J. Appl. Environ. Biol. Sci., 7(2)39-44, 2017
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ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Technical Evaluation of Solid Waste Transport in Rappocini District in Makassar

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Received: November 1, 2016
Accepted: January 2, 2017

ABSTRACT

Being occupied by 160,499 residents, the solid waste (SW) generation rate in Rappocini district in Makassar City was 441.37 m³/day. The SW service coverage was only 117.04 m³, or 27% from the total SW. The SW transport efficiency is generally low, mostly only 1 trip/day. This research was aimed to evaluate the technical aspect of SW transport in Rappocini District. The SW transport method applied manual single location (SLS) service and multi-location service (MLS). Daily operation of eight SW transport vehicles was observed in order to determine the transport efficiency. The SW transport activity of each vehicle was followed in order to measure the travelling time duration from pool to transfer station and return, SW loading and unloading to and from the vehicle, from transfer station to final disposal station, SW disposal to landfill, return from landfill to garage, between served transfer stations, and off route factor. Results of this study showed that the both SLS and MLS transport efficiencies were only 1 trip/day. Optimization of the SW transport efficiency was done by recommending the decrease of off route factor to 0.15 and the use of armroll truck for reducing the pick-up time of the SLS mode. This approach could increase the SLS transport efficiency to 4 trips/day. Achievement of national target for 100% SW service in 2020 requires the provision of 38 containers of 8 m3 and 10 armroll trucks. The MLS operation could only serve SW transport of 5 trips/day. Accomplishment of the MLS service could be made by adding the three SLS dump trucks after replacement with armroll trucks, and one additional dump truck with daily service of 2 trips/day.

INDEX TERMS—efficiency, solid waste, transport efficiency, transfer.

I. INTRODUCTION

The solid waste (SW) transport service in Rappocini District of Makassar City has curently served by 8 vehicles, which consisted of 5 dump trucks of 11-14 m^3 capacity for single location operation, and 3 dump trucks of 8 m^3capacity for multi-location service. These trucks were operated for afternoon to evening service. The total population of 160.499generated441.37 m³/day ofSW. The SW transport only covered 8 sub-districts in Rappocini District from a total 10. The SW haul time from the transfer station (TS) to the landfill took 2-3 hours. This haul time was too long due to the SW transport operation was performed during peak time.

The sub districts in Rappocini have not been facilitated with permanent transfer stations (TS). The SW transport activities were still done manually. In some TS, transport activities were served by single location service (SLS) trucks, whereas in some other sites, multi location service (MLS) trucks were operated to pick-up the SW from sites to sites. In SLS mode of operation the SW should be loaded from handcarts onto the trucks by the collection crew. Therefore, these trucks should park and wait for a considerably long time for loading process. The MLS transport vehicles picked up the SW which was piled in roadsides manually. These trucks picked-up the piled SW from sites to sites. When the SLS and MLS vehicles had been fully loaded, they would haul the SW to the landfill for final disposal. This situation reflects typical SW management performance in developing countries, which was generally supported with limited funding, infrastructure facilities, human resource, and technological and management skill[1][2].

The SW transport service in Rappocini District was done for 1 trip/day only. This low transport efficiency value does not meet the minimum service standards according to the Decree of the Minister for Human Settlement and Regional Infrastructure No. 534 / KPTS / 2001, which stipulated that the ideal SW transport service should be 2-6 trips/day [3].

The objectives of this study were to perform technical evaluation the SW transport activities in Rappocini District, and to provide recommendations for better service.

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II. MATERIALS AND METHODS

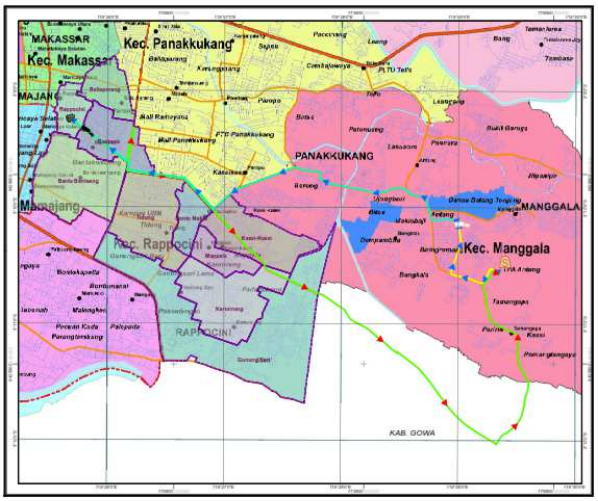

Figure I. Map of Solid Waste Transportation

The SW transport efficiency was evaluated by measuring the daily operation performance. Eight dump trucks were followed for 8 days in order to observe the unit operation time periods. The following operation time periods of the trucks were recorded: (a)travel from garage to TS (t_1), (b) loading the SW onto the trucks (pc), (c)travel between TS's (dbc), (d)SW haul from TS to landfill (h), (e)SW unloading in landfill (s), (f)return from landfill to garage (t_2), (g)daily work activities (H), and (h) off route factor (W). The SW transport efficiency for the SLS operation was calculated according to Hauled Container System (HCS) method, whereas that of the MLS was determined based on Stationary Container System (SCS) method [4] [5].

Equations for SLS transport operation method:

- Pick up time : $P_{SLS} = p_c + u_c + dbc$ (1)
- Transport time (hr/day) : $T_{SLS} = P_{HCS} + s + h$ (2)
- SW transport efficiency (trip/day) : $N_d = [(H*(1-W)) - (t_1+t_2)]/T_{SLS}$ (3)

Equations of MLS transport method:

- Number of SW pick-up site : C_t = truck container capacity/SW volume in each pick up site (4)
- Pick up time : $P_{MLS} = C_t.U_c + (np-1)\ dbc$ (5)
- Transport time (hr/day) : $T_{MLS} = Pscs + s + h$ (6)
- SW transport efficiency (trip/day): $Nd = [(H*(1-W)) - (t_1+t_2)]/T_{MLS}$ (7)

The number of SW container for MLS service could be determined using the following equation:

$$\text{Estimated total number of container} = \frac{total\ number\ of\ population * SW\ generation\ rate}{container\ capacity * compaction\ factor} \quad (8)$$

III. RESULTS AND DISCUSSION

SW Density

The SW densities in handcarts and in truck's containers were done in order to determine the SW compaction factor. The compaction factor value is needed to determine the number of SW containers, which should be provided for supporting the SLS transport system. Data of the average SW densities in collection and transport vehicles were shown in Table 1.

Table I. Average SW densities of SW in collection handcarts and transport vehicles[6]

Type of vehicle	Average SW density (kg/m^3)	Compaction factor (2)/(1)
Handcart	151.41 (1)	1.33
Transport truck	200.85 (2)	

With the current SW generation rate of 2.75 L/person. Day (SNI), and total population of 160,499, the Rappocini District generated 441.37 m^3/day of SW. The current SW transport service capacity was17.657

tons/day[6]. Using SW density value in transport truck of 151.4 kg/m^3 (Table 1), the SW transport service coverage in Rappocini district was only 116.62 m^3 /day, or 27%. This value was very low, and would become a hard challenge for the municipality to reach the national target of 100% SW management service in 2020 [7].

Rappocini District has not been facilitated with TS facility. The SW was generally dumped in particular areas, and should be loaded to the transport trucks manually. The types of transport vehicles were open SLS dump trucks of 8m³ capacity, and the closed MLS truck with an average capacity of 11 to 14m³.

SW transport of SLS operation

The SW transport using SLS operation mode used dump trucks of 8m³ capacity (Figure 1). The trucks operated for 7 hours during afternoon to evening, from 04:00 to 11:00 pm. During the operation of the dump trucks, no container unloading time was required (uc=0), and no travel time was need to reach other TS (dbc = 0) for transport efficiency was only 1 trip/day. Using data in Table 2 and equations 1-3, the existing transport efficiencies of the SLS trucks in the 3 TS's could be determined.

Table 2. Unit operation time of SLS transport and efficiency determination

No	TS	W (Hour)	t_1 (hour)	t_2 (hour)	T_{SLS} (hour/trip)	H (hour)	Nd (trip/day)
1	2	3	4	5	6	7	8=(7*(1-3)-(4+5))/6
1	Buakana	0.23	0.71	0.14	3.69	7	1.23
2	Balaparang	0.20	0.66	0.09	3.82	7	1.27
3	Karunrung	0.27	0.65	0.28	3.42	7	1.22

Results of the SW transport efficiency (N_d) determination in the 3 TS's were 1 trip/day (Table 2), which was similar to the field observation. Reasons of this low efficiency were the long time periods for SW loading to the truck and hauling time (h), which caused the high value of transport time (T_{SLS}), and the high value of off route factor (W), which exceeded the maximum value of 0.15 [4]. In order to reduce the SW loading time, the use armroll trucks for SLS transport is recommended to replace the dump trucks. Use of armroll trucks, however, needs the provision of SW containers, which can be placed in the TS's. With the provision container facility in the TS's, the truck should not spend too much time for the SW loading activity.

Figure 1. Dump Truck With One Location Method

Use of the armroll truck was then optimized by lowering the off route factor to a maximum value of 0.15 [4], and the SW loading time for SLS of 20 minutes [8]. Using these values and equation 3, the transport efficiency can be determined (Table 3)

Table 3.Estimated SW transport efficiency if armroll trucks were used, with W value of 0.15.

No	TS	W (hour)	t_1 (hour)	t_2 (hour)	T_{SLS} (hour/trip)	H (hour)	Transport efficiency N_d(trip/day)
1	2	3	4	5	6	7	8=(7*(1-3)-(4+5))/6
1	Buakana	0.15	0.71	0.14	1.16	7	4.40~ 4
2	Balaparang	0.15	0.66	0.09	1.19	7	4.37~ 4
3	Karunrung	0.15	0.65	0.28	1.12	7	4.48~ 4

The optimized N_d value of the SLS trucks increased to 4 trips/day (Table 3).This value could be used to determine the need of container and armroll truck facilities for efficient operation. The Indonesian

National Standards SNI 3242-2008[9] classifies that the 8 m^3SW container can be used to serve 3.200 residents, and the 10 m^3 container can serve 5.330 people. Using these container capacity criteria, the need of containers and armroll trucks can be projected toward 2020, which was nationally targeted to reach 100% SW management service (Table 4). The SW container, which would be provided was of 8 m^3 capacity.

Using equation 8, projected population data in Table 4, and SW generation rate of 2.75 L/person. day, the SW container need for 2017 to 2020 can be determined. Estimation SW container needs for each sub-district until 2020 was shown in Table 4. The total number of SW containers which should be provided in all TS's in 2017, 2018, 2019, and 2020 were 12, 24, 34 and 38 units respectively. Accordingly, with SW transport efficiency of 4 trips/day, the estimated number of the number of armroll trucks for 2017, 2018, 2019, and 2020 were 3, 6, 9 and 10 units respectively

Table 4.Projected population and the needs of SW containers and armroll trucks in the TS in each sub-district.

No	Sub-district	Projected population* and need of SW containers				
		2016	2017	2018	2019	2020
		SC 27%	SC 46%	SC 65%	SC 84%	SC 100%
1	**Gunung Sari**					
	Population	42,196	43,037	43,887	44,718	45,558
	Number of container	0	2	5	8	10
2	**Karunrung**					
	Population	14,529	14,926	15,322	15,718	16,114
	Number of container	0	1	2	3	3
3	**Mappala**					
	Population	9,856	9,9934	10,012	10,091	10,169
	Number of container	0	1	2	2	2
4	**Kassi-Kassi**					
	Population	18,631	18,960	19,290	1,619	19,948
	Number of container	0	1	2	3	4
5	**BontoMakio**					
	Population	5,213	5,255	5,296	5,338	5,380
	Number of container	0	1	1	1	1
6	**Tidung**					
	Population	15,637	15,775	15,913	16,051	16,189
	Number of container	0	1	2	3	4
7	**Banta-Bantaeng**					
	Population	23,419	23,874	24,329	24,784	25,238
	Number of container	0	2	4	6	6
8	**Buakana**					
	Population	14,183	14,328	14,474	14,619	14,764
	Number of containers	0	1	2	3	3
9	**Rappocini**					
	Population	9,385	9,464	9,543	9,623	9,702
	Number of containers	0	1	2	2	2
10	**Ballaparang**					
	Population	12,761	12,879	12,997	13,115	13,235
	Number of containers	0	1	2	3	3
Total number of containers		**0**	**12**	**24**	**34**	**38**
Total number of armroll trucks		**0**	**3**	**6**	**9**	**10**

Note: SC = service coverage
*Prasetya, [6]

SW transport of MLS operation

Similar to the SW transport of SLS method, the operation of the MLS mode was 7 hours/day, from 04.00 to 11.00 pm. The off route factor (W) values of 0.14 to 0.21 (Table 5) were higher than the maximum criteria of 0.15 [4]. Application of equation 7 using observed unit operation time data, resulted in the transport efficiency (Nd) values of all MLS vehicles of 1 trip/day, with a total service of 5 trips/day (Table 5).

Figure 2.Transport vehicle for MLS operation

Table 5. Determination of existing transport efficiency (N_d) of the MLS trucks

No	Served Sub-district	W	t_1 (hour)	t_2 (hour)	T_{MLS} (hour/trip)	H(1-W) (hour)	Transport efficiency, N_d (trip/day)
1	2	3	4	5	6	7	8=(7(1-3)-(4+5))/6
1	Gunungsari 1	0.21	0.55	0.40	4.64	7	1
2	Gunungsari 2	0.14	0.24	0.11	4.35	7	1
3	Banta-bantaeng	0.16	0.41	0.24	3.97	7	1
4	Bontomakio	0.16	0.29	0.41	4.35	7	1
5	Rappocini	0.20	0.36	0.11	3.56	7	1
	Total						**5**

The number of SW piles for MLS operation (C_t) varied from 9 to 13 points, with SW volumes of 14.63 m^3 to 18.62 m^3 in each point. Based on these data, the transport efficiencies for MLS service could be determined, by dividing the total SW volume and truck capacity of 8 m^3/truck. The results showed that the required total N_d value for MLS service was 13 trips/day (Table 6). This means that the existing MLS trucks were not sufficient for transporting the SW from all pick-up points to the landfill. Additional trucks should be provided for 100% transport service.

Table 6. The need of MLS transport service

No	Served Sub-district	No. of MLS truck	Number of SW piled sites (C_t)	Total SW Volume (m^3)	Transport efficiency, N_d (trip/day)
1	Gunungsari 1	DD 8268 A	10	18.62	3
2	Gunungsari 2	DD 8030 AB	9	14.63	2
3	Banta-bantaeng	DD 8059 A	12	14.63	2
4	Bontomakio	DD 8257 A	11	18.62	3
5	Rappocini	DD 8369 A	13	18.62	3
	Total				**13**

Considering that the SLS vehicles would be replaced by armroll trucks, the three SLS dump trucks could be used for MLS operation. Thus, the total number of vehicles for MLS operation was 8, among which, 5 vehicles were the existing MLS trucks, and the three others were the SLS dump trucks. Determination of the total service efficiency is shown in Table 7.

Table 7. Optimization of MLS transport service

No	Served sub-district	No. of Truck	W (hour)	t_1 (hour)	t_2 (hour)	T_{MLS} (hour/trip)	H(1-W) (hour)	N_d (trip/day)
1	2		3	4	5	6	7	8=(7*(1-3)-(4+5))/6
1	Gunungsari1	DD 8268 A	0.15	0.16	0.20	4.89	7	1.14~ 1
2	GunungSari 2	DD 8030 AB	0.15	0.25	0.07	4.67	7	1.21~ 1
3	Banta-bantaeng	DD 8059 A	0.15	0.36	0.20	4.09	7	1.32~ 1
4	Bontomakio	DD 8257 A	0.15	0.24	0.20	4.39	7	1.26~ 1
5	Rappocini	DD 8369 A	0.15	0.26	0.07	3.56	7	1.58~ 1
6	SLS truck	DD 9001 AA	0.15	0.24	0.20	2.52	7	2.19~ 2
7	SLS truck	DD 9005 AB	0.15	0.26	0.07	2.31	7	2.44~ 2
8	SLS truck	DD 9313 AB	0.15	0.26	0.07	2.58	7	2.18~ 2
	Total Service							**11**

As shown in Table 7, the total transport service, which included the SLS truck involvement could increase the transport efficiency to 11 trips/day. This means that in order to achieve 100% SW service in MLS operation for Rappocini District which needs 13 trips/day, procurement of 1 dump truck with daily service of 2 trips/day is required.

IV. CONCLUSION

The SLS and MLS operations for serving the SW transport in Rappocini District were only 1 trip/day. This performance reflects the current transport service coverage of only 27%. Optimization of the SLS transport service required the procurement of 10 armroll trucks and 38 containers of 8 m^3 capacity for achieving the national target of 100% SW service coverage in 2020. The MLS operation could only serve 5 trips/day, which was not sufficient for covering a total requirement of efficiency of 13 trips/day. The solution was by adding the three SLS dump trucks and the provision of 1 extra dump truck with 2 trips/day service in order to accomplish 100% MLS transport service coverage.

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