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Mapping of Municipal Solid Waste Transportation System, Case Studies Seberang Ulu Region Palembang City

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Abstract. One of the human activities that affect the state of the environment is the domestic waste disposal. Palembang with economic growth and rapid population does not have adequate solid waste management, which is characterized by wild rubbish heaps in several locations, one of which is in the region Seberang Ulu. The results of this study show that the volume of solid waste generated in the research area by 2.98 liters/ person/ day. In planning for the needs of solid waste transportation systems, solid waste reduction activities such as solid waste bank unit and the 3R system (TPS 3R) need to be considered, with a target of solid waste reduction was 20%. Solid waste reduction can ultimately extend the life of the landfill. Projected needs garbage container (capacity 6 m³) and garbage trucks (capacity 8 m³ with 5-6 rit/day) in 2027 was 166 and 25 units, with the requirement of solid waste reduction in solid waste bank and 3R unit 29.93 m³/ day. The volume of solid waste generated is directly proportional to the increase in population, and solid waste reduction greatly influenced the community's active role as a producer of garbage.

Keywords: municipal solid waste, solid waste transportation system, solid waste reduction, solid waste bank, 3R system

1. Introduction

The solid waste transportation system plays an important role in the municipal solid waste management system. Solid waste transfer and transport systems include temporary solid waste storage at collection points, vehicles and equipment for transfer solid waste, as well as procedures for the operation and maintenance of facilities and equipment. The selection of vehicles in the transport and transfer of solid waste process should be based on careful cost analysis, ease of transportation, optimum volume of transportable waste, and vehicle operational and maintenance costs [2].

In many developing countries, there are weaknesses in the process of transporting solid waste, such as lagging solid waste and garbage falling during the transportation process, transporting solid waste with an inaccurate schedule resulting in accumulate in the waste bins, as well as the smell generated during the transport process [14]. Thompson stated from the results of research in Nigeria, some of the problems that occur in the solid waste management system include no proper allocation for solid waste containers, waste is not transported on a regular basis, there are many piles of garbage without waste containers, no sorting solid waste, and no communication between society and government as solid waste manager, or in other words, the solid waste management system runs inconsistently and effectively [10].

Similarly what happens in Palembang as one of the metropolitan cities located in Indonesia, with a population density of about 1.6 million people [4], it can generate a large amount of garbage every day.

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Until now, Palembang city does not have a municipal solid waste management system, the collection and disposal of solid waste is done simply way, without any sorting process or reduction efforts first. The solid waste that has been transported from the source is only dumped on the landfill. Behavioral factors in the disposal of garbage also greatly affect the city's solid waste management system in addition to technical factors such as collection, transportation, and disposal. This can be seen from the emergence of a pile of wild solid waste that is along the main road Ki Merogan, Seberang Ulu, on the sidewalk or roadside, and the river.

Palembang City is divided into two areas separated by a large river of Musi River, namely Seberang Ilir and Seberang Ulu. The location in this study is the area of Seberang Ulu which consists of Seberang Ulu I, Kertapati, Seberang Ulu II, and Plaju sub-districts. The selection of research sites in the area of Seberang Ulu is based on the many problems that occur. There are many piles of solid waste on the sides and median of the main roads as well as on the drainage and river streams on the side of the road, so the location becomes a slum area. In fact, the main road is the road connecting to other cities. This study discusses the mapping plan and calculation of municipal solid waste transport system needs in the area of Seberang Ulu until 2027 by considering several factors, namely the volume of solid waste generation generated, solid waste reduction efforts and target, and optimal ritation plan for transportation system to operate effectively and efficient.

2. Methodology

This study focuses on residential areas consisting of luxurious, permanent, semi-permanent, and nonpermanent residential type. Luxury housing type is the population with the highest income, permanent is middle to upper class, semi-permanent is kind of half permanent house (middle population down), while non-permanent is type of house which made of board / wood, with occupant category is resident low income.

Measurement of solid waste generation is done by weighing the garbage in the measuring container with dimensions of length and width of 20 cm and height of 100 cm. The garbage from each source of solid waste is compacted in a container then measured using a ruler to get the volume of solid waste, then weighed with a digital balance sheet to get the weight of the solid waste. Determination of the number of sample measurement of solid waste generated using stratified random sampling method and in accordance with Indonesian National Standard (SNI) 19-3964-1994 with total sample of 80 houses.

Equation (1) is a method of calculating average solid waste generation volume from the results of the survey of solid waste measurement and equation (2) is a method of measuring the needs of the mode of transporting solid waste [5].

$$\textit{Volume of solid waste generation} = \frac{\overline{\quad}}{\overline{\quad}} \quad (1)$$

Information:

Vs = volume of sample solid waste (liter) *u* = number of souls in one house

Sn = number of samples

$$\textit{Needs of transport units} = \frac{\%}{\textit{tool capacity x Fp x Rk}} \quad (2)$$

Information:

Fp = trucks compaction factor = 1,2

Rk = number of trucks ritation

The projection of solid waste generation in 2027 is obtained from the measurement of the average of solid waste generated based on the geometric population projection amount, namely:

$$Pn = Po\ (1 + \#) \tag{3}$$

In the planning of transportation system mapping, it is also necessary to calculate the number of needs of communal solid waste collection containers (TPS) in order to calculate the needs of the number of units and the ritation of garbage trucks. The equations used in accordance with the provisions of SNI [6], namely:

$$Number\ of\ TPS = \frac{\%}{\&'} \tag{4}$$

The calculation of the truck's ritation is affected by the work time of the trucker / day with the time it takes the truck to haul the trash up to the truck load and bring it to the landfill. The time taken in carrying the solid waste can be determined by following the truck for 7 days in a row so as to obtain time and average speed. The calculation of the optimum ritation number of garbage trucks uses the following equation [3]:

$$Number\ of\ ritation = \frac{working\ time/day}{LT+HT+DT+RT} \tag{5}$$

Information:
LT = Loading Time
HT = Hauling Time
DT = Unloading Time in Landfill
RT = Return Time

Loading Time is the time it takes the truck to haul the garbage on every communal containers (TPS), Hauling Time is obtained from the ratio of distance (x) to speed (v) in minutes (equation 6), Unloading Time is the time it takes the truck to disassemble the garbage and hoard it in the landfill, and the Return Time is the length of time the truck returns to the communal containers (TPS).

$$HT = \tag{6}$$

The mapping of the municipal solid waste transport system in the research location considers the technical aspects of solid waste reduction efforts by solid waste sorting methods. The method of solid waste reduction planning is done by evaluating the existing solid waste facility and the solid waste reduction target set by the central government regulation in 2027 [8].

3. Result And Discussion

3.1 Measurement of Generation and Solid Waste Composition

Table 2 indicate the relative importance of the CSFs in influencing the success of the PPP housing project in Abuja, Nigeria.

The factors 'Equitable risk allocation', 'transparency and good governance', and stable political system' are the 3 top ranked success factor that influence the success of PPP housing project Nigeria. The factors are considered very important due to the nature of procurement process in Nigeria which is lacks transparency and good governance in the PPP procurement and allocation of responsibilities to the parties involved in the partnership. Highly influential private sector companies got more land allocation under the scheme [37] based on personal acquaintances with FCT minister rather than based on due process [38].

Table 1. Ranking of the CSFS in Nigeria success

CSFs	Priorities	Normalized	Ranking
Equitable risk allocation	0.118	1	1st
Transparency and good governance	0.082	0.695	2nd
Stable political system	0.077	0.653	3rd
Competent private sector	0.071	0.602	4th
Stable economic system	0.06	0.508	5th
Competitive procurement process	0.058	0.492	6th
Government guarantee	0.049	0.415	7th
Availability of financial market	0.045	0.381	8th
Efficient legal framework	0.041	0.345	9th
Well-organized public agency	0.036	0.305	10th
Efficient approval process	0.033	0.28	11th
Trust and openness between parties	0.031	0.263	12th
Community support	0.024	0.203	13th
Consistent monitoring	0.023	0.195	14th
Action against errant developers	0.018	0.153	15th

Similarly, the factor 'stable political system' is ranked high (0.077) due to relative instability of the political system in Nigeria with regards to frequent changes in FCT ministers and in the PPP policy. This frequent changes in government's ministers and policies put the private developers in doubt with regards to the commitment of the incoming administration to meet contractual obligations undertaken by the previous ministers.

The 3 least ranked factors in Nigeria are 'community support' (0.024), 'consistent monitoring' (0.023), and 'action against errant developers' (0.018). The factor 'community support' is regarded less relevant in Nigeria due to an autocratic system of government and the land ownership policy in Nigeria. The Land use Act of 1979 has assigned all land to the government, thereby putting FCTA in control of land ownership in Abuja. The low ranking of the factors 'Consistent monitoring' and 'action against errant developers' is because the FCT PPP guidelines has made adequate provisions for monitoring and the FCTA has sanctioned errant developers by demolishing houses that have violated the terms of the partnership. Ranking of the CSFs of PPP housing construction project in Malaysia.

3.2. Ranking of the CSFs of PPP housing construction project in Nigeria

Before it is measured, solid waste is sorted from the source first by distributing two garbage bag to each respondent so that the solid waste can be separated between organic and non-organic. The result of measurement of solid waste generated on 80 samples of residential solid waste using a measuring container conducted in August 2016 then continued by calculating the average volume of solid waste generation based on equation (1) shown in the table below:

Table 2. Average solid waste generation of existing (liter/person/day)

Housing Type	Organic Solid Waste	Non-Organic Solid Waste	Avarage Solid Waste generation
Luxury (A)	3.73	13.92	17.65
Permanent (B)	4.58	10.85	15.43
Semi Permanent (C)	7.40	6.76	14.16
Non-Permanent (D)	9.88	2.46	12.34

Based on the calculation, the average volume of solid waste generation from 4 types of houses with the average number of family members in each house is 5 people is 2.98 liters / person / day. Most non-organic solid waste is produced by luxurious permanent type houses, while the largest organic waste is produced by non-permanent type houses. This is influenced by the different consumption patterns and income levels of the four types of houses, where luxury homes have the highest consumption level than other types of homes so it generates solid waste products which comes from product packaging (Fig 1). By 2017, the projected population of the Seberang Ulu area is 451,559 inhabitants, which means that city solid waste is 1,345.64 liters / day.

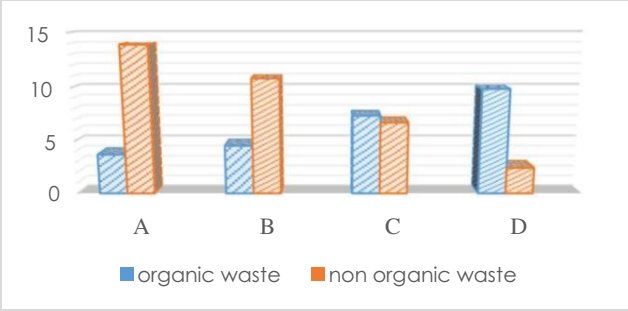

Figure 1. The composition of organic and non-organic solid waste in 4 types of houses in the Seberang Ulu (2016)

Percentage of organic and non-organic solid waste composition in examples plastic bags, hard plastics, metals, glass, and papers based on the measurement result in Seberang Ulu area can be seen in the following graph:

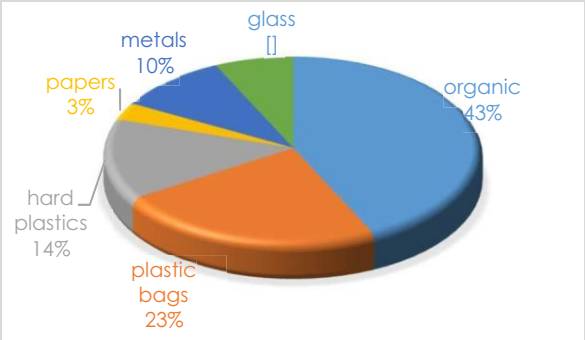

Figure 2. Composition of solid waste in the area of Seberang Ulu

Non-organic solid waste has a greater composition than organic waste (57%) dominantly produced by residents of luxury homes. Non-organic solid waste at the research site consisted of 23% plastic bags, 14% of hard plastics, 10% metals, 7% glass, and 3% papers. Plastic solid waste produced in such large quantities should be recycled into useful plastic products thereby reducing solid waste of discarded plastic.

3.3. Evaluation of Collection and Transportation Systems

Based on the survey results at the location of the research in August 2016, the number of existing communal containers (TPS) as many as 18 units, of which 9 units are not enough to accommodate the garbage, 6 units are damaged and leaking, and there are 4 locations of solid waste piles without a communal containers (wild solid waste) including in the median of main street Ki Merogan which is the main road in the area of Seberang Ulu but switch the function into a garbage dump (Fig.3).

Figure 3. Existing solid waste collection systems

Trucks carrying garbage in addition to duty to haul the garbage on every existing communal container (TPS) is also obliged to transport the piles of wild solid waste that people create then bring the waste to the

landfill. The garbage truck for the Seberang Ulu area consists of dump truck type and arm roll truck with 6 m bak truck capacity and 2 ritation / day serving 4 districts with number of truck units shown in the table below:

Table 3. Number of existing garbage trucks (unit)

Districts	Dump Truck	Arm Roll Truck
Seberang Ulu I	11	2
Kertapati	2	
Plaju	4	1
Seberang Ulu II	3	
Amount (units)	20	3

Solid waste is manually moved into trucks from one communal container to another communal container (TPS) until the truck is full and solid waste is brought to the Sukawinatan TPA as a landfill. Transportation carried out as much as 2 rit / day with the number of communal containers (TPS) served are 16 units, 4 wild bins, and along the street Ki Merogan. Currently the driver workload and route of each garbage truck are not the same so it is necessary to plan the route and schedule each truck in transporting the garbage.

3.4 Evaluation of Solid Waste Sorting Systems

Solid waste segregation facilities for residential areas that have been running in the area of Seberang Ulu are 3R unit and Solid Waste Bank. Unit 3R is an organic and non-organic waste separating facility. Organic waste is processed in a chopper machine to become compost. Non-organic waste mainly plastic is sold to collectors for recycling. While the Solid Waste Bank is a facility that operates like a bank, where the community as a customer will deposits solid waste to be converted into savings according to the weight of the deposited solid waste. The solid waste must first be sorted from the source to be processed at a Solid Waste Bank by type. Similar to processing in 3R units, organic waste is processed into compost and nonorganic waste is brought to collectors or directly recycled. Recycled of solid waste into various products can be resold on community or customer Solid waste segregation facilities for residential areas that have been running in the area of Seberang Ulu are 3R unit and Solid Waste Bank. Unit 3R is an organic and nonorganic waste separating facility. Organic waste is processed in a chopper machine to become compost. Non-organic waste mainly plastic is sold to collectors for recycling. While the Solid Waste Bank is a facility that operates like a bank, where the community as a customer will deposits solid waste to be converted into savings according to the weight of the deposited solid waste. The solid waste must first be sorted from the source to be processed at a Solid Waste Bank by type. Similar to processing in 3R units, organic waste is processed into compost and non-organic waste is brought to collectors or directly recycled. Recycled of solid waste into various products can be resold on community or customer.

However, the existing solid waste sorting system has not been able to run optimally. The success of solid waste reduction from the total solid waste generated of the Seberang Ulu area in Unit 3R and Solid Waste Bank during 2016 was only 2.94% (Table 3) of the central government's reduction target of 20% [8]. The most influential factor is the lack of community involvement as a solid waste producer in 3R and Solid Waste Bank activities so that it should be a special attention from the local government in overcoming the problem.

Table 4. Average reduction of the existing solid waste sorting

Sorting Name	Location	% Reduction
Unit 3R Junjung Biru	Seberang Ulu I	0.03
Unit 3R Sinar Fajar	Plaju	0.1
Unit 3R Bekal	Plaju	0.19
Solid Waste Bank Patraganik	Plaju	11.43
% avarage reduction		2.94

3.5 Mapping Solid Waste Transport

The first step in planning the mapping of the garbage transportation system is to calculate the number of transportations / ritations by the optimal truck unit in transporting the garbage of each communal containers (TPS) to the landfill. Mapping of planned solid waste transportation can last up to 2027, so it is necessary to first analyze the projection of solid waste generated and the number of communal containers (TPS) unit that needed with 6 m³ capacity (equations 3 and 4), as shown in table 4.

Table 5. Projection of solid waste generated (liter/day) and needs of communal container units in 2027 (@ 6 m³)

Districts	2017	2027	Communal Containers 2027
Seberang Ulu I	537.4	596.34	66
Kertapati	257.68	284.75	32
Plaju	301.62	333.58	37
Seberang Ulu II	248.94	274.98	31
Amount	1,345.65	1,489.65	166

Then, calculate the plan of ritation the garbage truck based on the average travel time each truck takes every 1 ritation so obtained the maximum number of ritations in 1 day using equations (5) and (6) is shown in table 5. CT (Cycle Time) is derived from summing LT, DT, RT, and HT. Working time in 1 day is 10 hours (07.00 - 17.00) which divided into 2 shifts for 1 unit of truck. It aims to make the truck function as an efficient means of transporting garbage. Next, calculate the number of truck units required until 2027 based on the optimal amount of ritation in table 5.

Table 6 shows the comparison of existing trucks in 2017 with a 6 m³ truck load capacity and the number of trucks needed in 2027 with truck load capacity to 8 m³ in accordance with Peraturan Menteri Pekerjaan Umum Indonesia (Regulation of Public Works Minister) [13]. Mapping of communal containers and transportation system plan in 2027 can be seen in fig. 4 and fig. 5.

Table 6. Number of optimum trucks rotation

Districts	LT (second)	DT (second)	RT (second)	x (Km)	v (Km/hour)	HT (second)	CT (second)	Ritation
Plaju	40	30	30	20	40	30,00	130,00	5
Seberang Ulu II	35	30	25	16,3	38	25,74	115,74	5
Seberang Ulu I	50	30	20	12,1	35	20,74	120,74	5
Kertapati	40	30	13	8,7	38	13,74	96,74	6

Table 7. The number and ritation of existing trucks (2017) and truck demand in 2027 (units)

Districts	2017 @6 m³	Ritation	2027 @8 m³	Ritation
Seberang Ulu I	5	2	5	5
Kertapati	3	2	6	5
Plaju	13	2	10	5
Seberang Ulu II	2	2	4	6
Amount (units)	23		25	

Table 8. Planned needs of communal containers and trucks (units) in 2027

Districts	Communal Containers	Trucks	Ritation/day
Seberang Ulu I	66	5	5
Kertapati	32	6	6
Plaju	37	10	5
Seberang Ulu II	31	4	5
Amount (units)	166	25	

Based on the results of the analysis, it can be concluded that the needs of the number of communal container units (TPS) and trash transport (trucks) for 2027 are as follows:

There are different needs of communal containers (TPS) and garbage transportation (trucks) in each districts in the area of Seberang Ulu, where Seberang Ulu I district of 66 units due to the highest population density so resulting in waste generation which is also high. The largest number of trucking needs is Plaju district (10 truck units) due to the distance factor of the district is furthest from landfill (TPA) compared to

other districts. Kertapati has the highest ritation (6 rit / day) due to the distance of the district is closest to landfill (TPA) so the truck can have a shorter time on the way to and from the landfill (TPA).

3.6. Solid Waste Reduction Efforts

The research location are 3R unit and Solid Waste Bank is targeted to reduce the waste in the Seberang Ulu area by 20% of the total volume of solid waste generated produced by the community. In 2027, solid waste reduction volume must reach the target as shown in the table below:

Table 9. Target of solid waste reduction efforts in 2027 (m³/day)

Districts	Projection of Solid Waste Generated	Reduction Target
Seberang Ulu I	596.34	119.27
Kertapati	284.75	56.95
Plaju	333.58	66.72
Seberang Ulu II	274.98	55.00
Amount (m³/day)	1,489.65	297.93

The target of solid waste reduction efforts in the area of Seberang Ulu in 2027 is 297.93 m³ / day from the existing 3R unit and Solid Waste Bank. These facilities can be upgraded or expanded so that the reduction target can go according to plan. The volume of solid waste that is served at the communal containers (TPS) is 80% of the waste generated in 2027 or 1,191.72 m³ / day with a total of communal containers (TPS) 166 units (according to Table 3) with each capacity of container is 6 m³.

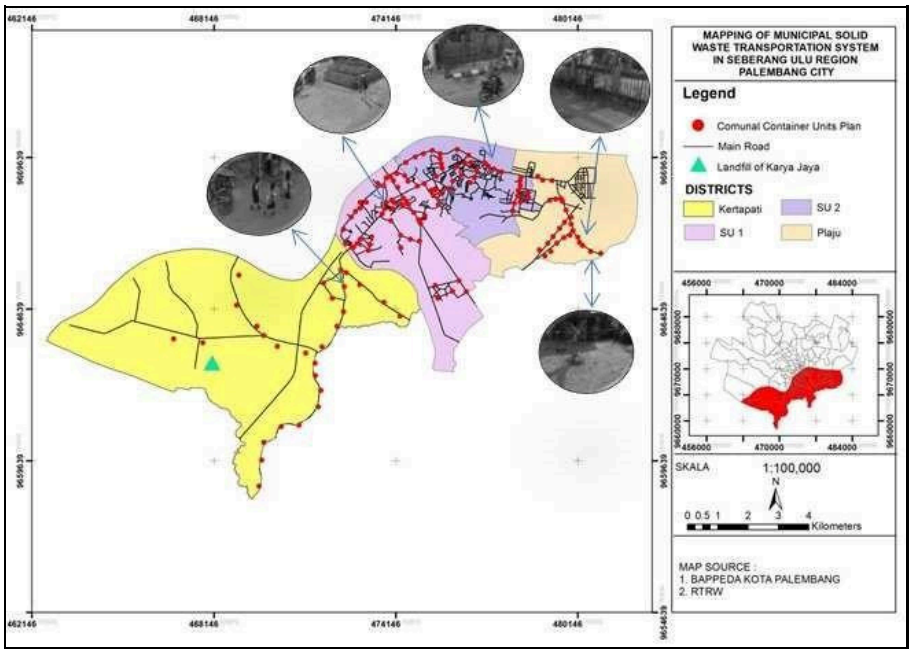

Figure 4. Mapping of distribution of comunal container units plan in 2027

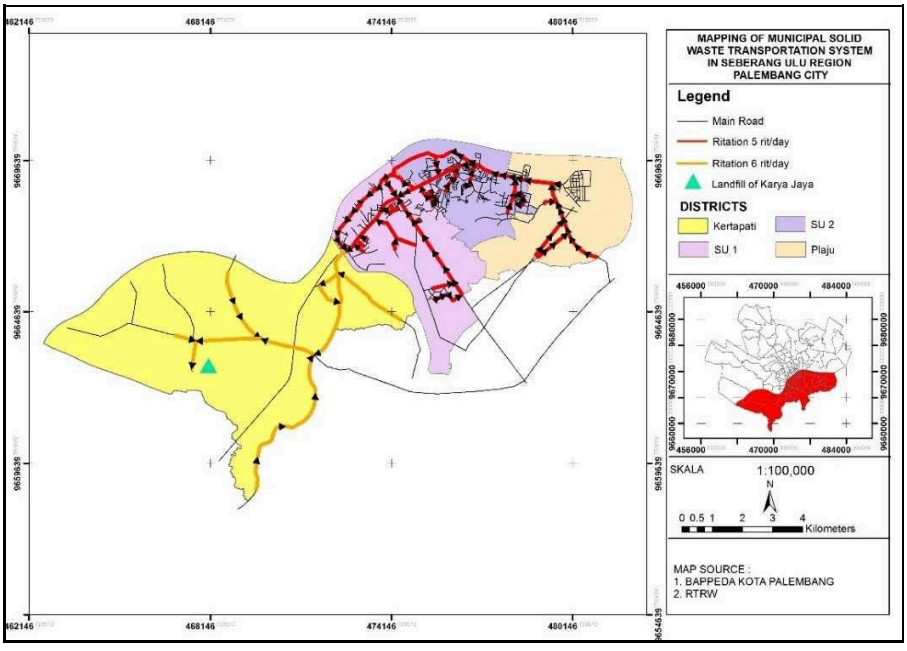

Figure 5. Mapping of transportation system plan in 2027

4. Conclusions

The conclusions can be obtained from the results of this study include:

1. Seberang Ulu area is part of Palembang city area which has problems in solid waste management of the city such as the formation of piles of wild garbage scattered in median, sidewalk or the main edge of road, and the flow of creeks. The pile of wild solid waste must be transported so as not to cause adverse impact vcc on the environment.
2. The generated of solid waste from residential areas in the Seberang Ulu is 2.98 liters / person / day, with the sample of waste measurements coming from resident types of luxury, permanent, semipermanent, and non-permanent housing. Non-organic solid waste has a greater composition than organic waste, which is 57% dominantly produced by residents of luxury homes. While organic solid waste of 43% more generated by the population in semi-permanent and non-permanent type of house. This is due to different consumption patterns of each type of house resulting in different types and composition of waste.
3. Number of existing communal container units (TPS) in 2017 is 16 units with capacity 4-6 m^3, while the number of communal container needs in 2027 is 166 units with a capacity of 6 m^3.
4. The existing solid waste transport system (2017) consists of 23 units of dump truck and arm roll truck truck with 6 m^3 capacity and 2 rit / day, while the 2027 waste transport system is 25 truck units with 8 m^3 capacity and 5- 6 rit / day depending on truck distances from solid waste haul to landfill and volume of waste generated based on population.
5. The reduction target in solid waste sorting and recycling activities from 3R and Waste Bank units is 20% in 2027 or 293.93 m^3 / day of total waste of 1,489.65 m^3 / day. While the success of reduction efforts to date (2017) only amounted to 2.94% of the total generation of solid waste generated.
6. It can be concluded that the existing transportation system and the existing solid waste reduction activities in the Seberang Ulu area have not been running optimally and it needs careful planning at least 10 years from now (2027) so the system can run effectively and efficiently.

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