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THE DETERMINATION OF TRANSPORT ROUTE AND VEHICLE OPERATING COSTS FOR WASTE COLLECTION TRUCK IN PURUK CAHU CITY

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Abstract
Problem that has always been a big issue in urban area is related to municipal solid waste. The problem is getting complex along with the increasing number of population which will result in garbage in the form of solid waste. The increasing number of population is proportional to the level of consumption and activities of the society, which will cause the increase of solid waste. This research will discuss about the analysis of the volume of solid waste, solid waste transportation route, and the number of rotation started from the process of collecting solid waste until the transportation to final landfill. This research also examines the Vehicle Operating Cost (VOC) for truck conventionally that carries the solid wastecollection of Puruk Cahu City. The process of collecting solid waste in PurukCahu City is conducted through two methods, namely collecting solid waste in trash bin by door-to-door technique on the route along the ways that are passed using dump truck with capacity of 8 m^3 andthe second technique isusing hauled containersystem with capacity of 7.5 m^3 by putting container that has been provided in certain locations spread in several places in PurukCahu City as the temporary disposal station (TPS). The volume of solid waste of PurukCahu City along the ways that are passed by the flatbed truck with stationary container system is 48.20 m^3 per day and the volume of solid waste on truck hauled container system is 13.70 m^3 per day.The transportation route for truck with stationary container system is divided into 6 zones of transportation and is conducted everyday. Transportation route for dump truck with hauled container system is divided into 7 zones. The average Vehicle Operating Cost for solid waste collection truckwith stationary container system is IDR.2,893.75/km/m^3 and with hauled container system is 4,690.50/km/m^3.

Keywords: Waste Collection Truck, Route, Vehicle Operating Cost.

Introduction
Puruk Cahu City can be said as a developing city categorized as small city in which the number of population in 2016 is 110,390 people [1]. The increasing number of people in Puruk Cahu City is proportional to the development of the city as well as the activities of the community. The effect of the increasing number of population in Puruk Cahu City is also proportional to the amount of solid waste obtained. The solid waste in the form of solid waste should be handled properly by the government, especially in terms of solid waste transportation in urban area.

Problem in solid waste management in Puruk Cahu City, especially in solid waste transportation from the location of garbage collection to the final landfill, will be discussed in this research. The process of collecting solid waste in Puruk Cahu City is conducted through two methods, namely collecting solid waste in trash bin by door-to-door technique on the route along the ways that are passed using solid waste collection truckwith capacity of 8 m^3 and—the second technique is—using arm roll truck with capacity of 7.5 m^3 by putting container that has been provided in certain locations spread in several places in Puruk Cahu City as the temporary disposal station (TPS) before carrying the solid waste to the final landfill (TPA). However, this condition is not supported by optimum transportation system, especially in terms of the determination of solid waste transportation route, which results in the accumulation of solid waste in some regions. Transportation system with 1 solid waste collection in a region using dump truck and irregular work hours become the causes of the less optimal solid waste transportation in Puruk Cahu City. The transportation pattern using arm roll

truck still carries the solid waste to the final landfill in Tahujan Ontu, and put the container back to the initial location. After then, the second container is brought, and so on. In a day, the arm roll truck carries out two times of transportation. Therefore, there is an accumulation of solid waste that causes the container full and the solid waste comes out. Such condition triggers the complaints from the local community. This research is conducted to identify optimal route of solid waste transportation , Vehicle Operating Cost of dump truck and arm roll truck, as well as to find out the volume of solid waste.

Literature Review

Definition of Solid waste

Solid waste is the waste of human activities or natural processes that have solid form consisting of [2]:

- Domestic solid waste is a result of daily activities in the household, excluding feces and specific solid waste.
- Domestic solid waste from industrial areas, commercial areas, special areas, public facilities, and/or other facilities.
- Specific solid waste includes those containing dangerous and toxic material solid waste which are obtained from disasters, debris, solid waste that technologically cannot be processed, and solid waste that does not occur periodically.

Solid waste is the solid waste from both useless materials and materials of which the main economic part have been used. Solid waste is the worthless solid waste and, in terms of environment, it is a useless material that causes polution and disruption in preserving environment [3]. Solid waste is a material that has no value for common or special production or use; damaged or defective items during manufacturing or excessive material or solid waste [4]. Solid waste is the solid waste with solid characteristic consisting of organic and inorganic materials considered as useless things which should be managed to minimize danger in the environment and to protect development investment [5]. Meanwhile, the sources of solid waste are from the area of settlement, trade, offices/government, industry, open field/parks, agriculture, and plantation [6].

Volume of Solid waste

Solid waste generated from a city can be obtained through survey of measurement or analysis directly in the field. Calculation of the amount of solid waste is conducted using Load-Count Analysis method. The volume of solid waste is measured by tracking the amount and types of the solid waste sources in the storage that has been provided in the form of solid waste bins put in houses and solid waste containers. After then, the volume, weight, type of transportation, solid waste sources are noted and measured are noted and measured. Therefore, the unit of solid waste of population per equivalence is found [7].

System of Solid waste transportation

Transportation is for an operational activity started from the last collection point in a collection cycle to landfill or temporary solid waste dump with a direct individual pattern or from Transfer Depo/Transfer Station, temporary solid waste dump, or communal solid waste shelter to the final landfill. Thus, transportation method as well as the equipment used based on the collection pattern applied.

The system of solid waste transportation is divided into three [8]:

- Solid waste transportation with direct individual collection system (door-to-door).
- Solid waste collection through direct communal collection system (indirect system) or stationary container system or SCS.
- Solid waste collection through transfer depo of hauled container system or HCS.

For solid waste collection using hauled container system or HCS, the collection pattern uses 3 methods, namely [8]:

- Container emptying system using method 1 is through the following process: the truck from the pool heads to the first filled container to carry out solid waste to the final landfill, and then the empty container is put back to the initial place heading to the next filled container to be carried out to the final

landfill, and then the empty container is put back to the initial place, and soon until the last solid waste collection.

- Container emptying system using method 2 is through the following process: the truck from the pool heads to the first filled container to carry out solid waste to the final landfill, and then the truck with empty container from the final landfill heads to the second location to put the empty container and takes the filled container to the landfill, and soon until the last solid waste collection. In the last solid waste collection with empty container from the landfill to the first location, and then the truck is back to the pool without container. This system is applied to certain condition (for example: carrying out solid waste collection in certain hour or minimizing traffic jam).
- Container emptying system using method 3 is through the following process: from the pool, the truck bringing empty container heads to the location of filled container to replace or to take and directly bring the solid waste to the landfill. The truck bringing empty container from the final landfill to the next filled container, and soon until the last solid waste collection.

Transportation method using stationary container system or SCS is:

- Transportation method using stationary container system is usually for small container and conveyance in the form of solid waste collection truckor ordinary truck through the following process: from the pool, the truck heads to the first container then the solid waste is put to the compactor truck and the empty container is put back. The truck heads to the next container until the truck is full, and then it directly goes to the landfill, and soon until the last solid waste collection.

Vehicle Operating Cost

Vehicle Operating Cost is defined as the cost of all factors related to one vehicle operation in a normal condition for certain puIDR.ose. Based on the economic consideration, it is necessary to have balance condition of tariff (the amount of income). Components of vehicle operating cost are divided into three categories, namely standing cost, running cost, and overhead cost [9]. Variable used for measuring transportation cost includes standing cost and running cost. Standing cost is calculated and stable, while running cost is divided into 5 (five) categories, namely tire, fuel, maintenance, labor, and total variable cost [10]. Other experts' opinion states that vehicle operating cost is the addition of all costs for fuel, engine oil, tire, maintenance, depreciation cost, interest rates, insurance, driver's wages, and overhead in which each of them is influence by the speed of the vehicle, which is variable cost per 1000 km [11], or variable cost per km [12]; [13]. Standing cost includes vehicle tax, accident insurance, and physical test of vehicles for a year [14]. In terms of business activity, transportation cost of a production of transportation service that will be offered to the service users is divided into 3 (three) categories [15], namely the cost for company management, vehicle operation, and some expenses like retribution, contribution, donation, and other expenditure related to the business owner and operation.

To make the calculation of basic cost easy, it is necessary to classify the costs with the following approach techniques [15]:

- Cost according to the main function of activity:
  - Production cost is the cost related to the production function or activity in a production process.
  - Organization cost is all of the costs related to the administration function and general cost of the company.
  - Marketing cost is the expense for service promotion.
- Cost according to the obtained service:
  - Direct cost is the cost related directly to the obtained service product, consisting of standing cost *) and running cost **)
  - Indirect cost is the cost related indirectly to the obtained service product , consisting of standing cost *) and running cost **)

    *) Standing cost is the stable cost in spite of the change of the volume of the service product up to certain level. **) Running cost is the cost that changes when there is a change in the volume of the service production.

Based on the categorization of cost, the structure of the main cost of transportation service is explained below [15] [16]:

- Direct Cost
  - Standing Cost
    Standing cost includes vehicle depreciation cost, vehicle investment capital interest, vehicle registration, vehicle test, and vehicle and driver insurance.
  - Running Cost
    Running cost includes driver's salary, fuel, tire, regular inspection, small service, big service, general inspection, body and container reparation, overhaul and rebuilt, truck wash, terminal/platform/port/parking/warehouse and retribution on the road.
- Indirect Cost
  - Standing Cost
    Salary for employees except driver, overtime pay, social allowance, health allowance, uniform, and insurance. Employees besides the driver are the head, administration staff, technical staff, and operating staff. The number of employees besides the driver depends on the size of the business.
  - Running Cost
    Management cost, depreciation of office building, depreciation of pool and workshop, depreciation of inventory/office equipment, depreciation of workshop facilities, cost of office administration/office maintenance, electricity and water cost, telephone and telegram cost, business trip besides driver, company tax, route permit, business permit, and marketing cost.
- Additional expenses and profits. Freight companies are allowed to take additional expense and profit as many as 10% of the vehicle operation.

Related to the production, highway passenger transportation can be determined in several forms of production calculation formula, namely:

- Production-km
  Production of production calculation of kilometer-travel of highway passenger transportation is calculated through the following formula:(Total of SO x frequency/day x operating day/month x operating month/year x km/rit) + Empty kilometer
- Production-ritation
  Production of ritation, total of rotation is calculated through the following formula:Total of bus SO x frequency/day x operating day/month x operating month/year.
- Production for passengers (passengers are transported)
  Production for passengers (passengers are transported). The number of passengers are calculated from: Total of SO x frequency/day x operating day/month x operating month/year x sold capacity/solid waste collection
- Production for km passengers (set-km)
  Production for Passengers-Km (seat-km) Total seat-km (pnp-km) is obtained from the following calculation: Total of SO x frequency/day x operating day/month x operating month/year x mileage/solid waste collection x sold capacity/solid waste collection

Research method

Steps of Data Collection

In this research, there are two types of data, namely primary data and secondary data. Primary data is a data resource obtained directly by conducting observation in the field (survey). Types of data needed for the analysis in this research are:

- Data of Solid waste Volume
  Data of solid waste volume is obtained from survey, in which the survey is conducted in home residents, shops, markets, and government building along the protocol road to the solid waste collection route until the final landfill.
- Data of Road Route and Mileage

Data of road route is obtained from the field observation in order to know the mileage and the length of road in each service area.

- Data of Transportation Time
  Data of transportation schedule is obtained from the field observation and interview with dustman.
- Data of Cycle Time
  Data of cycle time is obtained by calculating travel time from the pool to the location – from the landfill to the pool, time to take out the solid waste can, time to load the solid waste to the can, time to unload the solid waste, and time to take a rest.

Secondary data is an existing data. In this research, the resource can be obtained from the related instance. Types of data needed to support this research are as follow:

- Total population and geographical, social, and economic condition;
- Map of road network of PurukCahu City;
- Map of the location of Temporary disposal station and container (existing);
- Data of dustmen;
- Data of spare parts and operational service of solid waste truck.

Technique of Data Collection

Technique of Data Collection can be seen in Table 1.

Table 1 The Need of Primary Data and Secondary Data

No	Type and Name of Data	Data Collection Technique	Function of Data
1.	Secondary Data a. The number of population, geographical, social, and economic condition; b. Network map of road in PurukCahu City; c. Map Temporary disposal station and container (existing); d. Data of dustmen; e. Data of cost for operational activity and maintenance.	Obtained from related instance such as: Central Bureau of Statistics of Murung Raya Regency, Public Work and Spatial Planning Service of Murung Raya Regency.	a. To estimate the volume of solid waste for the next 5 years b. To determine the route of solid waste transportation c. To find out the volume of solid waste along the road of transportation d. To find out the number of dustmen e. To find out the Vehicle Operating Cost
2.	Primary Data a. Volume of Solid waste	Survey and recording the data of dustbin (plastic bag, solid waste can, container)	a. To calculate the volume of solid waste in urban area b. As a basis to predict the volume of solid waste for the next five years c. As a part of the calculation of the number of truck solid waste collection
	b. Road route and Travel Time	Survey and Observation	a. Identification of the existing route (service route, mileage, etc.) b. To calculate collection

Table 1 The Need of Primary Data and Secondary Data (advanced)

No	Type and Name of Data	Data Collection Technique	Function of Data
	c. Transportation Time	Observation and Interview	To arrange a schedule based on the condition of place and location to make it more effective
	d. Cycle Time	Observation	a. To make a diagram of the existing condition b. To know the loading time c. To know the unloading time d. To know the travel time e. To know the time off

Steps of Data Analysis

Based on the data collected, the data analysis applied in this research is as follow:

- Volume of Solid waste
  Basic theory used to calculate the volume of solid waste is by taking note the volume of solid waste in the place to collect the solid waste such as plastic bag, solid waste can, and container in PurukCahu City. The data collection of the volume of solid waste is conducted in residents and shops along the road route passed by the solid waste truck. Based on the data collection, the volume of solid waste and estimation of total houses are obtained.
- Analysis of Road Route
  The method used for the road route is time and motion study method which examine about the movement of vehicle and dustmen behavior. By using stopwatch, the time needed by the truck to transport solid waste includes loading time, unloading time, travel time from the pool to the first solid waste can heading to the final landfill, factor of road of the condition of non-productive time in all activities. Through GPS and speedometer, the travel time is found out.
- Vehicle Operating Cost is calculated through conventional method using secondary data.
- Prediction of the volume of solid waste for the next-five-year planning toward the number of solid waste vehicle.
  The calculation of solid waste vehicle for the next five years is based on the prediction of the volume of solid waste until the next five years. Through exponential method, the volume of solid waste of the result of research in the field (m^3/day) is calculated. Common method used to estimate the volume of solid waste is through grow-value method. The formula of compound growth is explained below [17]:
  $\boldsymbol{P_n = P_0(1+i)^n}$.
  Information:
  P_n = year of prediction of the volume of solid waste
  P_0 = volume of solid waste based on the research result
  i = the average volume of solid waste (%)
  n = projection time

Results and discussion

Data of Solid Waste Container

Based on the survey in PurukCahu City, solid waste is collected from residents, market, and shops. Survey is conducted in all solid waste containers along the road in PurukCahu City. The volume of solid waste is 61.90 m^3/day. The number of family estimated is 3402. The volume of hauled solid waste containers with arm roll system is 7.5 m^3spread in 14 locations. Survey is conducted for 1 week, and the volume of solid waste is about 96.5 m^3/week. Based on the condition, the volume of solid waste in hauled container with arm roll system in a day is about 13.70 m^3/day. The recapitulation of the survey can be seen in table 2.

Table 2.Data of Recapitulation of Solid waste in PurukCahu and the Surrounding Places

No.	Types of Media to Dump Solid waste	Estimation of the Number of Family	Location	Estimation of the Volume of Municipal solid waste (m^3)
1	2	3	4	5
1	Trash bin	49	Street of Sengaji	0.248
2	Trash bin	44	Street of BinaWarga	0.436
3	Trash bin	41	Street of T. Thiong	0.236
4	Trash bin	539	Street of Ahmad Yani	4.411
5	Trash bin	377	Street of Jend. Soedirman	3.63
6	Trash bin	40	Street of MayjendKatamso	0.413
7	Trash bin	104	Street of K.H. Dewantara	5.205
8	Trash bin	202	Street of Veteran	2.243
9	Trash bin	270	Street of UntungSurapati	6.587
10	Trash bin	50	Street of LetjendSoeprapto	5.11
11	Trash bin	50	Street of GatotSoebroto	0.622
12	Trash bin	54	Street of MakamPahlawan	0.481
13	Trash bin	102	Street of Bukit Tinggi	1.476
14	Trash bin	100	Street of T, Silam	4.308
15	Trash bin	108	Street of Merdeka	6.202
16	Trash bin	70	Street of P. BatuBondang	0.702
17	Trash bin	236	Street of TjilikRiwut	3.707
18	Trash bin	141	Street of Teuku Umar	2.186
19	Container	500	PurukCahu City	13.7
		3042	Total MSW	**61.90**

Data of Survey of Solid waste CollectionTruck

Based on the field observation and interview conducted to the truck's driver and dustmen everyday from Monday to Sunday, the survey locations are divided into 4 zones, namely zome-1, zone-2, zone-3, and zone-4. For zone 1, 2, and 3, the transportation is conducted in the morning. The working hour is from 4:00 a.m. to 9:00 a.m. Meanwhile, service in zone-4 is at noon, with working hours from 2:00 p.m. to 6:00 p.m. The route is the repetition of zone-2 and zone-3. The service areas of truck with arm roll container system are spread in 14 locations. The solid waste collection is carried out alternately everyday by using emptying container system of method 1. The following data in table 3.and table 4. show the result of field observation:

Table 3. Data of Field Observation of Truck with Stationary Container System

No	Zone	Day	Start/End Work Time	Vehicle Capacity (m3)	Capacity of Solid waste (m3)	Average Speed (km/hour)	Time Per Solid waste collection (Hour)	Solid waste collection	Mileage Per Solid waste collection (km)
1.	1	Monday-Sunday	04:22 a.m. – 06:27 a.m.	8.86	± 8	20	2 hours 5 minutes	2	32.25
2.		Monday-Sunday	06:27 a.m. – 07:37 a.m.	8.86	± 6	20	1 hour 10 minutes		
3.	2	Monday-Sunday	04:00 a.m. – 06:00 a.m.	8.21	± 8	15	2 hours	1	19.2
4.	3	Monday-Sunday	05:45 a.m. – 08:19 a.m.	8.21	± 8	13	2 hours 34 minutes	2	39.78

Table 3. Data of Field Observation of Truck with Stationary Container System (advanced)

No	Zone	Day	Start/End Work Time	Vehicle Capacity (m3)	Capacity of Solid waste (m3)	Average Speed (km/hour)	Time Per Solid waste collection (Hour)	Solid waste collection	Mileage Per Solid waste collection (km)
5.		Monday-Sunday	08:19 a.m. – 09:09 a.m.	8.21	± 7	15	50 minutes		
6.	4	Monday-Sunday	13:25 a.m. – 15:20 a.m.	8.42	± 8	15	1 hour 54 minutes	1	22.58

Table 4. Data of Field Observation of Truck with Hauled Container System

No	Service Area	Day	Start/End Work Time	Vehicle Capacity (m^3)	Capacity of Solid waste (m3)	Average Speed (km/hour)	Time Per Solid waste collection (Hour)	Solid waste collection	Mileage Per Solid waste collection (km)
1.	Container Hungan Container Pasar	Monday	09:26 a.m. – 11:18 a.m	± 7.5 ± 7.5	± 7.5 ± 7.5	40	1 hour 52 minutes	2	35.5
2.	Container Kecamatan Container Street of Pahlawan	Tuesday	11:00 a.m. – 12:44 a.m.	± 7.5 ± 7.5	± 7.5 ± 6.5	30	1 hour 44 minutes	2	32.9
3.	Container Sanggrahan Container Bondang	Wednes-day	12:11 a.m. – 13:45 a.m.	± 7.5 ± 7.5	± 7.5 ± 7.5	30	1 hour 34 minutes	2	30.85
4.	Container Rumah Sekda	Thursday	10:37 a.m. – 12:45 a.m.	± 7.5	± 3.0	40	2 hour 18 minutes	2	31.43
	Container Pasar Bahitom			± 7.5	± 7.5				
5.	Container 1 Alun-Alum	Friday	11:27 a.m. – 12:53 a.m.	± 7.5	± 7.5	45	1 hour 26 minutes	3	23.86
	Container 2 Alun-Alun			± 7.5	± 7.5				
	Container Gor Futsal			± 7.5	± 6.0				
6.	Container Kantor PU	Saturday	09:10 a.m. – 10:15 a.m	± 7.5	± 7.5	40	1 hour 5 minutes	2	21.65
	Container 3 Alun-Alun			± 7.5	± 7.5				
7.	Container Komp.Dam	Sunday	09:30 a.m. – 10:08 a.m.	± 7.5	± 7.0	40	40 minutes	1	9.47

Data of Production Cost (Vehicle Operating Cost)

Result of secondary data obtained from technical department operating solid waste collection truckinforms the data of the component of vehicle operating cost with the details of spare part, service fee, price per unit, and frequency of use as in Table 5.

Table 5.Components of Vehicle Operating Cost of Stationary Container Truck

No	Details of Activities	Volume	Price	Frequency
1	2	3	5	6
1.	Standing Cost			
	1) Direct Cost			
	a Vehicle Registration Certificate	1 Set	IDR.1,500,800.00	10,000 km
	b KIR Vehicle	1 Set	IDR.640,000.00	10,000 km
	c Depreciation	1 Set	IDR.300,000,000.	10,000 km
	d Crew salary			
	a) Driver	1 person	IDR.1,900,000.00	10,000 km
	b) Dustman	3 people	IDR.1,700,000.00	10,000 km
	2). Indirect Cost			
	a Controller cost	1 person	IDR.1,700,000.00	10,000 km
	b Cleaning Service cost	1 person	IDR.1,700,000.00	10,000 km
2	Running Cost			
	1) Direct Cost			
	a Fuel	1 liter	IDR.11,100.00	2 km
	b Tire Use (quantity: 7 pieces)			
	a) Outer tire	7 pieces	IDR.1,975,000.00	30,000 Km
	b) Inner tire	7 pieces	IDR.195,000,00	30,000 Km
	c) Tire layer	7 Liters	IDR.75,000.00	30,000 Km
	c Small Servicein each 5.000 km			
	1. Machine oil	10 Liters	IDR.40,000.00	5,000 Km
	2. Grease	2 Kilograms	IDR.25,000.00	5,000 Km
	3. Brake fluid	1 Bottles	IDR.95,000.00	5,000 Km
	d Big Service in each 20,000 km			
	1. Machine oil	10 Liters	IDR.40,000.00	20,000 Km
	2. Transmission oil	4 Liters	IDR.75,000.00	20,000 Km
	3. Axle oil	4 Liters	IDR.75,000.00	20,000 Km
	e General Check up			
	1. Welding air filter housing	1 Unit	IDR.150,000.00	70,000 Km
	2 *c/o assy*dyna (HT 130)	1 Set	IDR.350,000.00	70,000 Km
	3. *Halogen guartz* lamp	1 Unit	IDR.125,000.00	70,000 Km
	4. Air filter	1 Piece	IDR.200,000.00	70,000 Km
	5. Fuse 10Ah	3 Pieces	IDR..8,000,-	70,000 Km
	6. Fuse 15 Ah	5 Pieces	IDR.8,000.00	70,000 Km
	7. 40 Kit HT Dyna	1 Set	IDR.70,000.00	70,000 Km
	8. Bolamp 24 volt H4	2 Pieces	IDR.70,000.00	70,000 Km
	9. Bolamp 24 volt	4 Pieces	IDR.7,500.00	70,000 Km
	10. Radiator water	1 Gallon	IDR.100,000.00	70,000 Km
	f Regular Chek up			
	1. Machine Oil	0,2 Liter	IDR.40,000.00	400 Km
	2. Service for changing seal clutch	1 Set	IDR.60,000.00	400 Km
	3. Accu water	2 Bottles	IDR.25,000.00	400 Km
	4. Tire repairs	1 Piece	IDR.35,000.00	1,429 Km
	5. Filter solar dyna 125 HT	1 Piece	IDR.120,000.00	2,500 Km
	g Maintenance (machine and transmission)			
	1. Maintenance ofnozle, valve,branstop, oil pump cleaning, andradiator cleaning	1 Unit	IDR.780,000.00	70,000 Km

Table 5. Component of Vehicle Operating Cost of Stationary Container Truck (advanced)

No	Details of Activities	Volume	Price	Frequency
1	2	3	**5**	6
	2). Indirect Cost 1. Depreciation cost of Final landfill 2. Maintenance cost ofFinal landfill	1 Unit 1 Unit	IDR.250,000,000. IDR.850,000.00	70,000 Km 70,000 Km
3	*Overhead* - 10% x total components			
4	Production cost - Overhead + total components			

Vehicle Operating Costof Solid waste CollectionTruck

According to table 5., there is an example of the calculation of production cost of solid waste collection truckbased on the price per one unit of solid waste collection truckcomponent as seen below:

Toyota Dyna 110 ET

1) Stationary
   (1) Direct cost
      a. Vehicle registration certificate: 150.08 IDR./km
      b. *KIUER* : 128.00 IDR/km
      c. Depreciation: 4,800.00 IDR/km
      d. Crew salary
         a) Driver's salary: 2,280.00 IDR/km
         b) Dustmen's salary: 6,120.00 IDR/Km
   (2) Indirect cost
      a. Controller's salary: 2,040.00 IDR/km
      b. Staff's salary at the final landfill: 2,040.00 IDR/km
2) Running cost
   (1) Direct cost
      a. Fuel: 5,550.00 IDR/km
      b. Tire use (quantity: 7 pieces)
         a) Inner tire: 460.86 IDR/km
         b) Outer tire: 45.50 IDR/km
         c) Tire layer : 17.50 IDR/km
      c. Small Service every 5,000 Km
         a) Machine oil: 80.00 IDR/km
         b) *Grease* : 10.00 IDR/km
         c) Brake fluid: 19.00 IDR/km
         d) Service cost (15%) : 16.35 IDR/km
      d. Big Service every 20,000 Km
         a) Transmission oil: 15.00 IDR/km
         b) Axle oil: 15.00 IDR/km
         c) Machine oil: 20.00 IDR/km
      e. General check up
         a) Welding air filter housing: 2.14 IDR/km
         b) *c/o assydyna (HT 130)* : 4.50 IDR/km
         c) Guartz halogen lamp: 1.79 IDR/km
         d) Air filter: 2.86 IDR/km
         e) Fuse 10 Ah : 0.34 IDR/km
         f) Fuse 15 Ah : 0.57 IDR/km
         g) 40 Kit HT Dyna: 1.00 IDR/km
         h) *Bolamp* 24 volt H4: 2.14 IDR/km

i) *Bolamp*: 0.43 IDR/km
j) Radiator water: 1.43 IDR/km

f. Regular check up
a) Machine oil: 20.00 IDR/km
b) Service for changing clutch seal: 150.00 IDR/km
c) Accu water: 31.25 IDR/km
d) Tire repair: 24.49 IDR/km
e) Solar filter: 48.00 IDR/km

g. Maintenance (machineand transmission)
a) Maintenance ofnozle, valve,branstop, oil pump cleaning, andradiator cleaning: 11.14 IDR/km

(2) Indirect cost
a. Depreciation cost of final landfill(20 years): 89.29 IDR/km
a. Maintenance cost of final landfill (12 months) : 145.71 IDR/km

3) Over head

*Over head*is calculated by the addition of stationary cost and running cost multiplied with 10%:
10% x 24,344.36 = 2,433.44 IDR/km

4) Production cost

Production cost is the toal of all components of stationary cost and running cost added with *Over head*, so the calculation will be seen below:

$2{,}434.44 + Rp\ 24{,}344.36 = 26.778{,}78$ IDR/km.

Recapitulation of production cost of solid waste collection truckwith stationary container (flatbed container) and hauled container as in table 6.

From Table 6.the results of the solid waste transport vehicle cost calculation, the production cost per kilometer is obtained. Further, based on the route/track passed by the solid waste transport truck, the cost needs which are spent for the vehicle operational can be calculated. From four types of the stationary (flatbed container) container system truck vehicle, the cubic content of solid waste per m^3 in each container size can be calculated. The size of stationary container can be seen in table 7. In the types of hauled container system, 1 unit of sample with 13 unit of container. In a day, hauled container operates in 2 solid waste collection so that the hauled container is able to carry solid waste as much as ± 15 $m^3$of solid waste per day. Data of Vehicle Oeprating Cost (BOK) for each truck is presented in table 7. and table 8.

Table 6. Vehicle Operating Cost of Truck with Stationary Container System and Hauled Container System

No	Production Tariff of Solid waste Collection Truck					
		Stationary Container				Hauled Container
	Details of activities	Toyota Dyna 110 ET IDR/Km	Toyota Dyna 110 ET IDR/Km	Toyota Dyna 115 ET IDR/Km	Mitsubishi Fuso HD 125 PS IDR/Km	Toyota Dyna 130 HT IDRh/Km
1	Standing cost	17,558.08	16,384.92	17,558.00	15,913.22	27,423.63
2	Running cost	6,787.28	6,616.46	7,079.81	4,424.27	4,557.16
3	Over Head	2,434.44	2,300.14	2,463.78	2,033.75	3,198.08
	Total	26,778.79	25,301.52	27,101.59	22,371.24	35,178.87

Table 7. The Vehicle Operational Cost based on IDR per kilometer per cubic meter

No	TypeVehicle	IDR/km	Vehicle Capacity	IDR/km/m^3
1	Toyota Dyna 110 ET	26,778.79	8.208	3,262.52
2	Toyota Dyna 110 ET	25,301.52	8.208	3,082.54
3	Toyota Dyna 115 ET	27,101.59	8.417	3,219.86
4	Mitsubishi Fuso HD 125 PS	22,371.24	8.86	2,524.97
5	Toyota Dyna 130 HT	35,178.87	7.5	4,690.50

Table 8. Vehicle Operational Cost of the Average IDR per kilometer per cubic meter

No	Type Vehicle	IDR/km/m^3		
		Lower Limit	Upper Limit	Average
1	Stationary Container	2,524.97	3,262.52	2,893.75
2	Hauled Container	35,178.87		4,690.50

Service Route Plan

The service route for the solid waste collection truckis planned by finding out the results from the data analysis based on the field survey. The service route can be seen on Table 9.and Table 10.

Table 9. The Service Plan Area for the Stationary Container Truck and the Vehicle Operational Cost (VOC)

Zone	Route Names	Volume of Solid waste (M^3)	Distance (Km)	VOC (IDR/Km/m^3)	VOC (IDR/Trip/day)
1	Street of Bukit Tinggi, Street of Pahlawan, Street of Sengaji, Street of T.Thiong, Street of A.Yani,Street of Puruk Batu Bondang	7.554	18.86	2,893.75	412,290
2	Street of Temanggung Silam, Street of Merdeka	8.108	9.595	2,893.75	225,125
3	Street of Merdeka, Street of Bina Warga, Jalan Ki Hajar Dewantara, Street of Ki Hajar Dewantara I,II,III	8.043	16.343	2,893.75	380,392
4	Street of Veteran, Street of Untung Surapati	8.23	13.824	2,893.75	353,228
5	Jl Letjend. Soprapto, Street of Utama Praja, Street of Diponegoro, Street of Gatot Seobroto, Street of Soedirman	7.732	8.63	2,893.75	193,091
6	Street of Sudirman, Street of Mayjend Katamso, Street of Tjilik Riwut, Street of Teuku Umar,Street of Teuku Umar I,II dan Street of Komplek Dam	7.936	12.101	2,893.75	277,897

Table 10. The Service Area of the Hauled Container Truck and Vehicle Operational Cost

No	Service Area	Volume of Solid waste (M^3)	Distance (Km)	VOC (IDR./Km/m^3)	VOC (IDR./Trip)
1	Container Hungan	7.5	18.34	4,690.50	645,178
2	Container Pasar Pelita Hilir	7.5	17.14	4,690.50	602,964
3	Container Kecamatan	7.5	16.2	4,690.50	569,896
4	Container Street of Pahlawan	6.0	16.69	4,690.50	469,707
5	Container Sanggrahan	7.5	15.73	4,690.50	553,362
6	Container Bondang	7.5	15.12	4,690.50	531,903
7	Container Rumah Sekda	3.0	12.3	4,690.50	346,159
8	Container Pasar Bahitom	7.5	19.0	4,690.50	668,396
9	Container 1 Alun	7.5	8.7	4,690.50	306,055

Table 10. The Service Area of the Hauled Container Truck and Vehicle Operational Cost (advanced)

No	Service Area	Volume of Solid waste (M^3)	Distance (Km)	VOC (IDR./Km/m^3)	VOC (IDR./Trip)
10	Container2 Alun	7.5	9.2	4,690.50	323,645
11	Container Kantor PU	7.0	8.8	4,690.50	288,935
12	Container 3 Alun	7.5	12.7	4,690.50	446,770
13	Container Komplek Dam	7.0	7.53	4,690.50	247,236
14	Gor Futsal	6.0	8.23	4,690.50	231,617

From Table 9. and Table 10. above, the route of the stationary container system truck service, whose solid waste collecting keeps being maintained every weekday, and the hauled container system truck for the container collecting alternately. The route of the service and rotation can be seen on Table 11. And 12.

Table 11. The Route for Stationary Container System Truck Service and Solid waste collection

No	**Zone**	**Day**	**Solid waste collection per Day**	**Information**
1	1	Monday s/d Sunday	1	1 Truck
2	2 and 3	Monday s/d Sunday	2	1 Truck
3	4	Monday s/d Sunday	1	1 Truck
4	5 and 6	Monday s/d Sunday	2	1 Truck
			Total	4 Trucks

Table 12. The Route Plan for the Hauled Container Truck Service and Solid waste collection

No	**Zone**	**Day**	**Service Area**	**Solid waste collection/Day**	**Information**
1	1	Monday	ContainerHungan, ContainerPasarPelitaHilir	2	1 Truck
2	2	Tuesday	ContainerKecamatan, ContainerStreet ofPahlawan	2	
3	3	Wednesday	ContainerSanggrahanandBondang	2	
4	4	Thursday	Container Alun3, PasarBahitom	2	
5	5	Friday	ContainerAlun1,ContainerAlun2	2	
6	6	Saturday	ContainerPU,ContainerRmhSekda	2	
7	7	Sunday	ContainerKomplek Dam, ContainerGor Futsal	2	
				Total	1 Truck

The prediction of the number of solid waste transportation truck vehicles up to 5 years ahead can be predicted by calculate the solid waste generation volume which is obtained from the research results data.

$Pn = Po\ (1 + r)^n$ whereas:

Po = Solid waste Production

r = The average of annual population growth (1.49% per year)

n = Projection period (5 years)

Po = 61.90 x 360

= 22,284 m^3/year

$Pn = 22,284 \times (1 + 0.0149)^1$

= 22,616.03 m^3/year

Thus the next calculation can be seen on Table 13.

Table 13. Projection of the Volume of Solid waste until 2023

Year of Projection	Projection of the Volume of Solid waste m^3/year	Projection of the Volume of Solid waste m^3/day
2018	22,284.00	61.90
2019	22,616.03	62.82
2020	22,953.01	63.75
2021	23,295.01	64.71
2022	23,642.11	65.67
2023	23,994.37	66.65

It can be seen from Table 5.7 that the projection of the solid waste generation is 66.65 m^3/day until 2023, and then the prediction of the fleet needed for 5 years ahead is:

Pn = 66.65 m^3/day

k = Truck tub capacity = 8 m^3

Fleet = $\frac{66.65}{8}$

= 8 truck units

The number of solid waste transport trucks fleet in PurukCahucity is 4 (four) units of fixed container systems, and 1 (one) unit of arm-roll container system truck (Arm roll). In the operational implementation, 1 (one) truck can do 2 (two) solid waste collections. The solid waste trucks fleet needed, 5 (five) pieces of solid waste collection truckvehicles can still serve up to 2023.

Conclusion

Based on the research results and the data analysis about the thesis title, The Analysis of the Determination of Transport Route for solid waste collection truckand Vehicle Operating Costs in PurukCahu City, it can be concluded:

- The Volume of the solid waste generated on the street section in PurukCahu City along the street that can be taken by the stationary container truck system is 48.20 m^3/day. The volume of solid waste generation in the hauled container system is 13.70 m3 / day
- The route for the stationary container system solid waste collection truck is divided into 6 transport zones. Whereby 2 trucks take 1 ritation of solid waste, and 2 trucks take 2 ritation of solid waste. The arm-roll container trash truck route is divided into 7 zones. The solid waste collecting in the container system is still carried out every working day, while the arm-roll container system truck carries 2 containers in a day,alternately for ± 1 week.
- The average vehicle operational cost for the solid waste transportation with stationary container system is IDR 2,893.75/km/m^3, and with the arm-roll container system is 4,690.50/km/m^3

References

[1] Central Bureou of Statistic. (2016). Murung Raya dalam Angka 2016 (Murung Raya in Pigures 2016). Puruk Cahu City Central Bureou of Statistic, Murung Raya Distric.
[2] Ministry of Low and Human Right. (2008). Undang-undang Republik Indonesia Nomor 18 Tahun 2008 tentang Pengelolaan Sampah (Law of The Republic of Indonesia Number 18 Year 2008 Concerning Solid waste Management). Ministry of Low and Human Right of Republic of Indonesia, Jakarta.
[3] Hadiwiyoto, Soewedo. Penanganandan Pemanfaatan Sampah (Handling and Utilization of Solid waste). Jakarta: Yayasan Idayu.
[4] Basriyanta. (2007). Memanen Sampah (Harvest Solid waste). Yogyakarta :Kanisius.
[5] National Standardization Agency. (1994). SNI 03-3243-1994: Tata Cara Pengelolaan Sampah Di Permukiman *(*SNI 03-3243-1994: Procedurs Municipal Solid waste Management in Settlement).
[6] Tchobanoglous, G., Theisen, H., Eliassen, R. (1993). Solid wastes Engineering Principle and Management Issues. International Student Editions. New York: McGraw-Hill Kogakusha.

[7] Damanhuri, Enri and Padmi, Tri. (2010). Pengelolaan Sampah. Diktat Kuliah TL-3104 (Managemant Solid waste. Lecture Dictate TL-3104). Environmental Engineering Study Program, Bandung Institute of Technology.
[8] Ministry of Public Works .(2011). Materi I dan II Bidang Sampah.(The Field of Solid waste,1 and 2) Jakarta: Director General of Cipta Karya.
[9] Rahman, Ramatang (2012). Analisa Biaya Operasional Kendaraan (BOK) Angkutan Umum Antar Kota Dalam Provinsi Rute Palu – Poso (Vehicle Operational Cost Analisys of Public Transportation Between in The Route Province of Palu – Poso).Journalof Engineering and Transportation ManagementVol.2 No.1, 8-21.
[10] Berwick, Mark and Moh. Farooq. (2003). Truck Costing Model for Transportation Managers. Upper Great Plains Transportation Institute North Dakota State University. North Dakota, 2003.
[11] Yanagiya, Kensuke. (1990). Feasibility Study on TheCikampek-Cirebon Toolway Project. Japan International Coorporation Agency. Jakarta.
[12] Lavinson, D, dkk. (2005). Operating Costs for Trucks. Twin Cities : Department of Civil Engineering University of Minnesota, Minnesota.
[13] Sugiyanto, Gito. (2011). Estimation of Congestion Cost of Motorcycles Users in Malioboro, Yogyakarta. Indonesia. International Journal of Civil & Environmental Engineering (IJCEE-IJENS)Vol.11 No.01, 56-63.
[14] Burhamtoro., Wicaksono, Achmad., Bisri, M., Soemarsono.(2013). Model of Municipal Solid Wastes Transportation Cost Type Dump Truck (Case Study at Malang City, Indonesia). International Journal of Engineering & Technology IJET-IJENS Vol.13 No.3, 34-40
[15] Ministry of Transportation of Republic of Indonesia. (2002). Pedoman Teknis Penyelenggaraan Angkutan Penumpang Perkotaan Dalam Trayek Tetap dan Teratur (Technical Guidelines for Implementing Urban Passenger Transportation in Regular and Regular Routes). Decree of The Directorate General Of Land Transportation, Number:SK.687/AJ.206/DRJD/2002. Jakarta.
[16] Ministry of Public Works. (2005). Pedoman Konstruksi Pembangunan Perhitungan Biaya Operasi Kendaraan (Contruction Guidlines for Vehicle Operating Costs),Pd T-15-2005-B.
[17] Supranto, J. (2000). Statistik Teoridan Aplikasi. Jilid 1 Edisi 6 (Theory and Aplication Statistic, Volume 1 Issue 6). Jakarta : Erlangga.