SURABAYA MUNICIPAL SOLID WASTE TRANSPORTATION ROUTING ANALYSIS (STATIONARY CONTAINER SYSTEMS WITH COMPACTOR TRUCKS)

Oni Priasta Eka Risti [1], Hitapriya Suprayitno [2], I.D.A.A.Warmadewanthi [3]

Abstract *– As an improvement policy in municipal solid waste services, since 2013 Dinas Kebersihan dan Pertamanan of Surabaya City has been implemented Stationary Container Systems (SCS) solid waste transportation system using compactor trucks at existing TPS/LPS. Different type of collection system from the old type of collection systems which is Hauled Container System (HCS) using armroll truck, will affect to the amount of transported solid waste at each TPS/LPS, pick up time and transportation time also. Research focused on HCS solid waste transportation system already had been done, therefore this research is focused on SCS solid waste transportation system using compactor truck.*

As the beginning step of this research, descriptive analysis from various literature already has been done to get seven solid waste transportation routing analysis components. There are two aspect of analysis to analyze existing condition of solid waste transportation. The first aspect is technical analysis that calculate value off route factor for each existing solid waste transportation route and the second aspect is financial analysis. This research also analyze ideal condition by optimizing solid waste transportation route and volume. There are two optimization scenarios that is distinguished by number of ritase basis determination. Algorithm of Vehicle Routing Problem with Sequential Insertion is apllied to get route, volume and schedule of solid waste transportation ideal condition. The objective functions of this algorithm are minimizing number of trucks and transportation time but maximizing the use of compactor capacity. The comparison results between existing and ideal conditions show that ideal solid waste transportation condition better than existing solid waste transportation condition because all trucks have equal workload, all ideal solid waste transportation trips have 2 ritase, the value off route factor reduced between 0.13 up to 0.27, average waiting time for each trip reduced to 1.31 hour and cheaper total transportation costs.

The improvement actions to escalate solid waste transportation services based on this research are adding 8 (eight) new TPS/LPS's or ± 6 (six) new trip that the solid waste transportation is served by compactor trucks and addding mini bin of existing TPS/LPS's which have large solid waste volume.

Keywords – ***Surabaya Municipal Solid Waste Transportation, Stationary Container System, Number of Ritase and Off Route Factor Value, One Trip Transportation Time, Route and Volume Optimization, Vehicle Routing Problem with Sequential Insertion Algorithm***

I. INTRODUCTION

Surabaya city government has been increasing compactor trucks only since 2014 as the solid waste transportation vehicle [1]. Solid waste (SW) transportation system which suitable with solid waste loading from garbage bins into compactor, is Stationary Container Systems (SCS). As a different SW transportation systems from TPS/LPS to TPA, therefore transportation time per trip and transported SW volume per ritase will also different from Hauled Container Systems which use arm roll trucks as transportation vehicle.

Total SW transportation operational budgets is only about 2% from whole sanitation sector budgets. Therefore SW transportation routing as one factor of SW transportation asset management is very important to analyse so that all SW will be transported optimally, effectively and efficiently.

With that SW transpotation issues, it is very nessecery to do some research about Surabaya Municipal SW Transportation Routing, especially in Stationary Container SW Transportation Systems using compactor trucks. From this research are expected excellent services in municipal solid waste sector specially on SW transportation.

II. METHODE

Research methodology's are as follows :

1. Literature study at NSPM and reviews of related issues to identify the components of Surabaya municipal SW transportation routing analysis aspects.
2. Field surveys to obtain secondary data from an asset manager of transporting waste which will be used as material SW transportation route analysis.
3. SW transportation field surveys data processing to get existing conditions and doing some route optimization to get ideal condition of Surabaya municipal SW transportations.
4. Doing technical dan cost analysis on both existing and ideal Surabaya municipal SW transportations condition.

Oni Priasta Eka Risti is Master Student with Departement of Civil Engineering, ITS Surabaya, 60111, Indonesia. oni14@mhs.ce.its.ac.id.
Hitapriya Suprayitno is Lecture with Departement of Civil Engineering, ITS Surabaya, 60111, Indonesia. suprayitno.hita@gmail.com.
I.D.A.A.Warmadewanthi is Lecture with Departement of Enviromental Engineering, ITS Surabaya, 60111, Indonesia. warma@its.ac.id.

5. Existing and ideal SW transportations condition comparison to get improvement efforts of Surabaya municipal SW transportations routing.

III. RESULT AND DISCUSSION

3.1. Aspects Of The Surabaya Municipal Solid Waste Transportation Routing Analysis Components

From the observation of existing transportation and learning theory and literature studies on waste transportation, then produced seven aspects of waste transportation routing analysis are as follows :

1) One trip solid waste transportation time .
2) Off Route factors value as transportation boundry time expressed as friction.
3) Number of ritase in each one trip solid waste transportation time.
4) Solid waste volume that transported in each ritase.
5) Waiting time in each solid waste transportation trip.
6) Total solid waste compactor truck.
7) The total overall cost of solid waste transportation.

These factors were obtained based on the calculation formula analysis of solid waste transportation routing, are as follows:

a. The total number of trucks is 19 units with a capacity of 20 m3 per compactor
b. The number, condition and Volume of Solid Waste Mini Bin..
c. Solid Waste Source Volume
d. Time variables of Waste Transportation, which consists of unloading time, charge time, waiting time, time in the landfill and waste transportation operational time.
e. Number of existing ritase and Solid Waste Transportation Route.
f. Travelling route to gain travelling time.
g. Each Solid Waste Mini Bin Weight is 156,14 kg and solid waste density is 353,098 kg.
h. Average speed is 26 km/hour.
i. Transportation cost unit each *Compactor* trucks is Rp. 13.256,29 / km

3.2. Existing SCS Solid Waste Transportation Routing Condition Analysis

From the primary data from waste transportation survey, this research will do technical and cost analysis of existing conditions of transporting waste Surabaya.

Technical analysis use one ritase Solid Waste Transportation Time (P_{scs}), one trip Solid Waste Transportation Time (T_{scs}) dan W (off route factor) are as follows [4] :

$$T_{scs} = P_{scs} + s + a + bx \quad \ldots\ldots\ldots \quad (1)$$

$$P_{scs} = C_t U_c + (N_p - 1) d_{bc} \quad \ldots\ldots\ldots \quad (2)$$

$$W = \frac{H-(t_1+t_2)-N_d\, T_{H/SCS}}{H} \quad \ldots\ldots\ldots \quad (3)$$

Pscs, *Tscs* and W value for all compactor trucks of Surabaya Municipal Solid Waste Transportation Existing Condition are as follows :

Table 1. *Pscs*, and *Tscs* of Surabaya Municipal Solid Waste Transportation Existing Condition

Compactor Truck	Pscs		Tscs	
	survey 1	survey 2	survey 1	survey 2
L 9386 NP	1.23	0.92	3.40	3.62
L 9385 NP	2.62	3.04	4.46	5.02
L 9561 NP	2.20	1.72	6.11	7.05
L 9448 NP	0.82	0.43	4.98	2.48
L 9555 NP	0.83	0.75	2.00	3.47
L 9452 NP	1.03	1.97	4.11	3.64
L 9454 NP	1.06	0.88	6.69	3.78
L 9704 NP	0.58	0.78	4.67	5.02

Source : Calculation Result

Table 2. Off Route Factor Value of Surabaya Municipal Solid Waste Transportation Existing Condition

Compactor	Survey 1		Survey 2	
	T_{scs}	w	T_{scs}	w
L 9386 NP	3.40	0.48	3.62	0.45
L 9385 NP	4.46	0.33	5.02	0.30
L 9561 NP	6.06	0.17	7.05	0.07
L 9448 NP	4.98	0.34	2.48	0.66
L 9555 NP	2.00	0.54	3.47	0.50
L 9452 NP	4.11	0.40	3.64	0.35
L 9454 NP	6.69	0.11	3.78	0.40
L 9704 NP	4.67	0.31	5.02	0.16

Source : Calculation Result

The results of direct observation of existing solid waste transporting compactor trucks is the truck need to wait until whole mini bin filled and caused idle time, whereas a waste transport operations continue to run. Compactor trucks idle waiting time is a factor of big off route factor value and the solid waste transportation time exceeding the operational time of transporting waste ehich is assigned by DKP Kota Surabaya, starting at 05:00 up to 13.00 WIB.

The total cost of the existing condition of one solid waste transportation trip per compactor is as follows:

Table 3. The Total Cost Of The Existing Condition Of One Solid Waste Transportation Trip

Compactor	TPS/LPS	Transportation Time			Transportation Total Cost (Rp.)	Per One Kg Solid Waste (Rp/Kg)
		Survey 1 (hour)	Survey 2 (hour)	Ave (hour)		
L 9386 NP	Pandegiling	4.18	4.40	4.29	1,436,044.72	227.08
L 9385 NP	SCS Jalan 03	5.36	5.59	5.47	1,831,109.89	293.19
L 9561 NP	Kayun, Simpang Dukuh, Candipuro, Pecindilan, Tambak Rejo	6.61	7.45	7.03	2,352,975.54	154.56
L 9448 NP	Semut Kali	5.27	2.73	4.00	1,338,449.45	192.64
L 9555 NP	Keputran	3.70	3.97	3.83	1,282,680.72	273.84
L 9452 NP	Ngagel, Gayung Pring, Boktong	4.83	5.21	5.02	1,678,173.94	170.61

Compactor	TPS/LPS	Transportation Time			Transportation Total Cost (Rp.)	Per One Kg Solid Waste (Rp/Kg)
		Survey 1 (hour)	Survey 2 (hour)	Ave (hour)		
L 9454 NP	Jemur Wonosari, Boktong	7.14	4.80	5.97	1,997,914.64	266.58
L 9704 NP	Taman Flora	5.50	6.70	6.10	2,041,135.41	297.11
Transportation Average Cost					1,744,810.54	233.12

Source : Calculation Result

3.3. Ideal SCS Solid Waste Transportation Routing Condition Analysis

In this study conducted by two (2) optimization scenarios, is as follows :

A. The first scenario is the optimization of the waste transport route optimization with no change in the composition of the TPS / LPS with compactor charge for transporting the garbage in TPS / LPS. Optimization is done in this first scenario is to try to maximize the total volume transported and eliminate staple condition that the existing condition often occurs in a single trip waste transportation using this compactor trucks.

B. The second scenario is the optimization of waste transportation route optimization that maximizes the total volume transported, and minimize the time transporting waste. The second scenario is no longer considering the composition antaraTPS / LPS with compactor charge for transporting the garbage in TPS / LPS. Optimization in this scenario using Vehicle Routing Problem with Sequential Intertion algorithm.

The results of the transport route optimization with scenario A generate off route factor value and transported solid waste volume is as follows:

Table 4. Value of One Ritase Solid Waste Transportation Time (P_{scs}), One Trip Solid Waste Transportation Time (T_{scs}) Dan *W* (Off Route Factor) of Scenario A Optimization

Compactor	Ritase	Pscs (hour)	Tscs (hour)	t_1 (hour)	t_2 (hour)	W (hour)
L9561NP	1	0.56	4.08	0.30	0.53	0.39
	2	0.57				
L9553NP	1	0.52	4.16	0.23	0.53	0.38
	2	0.45				
L9386NP	1	0.96	4.83	0.37	0.53	0.28
	2	0.77				
L9557NP	1	0.96	2.33	0.37	0.53	0.60
L9455NP	1	0.57	1.79	0.37	0.53	0.66
L9454NP	1	0.82	5.15	0.28	0.53	0.25
	2	0.41				
L9453NP	1	1.44	2.88	0.08	0.53	0.56
L9451NP	1	0.57	1.86	0.93	0.53	0.58
L9448NP	1	0.61	4.41	0.43	0.53	0.33
	2	0.80				
L9554NP	1	0.62	4.59	0.43	0.53	0.31
	2	0.62				
L9560NP	1	0.62	4.56	0.43	0.53	0.31
	2	0.59				
L9384NP	1	0.51	5.73	0.18	0.53	0.19
	2	0.82				
L9389NP	1	0.51	5.38	0.18	0.53	0.24
	2	0.70				
L9555NP	1	0.79	5.24	0.28	0.53	0.24
	2	0.61				
L 9704 NP	1	0.70	5.75	0.25	0.53	0.18
	2	1.01				
L9452NP	1	0.68	5.35	0.55	0.53	0.20
	2	0.56				
L9385NP	1	3.31	4.13	0.34	0.53	0.37

Source : Calculation Result

Table 5. Transported Solid Waste Volume of Scenario A Optimization

Compactor	TPS/LPS	Tranpsorted Volume	
		Ritase 1 (m^3)	Ritase 2 (m^3)
L 9561 NP	Simpang Dukuh	20	3.76
	Kayun	-	16
L 9553 NP	Kayun	20	
	Candipuro	-	17.6
L 9386 NP	Pandegiling 1	20	16
L 9557 NP	Pandegiling 2	20	-
L 9455 NP	Taman Ketampon	20	-
L 9454 NP	Jemur Wonosari	20	-
	Srikana 1	-	16
L 9453 NP	Boktong	20	-
L 9451 NP	Ngagel	20	-
L 9448 NP	Semut Kali	20	6.4
	Ngagel	-	6.4
L 9554 NP	Tambak Rejo 1	20	20
L 9560 NP	Tambak Rejo 2	20	19,2
L 9384 NP	Srikana 1	20	-
	Jemur Wonosari	-	20
L 9389 NP	Srikana 2	20	-
	Taman Flora 2	-	20
L 9555 NP	Keputran	14	-
	Gayung Pring	-	2
	Jemur Wonosari	-	2.24
L 9704 NP	Taman Flora 1	20	-
	Boktong	-	6.4
	Taman	-	6.4
L 9452 NP	Gayung Pring	20	-
	Taman Flora 3	-	16
L 9385 NP	SCS Jalan 03	15.92	-
TOTAL		524.32	

Source : Calculation Result

Vehicle Routing Problem with Sequential Intertion algorithm which used in this research has objection is as follow [2] :

$$\text{Minimize } Z = \{\omega_{NV} NV, \omega_{TCT} TCT\}$$

Illustration of Vehicle Routing Problem with Sequential Insertion algorithm Application for Solid Waste Transportation Route Determination is as follow:

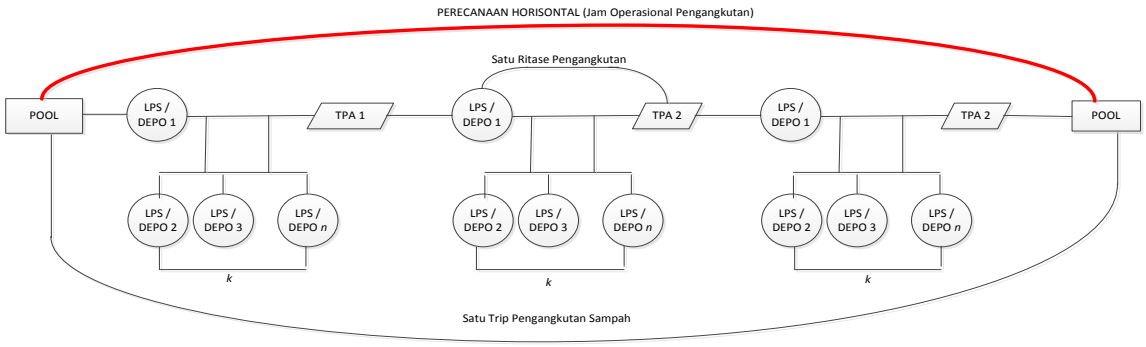

Figure 1. Illustration of Vehicle Routing Problem with Sequential Insertion algorithm Application for Solid Waste Transportation Route Determination

The results of the transport route optimization with scenario B generate off route factor value and transported solid waste volume is as follow :

Table 6. Value of One Ritase Solid Waste Transportation Time (P_{scs}), One Trip Solid Waste Transportation Time (T_{scs}) Dan W (Off Route Factor) of Scenario B Optimization.

Compactor Truck	Ritase	Pscs (hour	Tscs (hour	t1 (hour	t2 (hour	W (hour
A	1	1.04	6.00	0.28	0.53	0.15
	2	1.16				
B	1	1.08	5.96	0.08	0.53	0.18
	2	1.01				
C	1	1.34	6.01	0.41	0.53	0.13
	2	1.17				
D	1	2.11	5.85	0.37	0.53	0.16
	2	0.42				
E	1	0.70	5.49	0.25	0.53	0.22
	2	0.74				
F	1	1.27	5.64	0.30	0.53	0.19
	2	0.79				
G	1	0.94	5.54	0.25	0.53	0.21
	2	0.94				
H	1	0.85	4.96	0.37	0.53	0.27
	2	0.84				
I	1	1.06	6.03	0.18	0.53	0.16
	2	0.72				
J	1	0.86	5.60	0.43	0.53	0.18
	2	1.24				
K	1	0.69	6.09	0.25	0.53	0.14
	2	1.44				
L	1	0.87	5.08	0.28	0.53	0.26
	2	1.27				
M	1	3.31	6.06	0.34	0.53	0.13
	2	0.28				
N	1	0.98	5.81	0.28	0.53	0.17
	2	1.33				

Source : Calculation Result

Table 7. Transported Solid Waste Volume of Scenario B Optimization

Compactor	TPS/LPS	Transported Valume	
		Ritase 1 (m^3)	Ritase 2 (m^3)
A	Jemur Wonosari	17.69	-
	Boktong	2.31	11.06
	Simpang Dukuh	-	1.65
	Taman Ketampon	-	4.29
B	Boktong	8.74	4.29
	Gayung Pring	11.06	10.95
C	Tambak Rejo	20	13.17
	Pandegiling	-	6.83
D	Pandegiling	13.27	-
	Tambak Rejo	6.53	13.65
E	Taman Flora	20	16.37
	Ngagel	-	1.64
F	Simpang Dukuh	11.06	11.06
	Srikana	8.94	7.06
G	Ngagel	12.38	12.38
	Pandegiling	7.62	7.62
H	Taman Ketampon	11.06	11.06
	Candipuro	8.94	8.66
I	Srikana	20	-
	Jemur Wonosari	-	17.69
J	Semut Kali	14.15	-
	Tambak Rejo	5.85	-
	Srikana	-	20
K	Taman Flora	19.64	-
	Jemur Wonosari	-	6.86
	Pandegiling	-	7.41
	Kayun	-	5.73
L	Keputran	9.73	-
	Kayun	10.27	20
M	SCS Jalan	15.92	-
	Semut Kali	-	12.25
N	Keputran	4.27	-
	Pandegiling	13.26	-
	Tambak Rejo	-	20

Source : Calculation Result

The total cost of the ideal condition of one solid waste transportation trip per compactor as a result for both optimizations are as follows [3]:

Table 8. The Total Cost Of The Ideal Condition Of One Solid Waste Transportation Trip Scenario A Optimization

Compactor	TPS/LPS	Tranportation Time	Transportation Total Cost (Rp)	Per One Kg Solid Waste (Rp/Kg)
L9561NP	Simpang Dukuh, Kayun	4.92	1,645,280.03	117.19
L9553NP	Kayun, Candipuro	4.93	1,649,605.02	124.25
L9386NP	Pandegiling	5.73	1,916,064.85	150.73
L9557NP	Pandegiling	3.23	1,080,426.20	152.99
L9455NP	Taman Ketampon	2.69	900,331.74	127.49

Compactor	TPS/LPS	Tranportation Time	Transportation Totsl Cost (Rp)	Per One Kg Solid Waste (Rp/Kg)
L9454NP	Jemur Wonosari, Srikana	5.96	1,995,956.56	157.02
L9453NP	Boktong	3.49	1,169,326.59	165.58
L9451NP	Ngagel	3.32	1,112,472.24	157.53
L9448NP	Semut Kali	5.38	1,799,394.31	155.37
L9554NP	Tambak Rejo	5.55	1,857,898.60	131.54
L9560NP	Tambak Rejo	5.53	1,849,643.70	133.63
L9384NP	Jemur Wonosari, Srikana	6.45	2,158,528.33	152.83
L9389NP	Srikana, Taman Flora	6.09	2,039,090.35	144.37
L9555NP	Keputran, Gayung Pring,	6.05	2,025,676.58	314.52
L 9704 NP	Taman Flora, Boktong,	6.53	2,186,089.24	188.76
L9452NP	Gayung Pring, Taman	6.43	2,151,765.47	169.28
L9385NP	SCS Jalan 03	5.06	1,674,948.13	297.98
Transportation Average Cost			1,718,382.23	167.12

Source : Calculation Result

Table 9. The Total Cost Of The Ideal Condition Of One Solid Waste Transportation Trip Scenario B Optimization

Compactor	TPS/LPS	Tranportation Time	Transportation Total Cost (Rp)	Per One Kg Solid Waste (Rp/Kg)
A	Jemur Wonosari, Boktong, Simpang Dukuh, Taman Ketampon	6.82	2,281,417.26	174.65
B	Boktong, Gayung Pring	6.57	2,199,752.54	177.83
C	Tambak Rejo, Pandegiling	6.95	2,327,030.58	164.76
D	Tambak Rejo, Pandegiling	6.75	2,259,708.57	191.33
E	Taman Flora, Ngagel	6.28	2,100,192.98	156.50
F	Simpang Dukuh, Srikana	6.48	2,167,077.90	161.04
G	Ngagel, Pandegiling	6.33	2,116,548.35	149.86
H	Taman Ketampon, Candipuro	5.86	1,959,326.48	139.74
I	Srikana, Jemur Wonosari	6.75	2,259,057.28	169.75
J	Semut Kali, Tambak Rejo, Srikana	6.56	2,196,289.46	165.04
K	Taman Flora, Jemur Wonosari, Pandegiling, Kayun	6.87	2,300,262.54	164.38
L	Keputran, Kayun	5.90	1,972,849.17	139.68
M	SCS Jalan 03, Semut Kali	6.94	2,323,469.06	233.60
N	Keputraan, Pandegiling, Tambak Rejo	6.63	2,216,966.52	167.29
Transportation Average Cost			2,191,424.91	168.25

Source : Calculation Result

3.4. Comparison Between Existing and Ideal Solid Waste Optimizing Transportation Condition

Comparison Between Existing and Ideal Solid Waste Optimizing Transportation Condition is as follow :

Table 10. Comparison Between Existing and Ideal Condition

No.	Parameter	Eksisting Condition	Ideal Condition	
			Scenaio A Optimization	Scenaio B Optimization
1.	Single Transportation Trip Time	The Fastest is 2,48 hour, the longest is 7,45 hour	Between 2.69 until 6.55 hour	Between 5.83until 6.93 hour
2.	*Off route* Factor Value	Between 0,07 until 0,66	Between 0.18 until 0.67	Between 0.13 until 0.27
3.	Number of Ritase	0 - 2 ritase but with staple or uncomplete solid waste transportation condition	1 or 2 ritase	2 ritase

No.	Parameter	Eksisting Condition	Ideal Condition	
			Scenaio A Optimization	Scenaio B Optimization
4.	Transported Solid Waste in One Trip	Transported solid waste volume is much lower or bigger than compactor capacity that is 20 m^3	Smallest Transported solid waste volume in one ritase is 4.24 m^3	Smallest Transported solid waste volume in one ritase is 13.65 m^3
5.	Waiting Time	Between 0,95 until 4,33 hour, with average waiting time is 2,44 hour per transportation trip	Average solid waste unloading time is 1.5 hour plus endless waiting time of 8 hours opertional time	Average solid waste unloading time is 1.31 hour plus endless waiting time of 8 hours opertional time
6.	Number of Trucks	19 compactor truck units	17 compactor truck units	14 compactor truck units
7.	Transportation Average Cost	Transportation Average Cost is Rp. 1,744,810.54	Transportation Average Cost is Rp. 1,718,382.23	Transportation Average Cost is Rp. 2,191,424.91

Source : Analysis Result

3.5. SCS Solid Waste Transportation Routing Improvement Efforts

From the results of the optimization scenario A, there is a reduction of two compactor trucks and four routes of transportation which transporting waste time in one tripnya less than 4 hours. While the ideal conditions optimizations transport of scenario B, there is a reduction of five units of the compactor trucks. Therefore, it is necessary to do additional new TPS / LPS that served by compactor truck so that the truck compactor existing assets can increase solid waste transportation services.

The addition of new TPS / LPS that can be changed from the transportation services by armroll trucks into a compactor truck is TPS / LPS were transported by trucks armroll which have useful life of ≥ 20 years. From the data TPS / LPS and solid waste transporting vehicles asset Department of Hygiene and Landscape of Surabaya City obtained TPS / LPS that could be improved its transportation services using the compactor trucks are as follows:

Table 11. TPS/LPS Datas Which Have Huge Solid Waste Volume and The Transportation Served By ≥ 20 Year Usefull Life Armroll Trucks

TPS/LPS Name	Location	Solid Waste Volume (m^3)	Armroll Truck Police Number	Year of Armroll Truck Acquisition	Rayon
Demak (Kali Butuh)	Jl. Demak	28	L 8038 PP	1993	Central
Dupak Prau	Jl. Babatan Dupak	28	L 8061 SP	1995	Central
Pasar Kapasan	JL.Pasar Kapasan	14	L 8075 QP	1995	Central
Tubanan	Jl. Simpang Darmo	14	L 8038 RP	1993	West
Manukan Kulon	Jl. Manukan Kulon	28	L 8075 QP	1995	West
Tambak Deres	Jl. Tambak Deres	14	L 8042 RP	1993	North
Kalibokor	Jl. Kalibokor	28	L 8037 PP	1993	East
Depo Semolowaru	Jl. Semolowaru	28	L 8075 QP	1995	East

Source : Department of Hygiene and Landscape of Surabaya City

Assuming the number of trash cans at TPS / LPS above is ± 30 units and unloading time is ± 45 minutes, the time required for each truck compactor at each TPS / LPS per ritase is ± 1 hour. While assuming the time required for Pool - TPS / LPS plus TPA - Pool is ± 1 hour and travel time TPS - TPA -TPS is 2 hours. For additional TPS / LPS at Table 11 with the time constraints ideal for 1.12 hours, or the value of the route is off factor of 1.5, then dibutukan 6 trip transporting waste in TPS / LPS

Other than increasing the number of TPS / LPS which served to transport it by truck compactor, it is also necessary additional number of solid waste mini bin at existing TPS / LPS with large solid waste volume such as LPS Pandegiling, TPS Tambak Rejo, and TPS Jemur Wonosari. So one transportation trip can more effective because the waiting time of mini bin filling is also getting smaller.

IV. CONCLUSIONS

The conclusions that can be drawn from this study are as follows :

1. Seven component aspects of Surabaya municipal solid waste transportation routing analysis are as follows :
   1) One trip solid waste transportation time .
   2) Off Route factors value as transportation boundry time expressed as friction.
   3) Number of ritase in each one trip solid waste transportation time.
   4) Solid waste volume that transported in each ritase.
   5) Waiting time in each solid waste transportation trip.
   6) Total solid waste compactor truck.

7) The total overall cost of solid waste transportation..

2. Existing waste transportation from direct field observation have extremely different one trip transporting different to another which are the fastest time is 2.48 hours with off route factor value is 0.66 and the longest time is 7.45 hours with off route factor value is 0.07. This shows the workload on each truck compactor is not evenly distributed.
3. Transporting waste ideal conditions have been conducted with two scenarios waste transportation route optimization, with the result value of factor off Route W better than the existing condition of transporting waste. The both optimizing results are as follows:
   - Waste transportation route optimization scenario A still found time one trip transport and waste volume in one ritasenya that is too small, so that the highest value off route freight factor was 0.67.
   - Waste transportation route optimization scenario B is rated as the most excellent optimization scenario due to the workload of the entire truck compactor is 2 ritase in one trip transportation, one trip transporting entire truck compactor ± 6-7 hours. In addition, the obtained off route factor value for entire truck is between 0.13 up to 0.27 judged to have reached the most effective value of the transport optimization by using this compactor trucks.
4. Comparison between the ideal conditions and eksiting condition has been done with 7 (seven) aspects of the components, and concluded that the ideal conditions optimization results better than the existing condition of solid waste transportationg with compactor trucks.
5. Improvement efforts to improve solid waste transporting services by truck compactor is adding 8 (eight) new TPS / LPS or ± 6 (six) new solid waste transportation trip which using a pattern SCS and increase the number of solid waste mini bin assets on existing TPS / LPS's which have large solid waste volume such as TPS Jemur Wonosari, TPS Tambak Rejo, and LPS Pandegiling.

V. RECOMMENDATIONS

Suggestions from the research that has been done is as follows:

1. Futher research regarding waste transport by truck compactor at 2 or 3 years with the addition of TPS / LPS which served Stationary Container Systems.
2. The further research referred to in number 1 can be done using heuristic optimization solution with the preparation of the technical data for the transport of sufficient training data and testing the data, so that the schedulling and routing optimization results can be achieved more accurate. This is necessary because the total cost of the trip transportation is quite expensive, but on the other hand the transportation operating budget is only ± 5% of the total budget.

BIBLIOGRAPHY

[1] *Data Kendaraan Pengangkutan Sampah.* Surabaya: Dinas Kebersih**an dan Pertamanan Kota Surabaya, 2015.**

[2] Fitria, L., Susanty, S., & Suprayogi, Penentuan Rute Truk Pengumpulan dan Pengangkutan Sampah di Bandung, Jurnal Teknik Industri, 51-60, 2009.

[3] Marpaung, H. M, *Optimasi Kebutuhan Kendaraan Angkutan Sampah di Kota Surabaya*, Surabaya: Program Pasca Sarjana Jurusan Teknik Sipil FTSP-ITS Manajemen dan Rekayasa Transportasi ITS, 2004.

[4] Thobanoglous, G.T., *Integrated Solid Waste Management*., McGraw-Hill, 1993.