Ogan Ilir District Waste Transportation Cost Calculation Model Using an Engineering Economics Approach

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ABSTRACT

One issue that might lead to environmental disturbances in Indonesia's varied areas is solid waste. It is possible to execute waste management effectively, and one such implementation is the installation of waste transportation. If waste transportation fleet is unable to handle the current waste generation, which may result in waste accumulation, then the problem of transporting waste may arise. In order to address this issue, assistance is required in the form of waste transportation costs. In accordance with the local conditions at the time of the study, this paper analyzes the calculation of waste transportation fees. The collection of information was done to determine how waste transportation was currently operating, including the number of vehicles, the distance that went, their rotation, and their carrying capacity. According to the study's findings, the cost of garbage transportation is Rp. 3,277/km or Rp. 21,257/m^3 for armroll trucks and Rp. 5,980/km or Rp. 86,459/m^3 for dump trucks. These findings show that the fee for Armroll trucks is higher than the levy for dump trucks. This is because Armroll vehicles have a longer service route and use more fuel.

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1. INTRODUCTION

Solid waste is something that is useless or something that has been used and has lost its economic value. Solid waste is also something that is worthless and from an environmental perspective that can cause pollution and disruption to environmental sustainability [1,2]. Solid waste has become a major problem for some urban areas in Indonesia where there is still waste that has not been transported to the Final Disposal Site (TPA) and it is indicated that there are still those who burn or dump solid waste into rivers which can cause environmental damage [3,4]. This requires good waste management and is supported by the role of the government [5]. Infrastructure problems, financial restraints, insufficient service coverage and operational inefficiencies of services, ineffective technology and equipment, inadequate landfill disposal, and restricted use of waste reduction initiatives are the primary barriers to solid waste management in developing nations [6-8]. Integrated solid waste management is required to address these waste-related issues. Technical, institutional, legal, financial, and community involvement are some ways that this management may be put into practice [9,10]. One of the technical aspects is the waste transportation facility which is highly dependent on the financing aspect because this facility requires quite a large cost for its investment and operation [11]. This waste transportation facility is included in the waste management system whose purpose is to move waste from the Temporary Disposal Site (TPS) to the TPA. The types of waste transportation that are usually used are dump trucks and armroll trucks which have a large capacity of 6 m3 so that they can collect waste from more than one TPS. Distance, travel time, iterations and number of TPS are variables that greatly affect waste transportation in various regions [11,12].

Drawing from prior research on the waste transportation system in different parts of Indonesia, such as Aminuddin et al (2020) [13] and Ramadhani et al (2020) [14], which explain the waste transportation system in the Alang-alang Lebar District, Palembang City, we can draw conclusions. Referring to the Minister of Public Works' Regulation No. 03 of 2013, Ramadhani, et al. (2020) [14] examined the type, quantity, route, distance traveled, average speed, and placement of TPS on each vehicle in order to assess the current trash transportation system. The study's findings show that a person can travel between 43 and 93 km in between 1.08 and 2.33 hours. Furthermore, Aminuddin, et al (2020) [13] conducted further research on the time to transport solid waste, especially dump trucks, at the same location. This was done to review the time to transport waste [15]. From both studies, it was shown that the waste transportation system is very vulnerable to distance, travel time and the number of TPS served where each waste transportation service route has a different total working time. Travel distance is a variable in determining the waste transportation route to serve waste collection at each TPS where the route chosen is an efficient route [16]. An efficient route can affect the operational costs of waste transportation, this has been studied by Saputra, et al (2020) [5] who compared the number of waste transportation with the distance traveled. In addition to the distance traveled and the number of transportation, there are factors of route selection and transport capacity according to Ramdhanti, et al (2022) [17]. In order for the waste transportation system to run effectively, government support is needed to support this, one of which is by determining waste transportation fees.

Waste levies are included in regional levies as payment for services provided by the government. With this levy, it is hoped that it can improve the management of urban solid waste starting from reusing waste, composting and recycling and boosting the regional economy [18]. Waste levy rates in each region in Indonesia have been regulated by the regulations of each region with different amounts. However, over time, a revision is needed to the amount of waste levies that are in accordance with the current state of waste management because the regulations that were formed have been around for a long time, around 10 years ago, as experienced by Ogan Ilir Regency. Ogan Ilir Regency has problems regarding the determination of waste levy rates because the regulations were formed in 2011. The determination of this levy rate should depend on the current amount of waste generation so that the amount of the 2011 levy cannot cover the operational costs of waste transportation. For research on the determination of waste levies in Indonesia, not many have done it and are limited to reviewing the operational needs of waste transportation, the contribution of waste levies to the economy and strategies for implementing levies [19 – 25].

The determination of the amount of waste transportation fees needs to be assessed for a certain period to adjust to the amount of waste generated so that the government can optimize waste transportation facilities [26]. Based on the background described, this paper will review the waste transportation fee calculation model with an engineering economic analysis that examines investment costs, operator costs, vehicle maintenance costs, fuel costs and personal protective equipment costs. To obtain this data, it can be done by surveys, observations and interviews with related stakeholders.

2. METHODS

2.1 Research Location

The research location is in Ogan Ilir Regency, South Sumatra Province, Indonesia by taking 5 sub-district locations, namely Tanjung Raja, Indralaya, North Indralaya, South Indralaya, Sungai Pinang where these five sub-districts are included in the waste transportation service area.

2.2 Data Collection Technique

The primary data collection technique uses a survey method and direct observation related to the existing condition of waste transportation referring to Regulation of the Minister of Public Works of the Republic of Indonesia Number/3/PRT/M/2013. Furthermore, the data obtained from these results are used to analyze the distance traveled, the number of trips and the capacity of waste for each waste transportation. Secondary data is obtained from the Central Statistics Agency of Ogan Ilir Regency and the Environmental Service of Ogan Ilir Regency. The waste transportation cost calculation model is modified from the Regulation of the Minister of Home Affairs of Indonesia Number 7 of 2021 where there are the following cost components (1) Operator costs consisting of operator salaries and insurance costs, (2) Truck maintenance costs which are 10% of the vehicle investment price, (3) Tire replacement costs are determined by the distance traveled, iterations, tire prices and tire technical age, (4) Truck fuel costs are influenced by the distance traveled, iterations, fuel consumption, fuel prices and number of vehicles and (5) Costs of personal protective equipment (PPE) used by operators such as safety helmets, vests and boots.

3. RESULTS AND DISCUSSION

3.1 Evaluation of Existing Waste Transportation

In general, waste transportation uses garbage trucks consisting of dump trucks and armroll trucks. Based on data obtained from the study location, there are 4 dump trucks and 3 armroll trucks where each truck has a different waste service area. Table 1 is the result of data collection on the number of trips, the distance from the TPA to the Pool and the capacity of the armroll truck where the furthest distance from the TPA to the Pool is 24.1 km. Table 2 is also the result of data collection on the number of trips, the distance from the TPA to the Pool and the capacity of the dump truck where the furthest distance from the TPA to the Pool is 14.0 km. From the results of the two tables, a waste transportation pattern can be made from the pool, TPS and to the TPA as shown in Table 3. Table 3 is the transportation pattern of armroll trucks and dump trucks which is shown by the trip pattern based on their respective service areas. Table 3 also shows the total distance traveled by dump trucks and armroll trucks where the AT-8099 truck traveled the furthest distance of 104.1 km with a service of 2 TPS points (C1 and C2). While the DT-8085 truck traveled the shortest distance of the other trucks, namely 15.16 km with a service of 5 TPS points (C10, C11, C12, C13 and C14). Table 3 shows that the further the distance from the pool to the TPS and TPS to the TPA, the fewer the number of trips, this is due to the large operational costs of garbage trucks when implementing the ideal number of trips. While the total distance traveled by trucks each day is influenced by the number of trips and the distance from the pool to the TPS, the distance from the TPS to the TPA and the distance from the TPA back to the Pool, the trip applied should be at least 2 trips/day.

To evaluate waste transportation in the study area, it can be done by comparing the waste generated by the population with the capacity of existing waste transportation. Table 4 shows the results of the evaluation of waste transportation in Ogan Ilir Regency where the existing waste transportation only serves 5 sub-districts. The amount of waste generated per day is 531.58 m3 with the assumption that waste generation per person per day is 3 liters/person.day. The total waste generation is not comparable to the capacity of existing waste transportation with a difference of 430.78 m3, which means that it is necessary to increase the number of waste transportation or increase the number of trips on AT-8099, AT-8083, AT-Baru, DT-8098 and DT-8086 trucks. For DT-8097 and DT-8085, additional trips cannot be made because they can exceed the working hour limit of 8 hours per day. Based on the results of the difference in waste generation, the right solution is to increase the number of waste transportation which can be calculated by:

$$Number\ of\ truck = \frac{430{,}78\ m^3}{6\ m^3\ x\ 2\ rotation\ x\ 1{,}2} = 29{,}9 = 30\ unit\ truck$$

Where it is assumed that the truck capacity is 6 m3 with 2 trips a day and a waste compaction factor of 1.2.

Table 1. Waste transportation data served by Armroll Truck (AT)

Kode Truck	Location	Code	Number of Ritations Per Day	Distance from TPA to Pool (km)	Capacity (m^3)
AT-8099	Pool- Serumpun	X1	-	24.1	
AT-8099	TPS Persada	C1	1	-	6
AT-8099	TPS Tanjung Batu	C2	1	-	6
AT-Baru	TPS Pasar Indralaya	C6	2	11.9	6
AT-8083	Pool-Koramil	X2	-	-	
AT-8083	TPS Perum Bakti Guna	C3	1	-	6
AT-8083	TPS Tanjung Putus	C4	1	-	6
AT-8083	TPS Kejaksaan	C5	1	11.6	6
-	TPA Indralaya	Y	-		

Table 2. Waste transportation data served by Dump Truck (DT)

Code of Truck	Location	Code of Location	Number of Ritations Per Day	Distance from TPA to Pool (km)	Capacity (m^3)
DT-8097	Pool- Al-Ittifaqiyah	X3	-	14,0	
DT-8097	Sukaraja	C7	1	-	6
DT-8098	Pool- Asrama Polsek Ogan Ilir	X4	-	10,6	
DT-8098	Tanjung Senai	C8	1	-	6
DT-8098	Tanjung Batu	C9	1	-	6
DT-8085	Pool- Timbangan	X5	-	7,58	
DT-8085	Terminal Timbangan	C10	1	-	6
DT-8085	Pom Bensin Unsri	C11	1	-	6
DT-8085	Jalan Nusantara	C12	1	-	6
DT-8085	RM Sederhana	C14	1	-	6
DT-8085	Palem Raya	X2	1	-	6
DT-8086	Pool- Koramil	C15	-	12,22	
DT-8086	Pasar Indralaya	C16	1		
DT-8086	Serai	Y	1		
-	TPA Indralaya		-		

Table 3. Overview of waste transportation patterns and distances

Code of Truck	Rotation -1	Rotation -2	Rotation - 3	Total Distance (km)	Average Speed (km/h)	Travil Time (h/day)
AT-8099	X1 – C1 – Y	Y – C2 – Y – X1	-	104.1	28.0	3.72
AT-8083	X2 – C4 – Y	Y – C5 – Y	Y – C6 – Y – X2	70.1	20.1	3.49
AT-Baru	X1 – C3 – Y	X1 – C3 – Y – X1	-	56.4	22.4	2.52
DT-8097	X3 – C7 – X3 – Y – X3	-	-	46.7	6.2	7.53
DT-8098	X4 – C8 – C9 – Y – X4	-	-	21.2	6	3.53
DT-8085	X5 – C10 – C11 – C12 – C13 – C14 – Y – X5	-	-	15.16	3	5.05
DT-8086	X2 – C15 – C16 – Y – X2	-	-	24.4	10	2.44

Table 4. Results of Waste Transportation Evaluation

No.	District	Population in 2022 (people)	Waste Generation (m^3/day)	Waste Transport Capacity (m^3/day)
1	Tanjung Raja	45338	136.01	100.80
2	Indralaya	42542	127.63	
3	Indralaya Utara	39515	118.55	
4	Indralaya Selatan	22835	68.51	
5	Sungai Pinang	26962	80.89	
	Total	177192	531.58	

3.2 Waste Transportation Cost Calculation Model

The amount of retribution for waste transportation can be determined by the amount of investment costs, maintenance costs and operational costs. This study modifies the calculation of the Minister of Home Affairs Regulation Number 7 of 2021 concerning waste handling retribution rates. In this section, the calculation of the amount of waste transportation retribution is carried out in existing conditions, namely 4 dump trucks and 3 armroll trucks. Table 5 is the result of the calculation of the amount of dump truck waste transportation levy with a total of 4 units obtained the result of Rp 3277 per km or Rp 21257 per m^3 of waste or Rp 6377 per family per month. The result depends on the investment cost of the truck, operator cost, maintenance cost, truck tire replacement cost, fuel cost and operator PPE cost. To fill in the data, a field survey and interviews with waste transportation drivers were carried out. The calculation of the amount of this levy is intended to obtain a reasonable price based on waste generation and conditions in the field so as to assist the government in optimizing the performance of waste transportation.

Table. 5. Calculation of the amount of Dump Truck levy

Parameter	Result	Information
Number of Truck	4	unit
Type of Truck	Dump Truck	
Investment Price of 1 Truck	Rp300,000,000	price of 1 garbage truck

Parameter	Result	Information
1) Total investasi truk	Rp1,200,000,000	
2) Operator fees	Rp175,200,000	Rp/year
Number of driver	1	people
Number of crew	2	
Number of Truck	4	unit
Driver Salary	Rp1,500,000	/person/month
Crew Salary	Rp1,000,000	/person/month
Insurance	Rp50,000	/person/month
3) Truck maintenance costs	Rp120,000,000	Rp/year
Maintenance percentage	10%	/year
Investment price	Rp300,000,000	price of 1 garbage truck
Number of Truck	4	unit
4) Tire replacement costs	Rp102,273,000	Rp/year
Mileage (km/trip/tire)	46,7	taken the furthest distance from the study
Number of ritations (ritations/day)	4	For 1 truck
Truck tire price (Rp/tire)	Rp3,000,000	For 1 tire
Number of tires per truck (tires/unit)	5	4 tires used + 1 spare tire
Number of trucks (units)	4	Unit
Technical life of truck tires (km/tire)	40,000	for 1 truck
5) Truck fuel costs	Rp409,092,000	Rp/year
Distance traveled (km/trip)	46.7	for 1 truck (taken at the furthest distance from the study)
Number of ritations (ritations/day)	4	For 1 truck
Fuel consumption (liters/km)	0.1	For 1 truck
Fuel price (Rp/liter)	Rp15,000	
Number of trucks for waste service (units)	4	Unit
6) Operator PPE costs	Rp6,000,000	Rp/year
Price of PPE	Rp500,000	/year
Number of driver	1	Person
Number of crew	2	Person
Number of truck	4	unit
TOTAL truck cost (Rp/year)	Rp812,565,000	
TOTAL truck costs are subject to 11% tax (Rp/year)	Rp893,821,500	
TOTAL truck distance per year (km/year)	272,728	distance traveled x rotation x 365 x number of trucks
7) Truck Cost Calculation		
Truck levy (Rp/km)	Rp3,277	total truck cost / total truck distance per year
Total volume of waste transported by trucks (m^3/year)	42,048	truck capacity x 1.2 x trips x 365 x number of trucks
Truck levy (Rp/m^3)	Rp21,257	total truck cost : total volume of waste transported
Waste generation for 1 family = 4 people (m^3/family/month)	0.30	assumed 1 family (4 people) waste volume 1 person 2.5 liters/day

Parameter	Result	Information
Truck Retribution (Rp/Family/Month)	Rp6,377	Truck levy (Rp/m^3) x waste generation for 1 household

Table 6 is the result of the calculation of the amount of retribution from armroll truck waste transportation. The result of the amount of retribution obtained is IDR 5980 per km or IDR 86459 per m3 of waste or IDR 25938 per family per month. From Table 5 and Table 6, it can be seen that the armroll truck retribution is greater than the dump truck retribution, this occurs because of the large cost for the truck fuel indicator where the engine consumption in the armroll truck is greater than the dump truck.

Table 6. Calculation of the amount of Armroll Truck levy

Parameter	Result	Information
Number of Truck	3	unit
Type of Truck	Armroll truck	
Investment Price of 1 Truck	Rp400,000,000	price of 1 garbage truck
1) Total investasi truk	Rp1,200,000,000	
2) Operator fees	Rp131,400,000	Rp/year
Number of driver	1	people
Number of crew	2	
Number of Truck	3	unit
Driver Salary	Rp1,500,000	/person/month
Crew Salary	Rp1,000,000	/person/month
Insurance	Rp50,000	/person/month
3) Truck maintenance costs	Rp120,000,000	Rp/year
Maintenance percentage	10%	/year
Investment price	Rp400,000,000	price of 1 garbage truck
Number of Truck	3	unit
4) Tire replacement costs	Rp170,984,250	Rp/year
Mileage (km/trip/tire)	104,1	taken the furthest distance from the study
Number of ritations (ritations/day)	4	For 1 truck
Truck tire price (Rp/tire)	Rp3,000,000	For 1 tire
Number of tires per truck (tires/unit)	5	4 tires used + 1 spare tire
Number of trucks (units)	3	Unit
Technical life of truck tires (km/tire)	40,000	for 1 truck
5) Truck fuel costs	Rp2,051,811,000	Rp/year
Distance traveled (km/trip)	104.1	for 1 truck (taken at the furthest distance from the study)
Number of ritations (ritations/day)	4	For 1 truck
Fuel consumption (liters/km)	0.3	For 1 truck
Fuel price (Rp/liter)	Rp15,000	
Number of trucks for waste service (units)	3	Unit
6) Operator PPE costs	Rp4,500,000	Rp/year
Price of PPE	Rp500,000	/year
Number of driver	1	Person
Number of crew	2	Person
Number of truck	3	unit
TOTAL truck cost (Rp/year)	Rp2,478,695,250	

Parameter	Result	Information
TOTAL truck costs are subject to 11% tax (Rp/year)	Rp2,726,564,775	
TOTAL truck distance per year (km/year)	455,958	distance traveled x rotation x 365 x number of trucks
7) Truck Cost Calculation		
Truck levy (Rp/km)	Rp5,980	total truck cost / total truck distance per year
Total volume of waste transported by trucks (m^3/year)	31,536	truck capacity x 1.2 x trips x 365 x number of trucks
Truck levy (Rp/m^3)	Rp86,459	total truck cost : total volume of waste transported
Waste generation for 1 family = 4 people (m^3/family/month)	0.30	assumed 1 family (4 people) waste volume 1 person 2.5 liters/day
Truck Retribution (Rp/Family/Month)	Rp25,938	Truck levy (Rp/m^3) x waste generation for 1 household

3.3 Strategy in Optimizing Waste Transportation Cost

There are several strategies that can be done to optimize waste transportation fees in the study area, namely:

1) Improving the mandatory retribution database
Mandatory retribution data is an important thing that can be done to increase regional original income in the retribution sector. With good and correct data collection on the potential objects of waste retribution, the ability and possibility of regional income from the retribution sector can be estimated and the possible obstacles that will be faced in the management process, from receipt to use, can be estimated.
2) Tariff adjustment
Efforts to increase regional original income in the Regional Retribution sector, basically regions are given the freedom to determine the rates for each retribution group according to regional policies.
3) Improving Human Resource Capacity
Human resources are needed as the axis in carrying out activities in an organization, so that the organization is able to carry out its plans so that the desired goals are achieved. In order for market retribution collection to be optimal, the government assigns people to become collectors in the designated markets.

4) Improving supervision
Supervision is carried out with the aim of finding out whether the implementation, in this case the officers with the managers of Regional Original Income, are able to realize the targets that have been planned initially and how the supervision itself is able to carry out its function in order to increase Regional Original Income which is then used to finance the implementation of development in the region.

4. CONCLUSION

Research on the analysis of the calculation of the amount of retribution for waste transportation has been completed. Several conclusions can be drawn from the results of this study, namely:

1) The existing condition of waste transportation in the study area has 2 types of waste transportation, namely armroll trucks and dump trucks, where each of these vehicles has a service route with 1 to 3 trips per day.
2) Based on the results of the evaluation of waste transportation against the amount of waste generated, there is a difference in waste generation of 430.78 m^3, which means that not all waste can be transported in 1 day. To overcome this, it is necessary to add 30 trucks so that all waste can be transported.
3) The calculation of the estimated amount of waste transportation retribution depends on the number, type and distance of transportation and the amount of waste generated by the waste source. The results of the analysis of the amount of waste transportation retribution can be in the form of units per distance (km), per volume (m^3) and per head of family per month.
4) From the results of the analysis of the amount of waste transportation fees, it was found that the waste transportation fees for the Armroll truck type were greater than for the Dump truck, this was due to the large service distance and fuel consumption experienced by the Armroll truck.

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