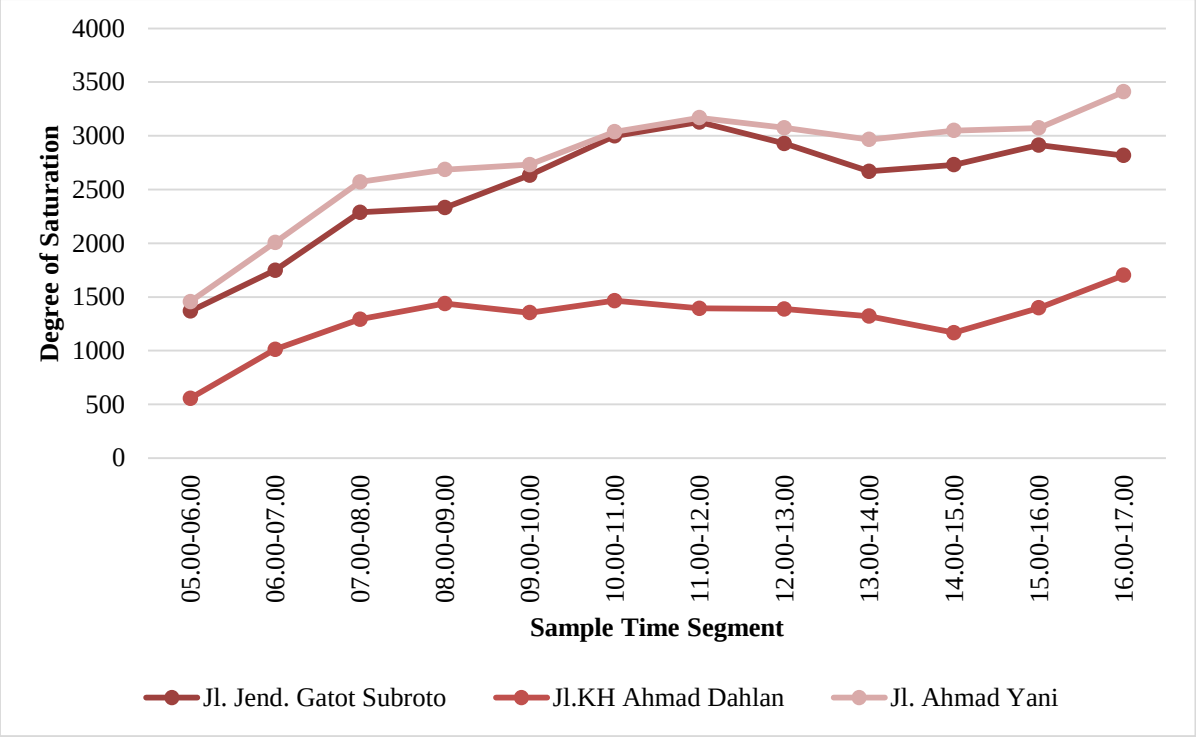

Figure 4. The volume of vehicles through the critical route from the Pemalang District Waste Transportation route on weekend

Based on the calculation above, it is found that the speed of the vehicle free flow on the Jl. Gatot Subroto 57 km/hour, to find out the speed of the vehicle's travel on the road section, was obtained by drawing a line of relationship between the speed of vehicle free flow on the road (FV) with the degree of saturation on the road section (DS). Based on the calculation results, the highest speed is obtained on Jalan Jend Gatot Subroto, 51.14 km/hour, and the lowest rate is on Jl. Ahmad Yani is 44.26 km/hour, so it can be calculated as the average speed of all the speeds of transport vehicles in Pemalang District that pass the road with the most optimal LOS, equal to 47.42 km/hour.

3.3 Analysis of Optimization of the Waste Transportation System in Pemalang District

Optimization of the Pemalang District waste transportation route was carried out by observation, interviews with truck drivers, interviews with the field coordinator of the transportation section, and network analyst features in the ArcGIS application. Three distance-optimized arm roll vehicles are marked in orange. On WCS Lap arm roll vehicles. The order has the most changes, with the difference reaching 3.7 km. Meanwhile, based on the calculation found the slightest change in distance in WCS Pasar Pagi. Dump truck vehicles have a difference in distance changes. The number of route changes to dump trucks was 13.37 km; the route changes with the most significant distance difference were G 9550 D vehicles serving SD Lawangrejo WCS and SPBG Lawangrejo WCS. Of the 12 dump trucks, this research did not optimize only four cars.

Table 5. Changes in distance and travel time for arm roll waste transportation routes after optimization

Vehicle license plate number	Route	Distance (km)	Total (km/hari)	Distance after optimization (km)	Total	differences
G 9533 D	Pool Ukp - Wcs Wijaya Kusuma	4.27	68.69	4.27	67.79	0.9
	Wcs Wijaya Kusuma - Landfill Pegongsoran	11.1		10.8		
	Landfill Pegongsoran - Wcs Wijaya Kusuma	11.4		11.4		
	Wcs Wijaya Kusuma - Landfill Pegongsoran	11.1		10.8		
	Landfill Pegongsoran - Wcs Wijaya Kusuma	11.4		11.4		
	Wcs Wijaya Kusuma - Landfill Pegongsoran	11.1		10.8		
	Landfill Pegongsoran - Pool Ukp	8.32		8.32		
G 9534 D	Pool Ukp - Wcs Lap. Tertib	3.31	64.13	3.31	60.43	3.7
	Wcs Lap. Tertib - Landfill Pegongsoran	10.5		9.76		
	Landfill Pegongsoran - Wcs Lap Tertib	10.5		9.76		
	Wcs Lap. Tertib - Landfill Pegongsoran	10.5		9.76		
	Landfill Pegongsoran - Wcs Lap Tertib	10.5		9.76		
	Wcs Lap. Tertb - Landfill Pegongsoran	10.5		9.76		
	Landfill Pegongsoran - Pool Ukp	8.32		8.32		
G 9598 M	Pool Ukp - Wcs Ps. Pagi	3.2	63.62	3.2	63.02	0.6
	Wcs Ps. Pagi - Landfill Pegongsoran	10.5		10.3		
	Landfill Pegongsoran - Wcs Ps. Pagi	10.3		10.3		
	Wcs Ps. Pagi - Landfill Pegongsoran	10.5		10.3		
	Landfill Pegongsoran - Wcs Ps. Pagi	10.3		10.3		
	Wcs Ps. Pagi - Landfill Pegongsoran	10.5		10.3		
	Landfill Pegongsoran - Pool Ukp	8.32		8.32		

Information:

Optimized route

The addition of containers is adjusted to the remaining working time and the number of repetitions per day. But The container must also change to WCS, which has excess generation such as

WCS Ps. Morning and WCS Lap. Orderly and spacious WCS so that the added containers are clear of the entry and exit of transport vehicles. In optimizing the transportation of waste in Pemalang District, there are additions. Details of adding containers to each WCS in Pemalang District are presented in Table 5.50. There are 2 WCS whose containers have increased so that the number of containers in Pemalang District, which was previously 7, has now become 9. The addition of 2 containers is placed at WCS Ps. Morning and one container at WCS Lap. It was orderly because much trash was scattered around the WCS, so when it rained, it caused a more pungent odour.

Table 6. Additional containers at WCS Pemalang district

Vehicle Police Number	WCS Name	Number of Rebates (Existing)	Container Capacity (m3)	Number of Containers	Number of Optimization Containers
G 9533 D	WCS Wijaya Kusuma	3	8	3	3
G 9534 D	WCS Lap. Tertib	3	8	2	3
G 9598 M	WCS Ps. Pagi	3	8	2	3

The percentage of services will increase due to the addition of containers and the rotation of both Arm roll vehicles and dump trucks so that the volume of waste that goes to the landfill will increase. The destruction that previously entered the landfill was 527.763 m3/day to 621.10 m3/day. At the same time, WCS's service level increased due to the addition of containers that initially numbered 7 to 9 waste containers. There was an increase in the number of served residents after optimization to 210267 people, and the percentage of waste going to landfill adjusted for waste generation, initially only 40.017% to 78.21%.

The calculation of operational costs for existing vehicles in Pemalang District in 2020 is based on data from the DLH Pemalang Regency in Table 5.53 and the PCI method, which requires an average daily vehicle speed. With this method, the data from the transport vehicle will be converted into a Rupiah value/1000 Km of distance travelled. Optimization by choosing a more optimal route, changes in vehicle speed, and the addition of roads and containers will affect vehicle operating costs.

Table 7. Basic data on vehicle operational costs in Pemalang district

No	Type	Units	Price	
1	Labor wages	Person/month	IDR	1,926,000
2	Fuel	L	IDR	5,150
3	Mechanic fee	Person/truck	IDR	50,000
4	Tire	4 fruit/truck	IDR	8,800,000
5	*Armroll trucks*	Unit	IDR	450,000,000
6	*Dump trucks*	Unit	IDR	450,000,000
7	Container	Unit	IDR	25,300,000
8	Lubricant	L	IDR	45,000
9	Arm Roll Truck Speed	km/hour	47.43	
10	Dump Truck Speed	km/hour	47.43	

The total vehicle operating costs in Table 5.55 has increased from before optimization due to the addition of 2 containers and the addition of existing routes. The previous fee was IDR 2,597,589,754

to IDR 2,913,093,684.31. According to the 2020 Pemalang Regency APBD regarding the Maintenance Budget for Waste Facilities and Infrastructure, which has a value of Rp. 7,340,000,000.00.

Table 8. Calculation of waste management costs in Pemalang district

Subject	Existing	Optimization
Year	2020	2021
Served Residents	57,200	91,650
KK Served	11,440	18,330
Total Budget/Year	IDR 2,597,589,754	IDR 2,913,093,684.31
Percent of Retribution Fee/Year	8%	8%
Retribution Fee/Year	IDR 207,807,180	IDR 233,047,495
Retribution Fee (Rp/KK/Year)	IDR 18,165	IDR 12,714
Retribution Fee (Rp/KK/Month)	IDR 1,514	IDR 1,059

Retribution fees are costs paid by served residents because, according to the Environmental Service, APBD funds not only consist of vehicle operating costs but also include retribution costs. According to table 5.55, the Pemalang District fee is 8% per month. So that each family head has to pay Rp. 1,059/month, this amount had decreased, although not significantly compared to the cost before optimization, which was Rp. 1,1514/month. This is because, after optimization, the number of served populations is more significant. Retribution fees are obtained from the total transportation management costs divided by the number of served households.

4. Conclusions

The existing waste transportation system in Pemalang District has 24 WCS in 9 villages and six sub-districts, with 21 WCS served by 15 dump trucks and 3 WCS served by arm roll trucks with seven containers, leaving an average working hour of 3.07 hours/day. So that the percentage of waste transportation services from WCS to landfill is obtained at 40.017%, and the operational vehicle costs incurred reach IDR 2,361,445,231.21. The existing condition of Kec. Pemalang is classified as not optimal. There need to be additional rotations and working hours that are not yet efficient. Traffic conditions and the roads passed by waste trucks in the existing conditions have a high saturation, namely on Jl. Jend Gatot Subroto, Jl. Ahmad Yani. So that the optimum time to pass through the three roads is obtained at 05.00-12.00 to avoid peak traffic jams at 13.00-17.00 with a vehicle travel speed of 47.42 km/hour. Route optimization was carried out at 16 WCS out of 25 WCS served by DLH Kab. Pemalang. Route optimization followed by transportation operational time becomes more efficient by optimizing the remaining working hours to 1.98 hours/day due to the addition of rotations and adding 38 repetitions/day to 50 repetitions/day and containers from 7 containers to 9 containers. So, the percentage of waste transportation services in 2020 from WCS to landfill is 78.21%. The operational costs of the vehicles incurred have become more efficient even though they are more significant than the existing conditions due to the addition of containers and the addition of remittances, which is IDR 2,913,093,684.31. Optimization is continued with projections for the next five years. The percentage of services in 2025 is 91.6%, with a population of 253,557 people. The number of containers added from 2021 – 2025 is 17 containers, followed by the addition of 15 repetitions and six arm roll trucks. Pemalang Sub-District needs to have SOPs, so transport officers are more orderly and avoid work accidents.

References

Ambariski, P. P., & Herumurti, W. 2016. Sistem Pengangkutan Sampah Berdasarkan Kapasitas Kendaraan Pengangkut dan Kondisi Kontainer Sampah di Surabaya Barat. Jurnal Teknik ITS, D64-D65.

Bachanova et al., 2009. The green issues of postal industry in Europe, 3rd Central European Conference in Regional Science, pp. 901-905.

Badan Pusat Statistik. 2019. Kabupaten Pemalang Dalam Angka 2018. BPS Jawa Tengah.

Badan Pusat Statistik. 2019. Kecamatan Pemalang Dalam Angka 2018. BPS Kabupaten Pemalang.

Badan Standarisasi Nasional. 2002. Standar Nasional Indonesia Nomor SNI 19- 2454-2002 tentang Tata Cara Teknis Operasional Pengelolaan Sampah Perkotaan

Bakas, et al., 2018. LCA of solid waste management systems, Life Cycle Assessment. Springer, pp. 887-926

Burhamtoro. 2016. Biaya Angkut Stationary Kontainer System (SCS) Pada Pengangkutan Sampah. Jurusan Teknik Sipil Politeknik Negeri Malang.

Damanhuri, E & Padmi. 2010. Pengelolaan Sampah. Bandung: Institut Teknologi Bandung.

Dobrowolski et al., 2018. Daily kilometrage analysis for selected vehicle groups. Advances in Science and Technology. Research Journal 12.

Han, H 2015. Waste Collection Vehicle Routing Problem: Literature Review. Journal of Traffic & Transportation. 27, 345-358

Khanza, F. R. 2018. Optimasi Sistem Pengangkutan Sampah Kecamatan Gayamsari Ke TPA Jatibarang Kota Semarang. Universitas Diponegoro Semarang

Ministry of Public Works. 2013. Regulation of the Minister of Public Works Number 03 of 2013 concerning Implementation of Waste Infrastructure and Facilities in Handling Household Waste and Household-like Waste.

MKJI. 1997. Manual Kapasitas Jalan Indonesia (MKJI). Direktorat Jendral Bina Marga Departemen Pekerjaan Umum. Jakarta.

Ridha, M.R., Abdi, C., Mahyudin, R.P. 2016. Studi Optimasi Rute Pengangkutan Sampah Kota Marabahan Dengan Sistem Informasi Geografis. Universitas Lambung Mangkurat. Banjarmasin.

Sri & Endah. 2014. Penentuan Rute Terpendek Pengambilan Sampah di Kota Merauke Menggunakan Algoritma Dijkstra. Seminar Nasional Teknologi Informasi dan Komunikasi Terapan. 4, 1

Stentiford et al., 2011. Solid Waste Technology & Management. Blackwell Publishing Ltd.

Subandriyo et al., 2014. Analisis Perbandingan Biaya Operasional Kendaraan (BOK) Jalan Lingkar Ambarawa dn Jalan Eksisting. Departemen Teknik Sipil. Universitas Diponegoro. Semarang

Wibowo, IF. 2011. Presiksi Kebutuhan Daya Tampung Tempat Pembuangan Akhir (LANDFILL) Sukosari Jumantono Karanganyar pada tahunan 2016. Program DIII Infrastruktur Perkotaan Jurusan Teknik Sipil Fakultas Teknik Universitas Sebelas Maret.