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Determining the Location of Temporary Landfills with Simultaneous Set Covering Model

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Abstract. The average amount of waste produced by the city of Yogyakarta reaches 260 tons per day. The volume of waste produced by the Ngasem-Gading sector (a sector in Yogyakarta City) exceeds the available temporary landfills' capacity. The volume of waste per day generated by households and markets is 293.76 m3, while temporary landfills' capacity is 189 m3. This study aims to determining the capacity of temporary landfills in accommodating waste sources with a simultaneous approach. The first step to address this inequality is location screening, which identifies facilities that can be enlarged and looking for new possible locations. The next step is to optimize using a set covering problem model by considering the capacity, type of facility, and area using pure integer non-linear programming (PINLP). From the processing results, it is obtained that it is sufficient to operate 13 of the 21 available facilities, with details of maintaining 5 old facilities, expanding 7 facilities, and opening 1 new facility. The total capacity of the 13 facilities is 315.18 m3 so it is expected to be able to accommodate sources of waste from the community and markets in the Ngasem-Gading Sector.
Keywords: temporary landfill, set covering problem, pure integer non linier programming.

INTRODUCTION

This document was prepared using the AIP Proceedings template for Microsoft Word. It provides a simple example of a paper and offers guidelines for preparing your article. According to the Indonesian government [1], waste is material left behind by daily human activities and natural processes that are no longer useful in solid form. Meanwhile, according to the Health Office, waste is semi-solid material from organic or inorganic materials that are biodegradable or non-biodegradable. Waste that is included in organic waste usually decomposes quickly, such as waste generated by nature, such as leaves that fall from trees, while there is also waste that is even difficult to decompose, such as glass waste. Waste is usually considered useless and thrown into the environment. This will only cause problems for a long time.

Waste in Indonesia continues to increase from year to year and becomes a serious problem, especially in big cities like Yogyakarta. The main issue related to waste is the provision of inadequate disposal facilities. The volume of waste generated by the community has exceeded the existing temporary garbage dumps' capacity, causing the waste to rot and uncontrollably. The accumulation of garbage around the facility can cause various kinds of pollution such as air pollution, water pollution, and soil pollution, which have an impact on public health and the environment. Population growth is one of the factors that significantly affect the increase in the high volume of waste. As a student city and tourist city, Yogyakarta has experienced a rapid rise in population growth and an increase in waste. According to Mr. Ahmad Haryoko [2], as the Head of the Yogyakarta City Environmental Service (DLH) section, the total waste produced by the city of Yogyakarta reaches 260 tons per day. The Ngasem-Gading sector also experiences this phenomenon, as one of the waste management sectors in Yogyakarta city. The amount of waste generated by residents exceeds the capacity of temporary landfills (in Indonesia, it is known as Temporary Waste Disposal Sites = TPS), garbage piling up, rotting, and out of control. The amount of waste per day in the Ngasem-Gading sector is around 293.76 m3, while the TPS capacity is only 189 m3 per day. This research aims to

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help DLH balance the amount of waste generated by the waste source and the government's TPS facilities. The balance is by determining the number of TPS, TPS capacity, and TPS locations that need to be provided in the Ngasem - Gading sector.

The municipal waste problem is a problem that always occurs from time to time in almost all regions, cities, and countries. Although there have been many studies on urban waste management such as [3], [4], [5], [6], [7], research opportunities on waste management are still very open and needed. Some researchers [3-5] view that the problem can approach urban waste with the concept of supply chain logistics, which integrates several chain components. Mathematical modeling will help solve problems with accounts for the characteristics of different waste types and multi-point a view. Mathematical modeling related to the problem of capacity imbalance that many locations and allocation theory approach as practiced by [3], [4], [5], [8]. Location and allocation theory uses a multi-purpose location model and an integer approach. Studies related to the location and allocation of landfills were carried out using the set covering method conducted by [4] and [5]. Susanty's research [5] aims to propose improvements in determining the location of temporary landfills for one type in the West Bandung area. Nugrahadi's study aims [4] to minimize the number of TPS locations based on weighting capacity without considering the type of temporary landfill in the Surakarta area. Research [9] used set covering to determine the minimum number of facilities and determine the facility location's size to meet the demand for community waste sources. Research [10] aims to determine the minimum number of facilities but does not consider the type of TPS and determine the location of facilities in the Boyolali area with the fastest travel time limit. Fathonah's study [11] aims to minimize the number of TPS in the Krasak Sector by considering TPS's storage capacity with a maximum distance of 1 km but without opening new facilities.

Set Covering Problem

The Set Covering Method is a site allocation optimization method that aims to minimize the number of sites needed to be able to cover other sites. The selected site will be able to cover the demand for other sites, so that it will minimize the number of existing sites so that it can save costs because the site can cover all demand [6]. According to Daskin (2008) in [6], Set Covering is a way to determine the lowest cost of the placement of a number of facilities where each demand node can be reached by at least one facility. Set Covering is one part of the allocation location problem. The purpose of the allocation location model is to determine the location of facilities that can minimize the cost of assigning facilities to customers with the limitation that each facility is used for a specified number of customers. Service can be forformed by the facility if the customer is within the specified distance and the facility is deemed incapable if the distance exceeds the critical value of the distance range. According to [12] the basic model of set covering problem is as :

- I = *demand point*
- J = Facility location point
- D_{ij} = Distance of demand point to location facility point
- D_c = *Distance coverage*
- N_i = $\{J \mid D_{ij} < D_c\}$ = The distance between the demand point and the facility is fulfilled because it is less than the distance as the fulfillment distance.
- X_j = Binary number, value 1 if the facility can serve demand and value of 0 if the opposite.

Based on the above notation, the mathematical model of set covering problem :

Minimize X_j (1)

Subject to $\Sigma_{j \epsilon Ni}\ X_j \geq 1 \quad \forall\ i \in I$ (2)

$X_j\ \{0,1\} \quad \forall\ j \in J$ (3)

METHODS

The data needed and used in this study are the location of waste sources from the community and the market, the location of facilities with the type of TPS, containers, and depots. The capacity of all TPS facilities, the volume of waste generated by the community and the market, the distance from the waste source location to the TPS facility location, and the maximum distance for disposal of waste from the waste source location to the facility location. An overview of all data can be seen in Figure 1.

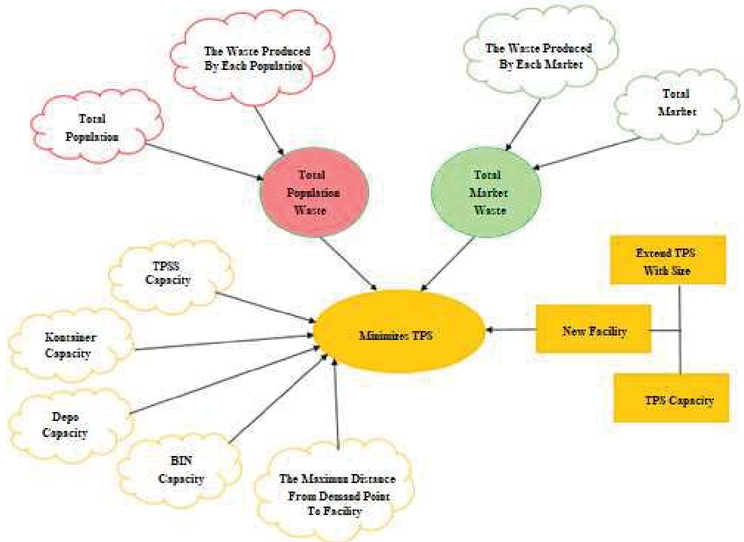

FIGURE 1. Relationship Diagram

The research object is the Temporary Waste Disposal Site (TPS) in the Ngasem-Gading Sector, Yogyakarta City. All TPS locations and volumes use data from the Environmental Agency. The volume of community waste used each sub-district population multiplied by the parameter of waste produced by each resident of 0.47 kg/person and multiplied again that each m^3 to equal to 0.004 kg. The source of market waste is calculated using the stipulation that every m^2 of the market area will produce 0.3 kg of waste. Data on population and market area were obtained from DLH. Location screening is done by going to the location to identify land that may still be expanded and new locations. The results of discussions with DLH were to expand the land using BIN, which can accommodate 10 m^3. After obtaining a decision on the TPS's location and capacity to be expanded and opened, then proceed with modeling the basic set covering model. The closure of the model set is done without considering the area. All existing polling stations, both existing and expanded in an area, are considered simultaneously. The same applies to all waste points, both from the community and from several markets. The decision variable to open or close a TPS facility is a binary variable [0,1]. Also, pay attention to the maximum distance from the source of waste to the TPS, which is not more than 1 km. Optimal decision-making is assisted with the help of LINGO 11.0 software.

RESULT AND DISCUSSION

Screening Location

Screening locations are carried out to overcome the imbalance between the source of waste and the TPS facilities' capacity in the Ngasem-Gading Sector. Table 1 shows that the total volume of waste sources from all sub-districts (239.76 m^3) is more than the TPS's total capacity in the Ngasem-Gading Sector (189 m^3), so that at least an additional capacity of 50.76 m^3 is needed. Location screening is carried out for all existing TPS to find several possible locations to be enlarged. Two locations can be expanded, namely TPS Kraton and TPS Wirobrajan.

TPS Extended/Expanded

TPS capacity expansion needs to be done to meet the demand for the volume of waste generated. TPS capacity expansion has different handling. Following are the decisions made on seven polling stations :

a. TPS Tungkak Bridge previously had a garbage storage capacity of 4 m^3. will be expanded because the land is indeed still vast and turned into a depot with a capacity of 28 m^3.
b. Prawirotaman Market previously had a capacity of 4 m^3, but with the emergence of the waste problem, an expansion was held so that the area became 26.44 m^3.

c. Legi Market, previously had a capacity of 4 m^3, expanded to 20.5 m^3 by adding a number of 25 BIN along the Bugisan Road.
d. TPS Serangan, has a building area of previously only had a capacity of 16 m^3 expanded to 22 m^3.
e. Klitikan Market, previously only had a capacity of 3 m^3, then expanded to 26.76 m^3. This expansion was carried out by adding 36 BIN which could be placed along the Jalan HOS Cokroaminoto.
f. DI Panjaitan I, previously had a capacity of 2 m3 and then expanded to 26.42 m^3. This expansion was carried out by adding 37 BINs along the Panjaitan Road.
g. Depo Dukuh, has a building area of approximately 36 m^3 so that previously the capacity of only 24 m^3 was expanded to 33 m^3.

TABLE 1. Waste Volume and TPS Capacity

No	Garbage Sources	Code	Volume (m^3)	Name of TPS	Code	Capasity (m^3)
1	Wirogunan	**M1**	26,49	Market Pujokusuman	**T1**	6
2	Keparakan	**M2**	23,39	Market Ciptomulyo	**T2**	5
3	Brontokusuman	**M3**	25,29	TPS Jembatan Tungkak	**T3**	4
4	Market Pojokusuman	**P1**	0,42	TPS Sisingamangaraja	**T4**	4
5	Market Prawirotaman	**P2**	2,41	Market Prawirotaman	**T5**	4
6	Market Ciptomulyo	**P3**	0,27	TPS ALKID	**T6**	4
7	Market Telo	**P4**	1,65	TPS Magangan	**T7**	2
8	Panembahan	**M4**	21,63	Market Kluwih	**T8**	2
9	Kadipaten	**M5**	16,07	TPS PDHI	**T9**	3
10	Patehan	**M6**	13,86	Market Ngasem	**T10**	24
11	Market Kluwih	**P5**	0,08	TPS Tamansari	**T11**	24
12	Market Ngasem	**P6**	7,36	Market Gading	**T12**	1
13	Mantrijeron	**M7**	23,84	Market Legi	**T13**	4
14	Suryodiningrat	**M8**	26,09	Market Seranggan	**T14**	3
15	Gedong Kiwo	**M9**	32,80	TPS Seranggan	**T15**	16
16	Market Gading	**P7**	1,37	Market Klitikan	**T16**	3
17	Patangpuluhan	**M10**	17,86	DI Panjaitan I	**K1**	2
18	Wirobrajan	**M11**	21,98	DI Panjaitan II	**K2**	2
19	Pakuncen	**M12**	25,36	Patangpuluhan	**K3**	2
20	Market Serangan	**P8**	2,34	Depo Pura Wisata	**D1**	50
21	Market Legi	**P9**	2,06	Depo Dukuh	**D2**	24
22	Market Klitikan	**P10**	1,14			
	TOTAL		**293,76**	**TOTAL**		**189**

New TPS

New TPS in the form of BIN is to meet the demand that is still not served by TPS. BIN itself has a capacity of 660 liters (Yogyakarta City Environment Services) and converted to 0.66 m3 to meet the source of waste (demand) from the community and the market must multiply it with a number of BIN. New of Bin which is located at Jl Taman Siswa Kelurahan Wirogunan is 41 BINs with a capacity of 27.06 m^3 which allows 2 BIN for 75 meters along Jalan Taman Siswa with access road to be passed by compactor cars. This addition is to meet the demand from the Wirogunan Village of 26.49 m^3 which had not been fulfilled before.

Mathematical Model

Model Notation

K = $\{1..3\}$ is an alternative set of container locations.
D = $\{1..2\}$ is an alternative set of depot locations.
B = $\{1\}$ is an alternative set of locations for new facilities (BIN).

Index :

i = point index of community and market waste sources
t = alternative point index TPSS location
k = Container location alternative point index
d = Depo location's alternative point index

b = new facility location point alternative index (BIN)

Parameter :

C_t = TPSS location capacity with t index (m^3/ day)

C_k = container location capacity with index k (m^3/ day)

C_d = depo location capacity with index d (m^3 / day)

C_b = new facility location capacity (BIN) with index b (m^3 / day)

V_i = the volume of production of community and market sources of waste index i (m^3 / day)

J_{max} = maximum distance of garbage disposal between demand and facilities

J_{it} = the distance between the point of community and market waste sources with index i with alternative location of TPSS with index t

J_{ik} = the distance between the point of community and market waste sources with index i with alternative container locations with index k

J_{id} = the distance between the point of community and market waste sources with index i with alternative locations for Depo with index d

J_{ib} = the distance between the point of community and market waste sources with index i with alternative location for new facilities (BIN) with index b

T_j = total mileage as the fulfillment distance

Ni = $\{t, k, d, b \mid J_{it} + J_{ik} + J_{id} + J_{ib} \leq T_j\}$ all alternative TPS locations which include the point of waste source index i

The decision variable:

X_t = (1, if TPSS t is the location of the waste source and 0, if TPSS t is not the location of the waste source)

X_k = (1, if Container k is the location of the waste source and 0, if Container k is not the location of the waste source)

X_d = (1, if Depo d is a location for placing waste sources and 0, if Depo d is not a location for placing waste sources)

X_b = (1, if BIN b is the location of the waste source and 0, if BIN b is not the location of the waste source)

Y_{it} = (1, if the source of waste i can be met by alternative location t and 0, if the source of garbage i cannot be met by alternative location t)

Y_{ik} = (1, if the source of waste i can be met by alternative location k and 0, if the source of waste i cannot be met by alternative location k)

Y_{id} = (1, if the source of waste i can be met by alternative location d and 0, if the source of waste i cannot be met by alternative location d)

Y_{ib} = (1, if the source of waste i can be met by alternative location b and 0, if the source of waste i cannot be met by alternative location b)

a. Objective Function

The objective function in this research is to minimize the number of TPS which consists of four types, namely TPSS, container, depot, and BIN by considering the capacity.

$$\text{Minimize } \sum_{t \in T} C_t X_t + \sum_{k \in K} C_k X_k + \sum_{d \in D} C_d X_d + \sum_{b \in B} C_b X_b \quad (1)$$

b. Limitation

1) Amount of rubbish that can be served. Every source of waste from the community and the market can be served by at least one polling station.

$$\sum_{t, k, d, b \in Ni} Y_{it} + Y_{ik} + Y_{id} + Y_{ib} \geq 1 \quad \forall \forall \in I \quad (2)$$

2) Capacity. Each TPS can only serve a number of TPS capacities

$$\sum_{i \in} V_i Y_{it} \leq C_t X_t \quad \forall t \in T \quad (3)$$

$$\sum_{i \in} V_i Y_{ik} \leq C_k X_k \quad \forall k \in K \quad (4)$$

$$\sum_{i \in} V_i Y_{id} \leq C_d X_d \quad \forall d \in D \quad (5)$$

$$\sum_{i \in} V_i Y_{ib} \leq C_b X_b \quad \forall b \in B \quad (6)$$

3) Maximum discharge distance. The distance between the source of waste and the facility does not exceed the maximum distance.

$$jmax.\, X_t \geq_{\geq} max \{J_t^i\}.\, Y_{it} \quad \forall t \in T \quad (7)$$

$$jmax.\ X_k \geq max\ \{j_k^i\}.\ Y_{ik} \quad \forall k \in K \tag{8}$$

$$jmax.\ X_d \geq max\ \{j_d^i\}.\ Y_{id} \quad \forall d \in D \tag{9}$$

$$jmax.\ X_b \geq max\ \{j_b^i\}.\ Y_{ib} \quad \forall b \in B \tag{10}$$

4) Decision

$$X_t\ \{0,1\} \quad \forall t \in T \tag{11}$$

$$X_k\ \{0,1\} \quad \forall k \in K \tag{12}$$

$$X_d\ \{0,1\} \quad \forall d \in D \tag{13}$$

$$Y_{it}\ \{0,1\} \quad \forall i \in I \tag{14}$$

$$Y_{ik}\ \{0,1\} \quad \forall i \in I \tag{15}$$

$$Y_{id}\ \{0,1\} \quad \forall i \in I \tag{16}$$

$$Y_{ib}\ \{0,1\} \quad \forall i \in I \tag{17}$$

TABLE 2. Results of Data Processing Output

Type	No	TPS facilities	Capacity (m^3)		Accommodate Garbage Sources	Garbage Volume (m^3)
			Before	After		
TPSS	1	Market Pujokusuman	6	6	-	-
	2	Market Ciptomulyo	5	5	-	-
	3	TPS Jembatan Tungkak	4	28	Brontokusuman	25.29
					Market Ciptomulyo	0.27
	4	TPS Sisingamangaraja	4	4	Market Telo	1.65
	5	Market Prawirotaman	4	26.44	Market Prawirotaman	2.41
					Mantrijeron	23.84
	6	TPS ALKID	4	4	-	-
	7	TPS Magangan	2	2	-	-
	8	Market Kluwih	2	2	-	-
	9	TPS PDHI	3	3	-	-
	10	Market Ngasem	24	24	Kadipaten	16.07
					Market Ngasem	7.36
	11	TPS Tamansari	24	24	Patehan	13.86
					Market Ngasem	7.36
					Market Gading	1.37
	12	Market Gading	1	1	-	-
	13	Market Legi	4	20.5	Patangpuluhan	17.86
					Market Legi	2.06
	14	Market Serangan	3	3	Market Serangan	2.34
	15	TPS Serangan	16	22	Wirobrajan	21.98
	16	Market Klitikan	3	26.76	Pakuncen	25.36
					Market Klitikan	1.14
LK	1	DI Panjaitan I	2	26.42	Suryodiningrat	26.09
	2	DI Panjaitan II	2	2	-	-
	3	Patangpuluhan	2	2	-	-
Depo	1	Depo Pura Wisata	50	50	Keparakan	23.39
					Market Pujokusuman	0.42
					Panembahan	21.63
					Market Kluwih	0.08
	2	Depo Dukuh	24	33	Gedong Kiwo	32.8
BIN	1	BIN BARU	0	27.06	Wirogunan	26.49
					Market Pujokusuman	0.42

The shortage of TPS facility capacity of 50, 76 m3, is done by adding capacity in seven TPS locations and opening a new location. Additional capacity was carried out by adding BIN along the road near the seven polling stations. The results of processing the output data using LINGO 11.0 software can be seen in Table 2. The empty

Accommodate Garbage Sources column means that the TPS does not need to be maintained. There were 9 polling stations closed, namely, Pujokusuman Market, Ciptomulyo Market, ALKID TPS, Magang TPS, Kluwih TPS, PDHI TPS, Gading Market, DI Panjaitan II, and Patangpuluhan. This is following the concept of Set covering problem, which minimizes the number of facilities available. The use of BIN is more straightforward because it does not require a large area and makes new vehicles owned by DLH efficient.

CONCLUSION

In the imbalance between the source of waste and the available TPS facilities in the Ngasem-Gading Sector, an additional TPS capacity was added, and a new TPS was opened. The TPS extended were 13 of the existing 21 TPS. The 13 TPS are five current TPS, seven TPS expansion, and one new TPS. The total capacity of 13 TPS is 315.18 m3 which is expected to accommodate the source of community and market waste in the Ngasem-Gading Sector of 293.76 m^3.

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