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Analysis of Location Determination for Temporary Waste Collection Points Using p-dispersion Method: An Application to Yogyakarta City, Indonesia

Donny Dwi Julianto, Annie Purwani*, Siham Bouguern

***Abstract*—** The city of Yogyakarta, particularly the Maliobro-Kranggan sector, with a total population of 117,656, has the potential to generate 221 m^3/day of waste, while the total capacity of the existing temporary waste collection points or Temporary Disposal Sites (TPS) is 17 units with a capacity of 306 m^3. The Yogyakarta Environmental Agency must reconsider the number of TPS facilities and their capacities to meet the community's needs. In certain areas, there are nearby TPS locations, causing some of them not to function optimally as the community chooses the ones that are easily accessible. On the other hand, the proximity of TPS facilities also disturbs the comfort of the community due to worsening odor pollution. In response to this issue, this research aims to determine the optimal number of TPS facilities and their ideal locations using the p-dispersion method. This method is used to determine facility locations by maximizing the minimal distance between each available facility. This research also adds a criterion by considering the travel distance from waste sources to the selected facilities. The study is conducted using Lingo 11.0 software. Based on the data processing results, 13 of 17 TPS facilities were established. The total capacity is 254 m^3/day, which can serve as the waste source for 13 community locations. The objective value obtained is 5900, which indicates that the minimum separation distance for the ideal facilities is 5900 meters.

***Index Terms*—** *Industrial Engineering, Location Determination, p-dispersion Method, Waste Collection Points, Waste Management, TPS, Location-Allocation, Travel Distance, Temporary Disposal Sites, Facility Location, Location Problem*

I. INTRODUCTION

THE The population development has implications for urban areas, including land availability and demand, as well as additional needs such as food production and energy demand. Each of these needs has implications for the environment. Despite the impact of development and industrialization, population growth is the most noticeable factor that shows an increase from year to year [1]. The rapid development of the population ultimately leads to the rise in diverse needs, which in turn increases the amount of waste or residue, both from activities carried out or consumption processes that result in waste.

According to information from the National Waste Management Information System (SIPSN) website, the average waste produced by Yogyakarta City's residents in 2021 reached 361.96 tons per day [2]. The Environmental Agency of Yogyakarta City (DLH) is the primary responsible party, supported by several private parties, for waste management, particularly waste collection, which is currently divided into five sectors, as shown in Table I. These sectors are the Malioboro-Kranggan sector, Kotagede sector, Ngasem-Gading sector, Gunung Ketur sector, and Krasak sector. The division of these areas aims to optimize waste collection and transport based on temporary waste collection points (TPS) towards the Piyungan Waste Disposal Site (TPA). This categorization allows the public cleaning service to extend its reach more effectively. Each sector consolidates a specific set of districts based on their geographical proximity and implements a targeted waste collection system [3].

TABLE I
GEOGRAPHICAL ALLOCATION OF WASTE COLLECTION SECTORS IN YOGYAKARTA CITY

Sector	Locality	District
01	Malioboro-Kranggan	Gondomanan
02	Kotagede	Umbulharjo
03	Ngasem-Gading	Yogyakarta Tengah
04	Gunung Ketur	Yogyakarta
05	Krasak	Yogyakarta

The Malioboro-Kranggan area was chosen for research due to its status as a tourist area, which has the potential to generate significant amounts of waste. The Malioboro-Kranggan area has 17 TPS facilities scattered across several districts with different capacities and categories.

Managing and handling the increasing amount of waste has become a challenge for the local government, particularly in urban areas such as Yogyakarta City. The DLH of Yogyakarta City, supported by various stakeholders, has implemented waste management measures, including waste collection, transportation, and disposal, through a network of TPS facilities. However, the increasing waste production has put pressure on the existing waste management infrastructure, including the TPS facilities in the Malioboro-Kranggan area.

The TPS facilities in the Malioboro-Kranggan area are

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designed to accommodate different types of waste, including organic and inorganic waste and recyclable materials. The capacities of the TPS facilities range from 10 to 17 cubic meters, with varying categories such as TPSS (Temporary Waste Collection Point), LC (Loading Center), and TPSS with Sorting (Temporary Waste Collection Point with Sorting). These TPS facilities are strategically located across different districts to ensure accessibility for waste collection by waste collection trucks.

However, several challenges must be addressed despite the efforts to manage waste through the TPS facilities. One of the challenges is the limited capacity of the TPs facilities, which may result in overflow and improper waste handling. Another challenge is the mixed waste composition in some TPS facilities, where organic and inorganic waste is not adequately separated, making implementing effective waste separation and recycling initiatives challenging. Limited public knowledge and engagement in waste management practices, like segregating waste at its origin, also pose challenges to achieving efficient waste management in the area.

To overcome these challenges, the DLH of Yogyakarta City, in collaboration with other stakeholders, has initiated various waste management programs, including waste reduction campaigns, waste separation at source, and recycling education programs. The DLH has also implemented waste collection schedules and routes to optimize waste collection efficiency and prevent overflow at TPS facilities. Additionally, efforts are being made to improve the infrastructure and capacity of TPS facilities, including upgrading TPSS facilities to TPSS with Sorting to promote waste segregation and recycling.

TPS facilities in the Malioboro-Kranggan sector can pose several issues, such as the proximity of TPS facilities to each other, resulting in an imbalance, with some TPS facilities needing to be more utilized to their maximum capacity while others are overloaded. The proximity of TPS facilities to residential areas can also result in unpleasant odours. TPS facilities along roadsides can cause traffic congestion during waste collection and transportation to the final disposal site. Some TPS facilities may need to be closed due to environmental issues or land use changes. The volume of waste in some TPS facilities may cause overload, necessitating the allocation of TPS facilities to ensure their optimal functioning and reduce environmental pollution.

The p-dispersion method can be used to address the waste management issues in the Malioboro-Kranggan sector. p-dispersion is a technique used to create facilities p in a network, intending to minimize the minimum separation distance between each pair of open facilities. In this case, the facilities referred to are specific TPS. This method can help the government and residents mitigate the negative impacts of waste-related issues. A reassessment of the location and allocation of TPS facilities in the Malioboro-Kranggan sector is needed to effectively address the social conflicts related to waste management.

II. LITERATURE REVIEW

The domain of location-allocation theory lacks extensive literature reviews and models. A literature review is obtained from various sources, such as books, journals, and other information. We divided the literature review into two sections, the studies of (1) temporary waste collection points, and (2) the studies p-dispersion method for location determination.

2.1. Waste collection points

Ref. [4] conducted a study using the Set Covering method to study dynamic waste sources. In this study conducted in the Krasak sector, waste management facilities, including Depots, Container Platforms, and TPSS, are examined. The volume of waste generated in the Krasak sector measures 110.536 m^3, which is smaller than the total TPS capacity of 131m^3, indicating an existing imbalance. The research aims to optimize the number of TPS while considering TPS capacity, waste volume, maximum disposal distance from waste source to TPS, and potential expansion costs. The study employs the Set Covering Problem method and utilizes Lingo 11.0 software for analysis. The research model is formulated as an Integer Non-Linear Programming [4].

In their research, Ref. [5] focus on addressing reverse logistics challenges encountered in municipal waste management, specifically related to the collection system in European Union (UE) countries. This study is dedicated to resolving the problem of strategically locating these collection areas. The researchers establish a connection between this issue, the set covering problem, and the MAX-SAT problem. Subsequently, they proceed to devise a genetic algorithm and a GRASP heuristic to solve each of these formulations separately. To assess the efficacy of the algorithms, the researchers conduct computational experiments using actual instances from the metropolitan area of Barcelona and a reduced set of set covering instances derived from existing literature [5].

Ref. [6] studies waste problem of the Malioboro-Kranggan sector this problem requires a solution for determining TPS locations by screening locations for existing and new TPS using Google Earth software. The screening location criteria is based on the number of location points that can meet the adequacy of waste volume in each region. Initially there were 13 TPS for the Malioboro-Kranggan Sector available. Based on the calculation results from the screening location, there were 8 TPS that were opened to accommodate the volume of waste from the community and hotels, namely: TPSS Jati, TPSS Wongsodirjan, Pringgokusuman Depot, Utoroloyo Mausoleum Depo, New Ngampilan Depo, New Gondomanan Container, Tegalrejo New Container and Depot [6].

2.2. P-dispersion method for location determination

In the study by Ref. [7], the author discusses the location of waste disposal sites (TPS) in the Klaten area, which is based on ineffective waste management due to the imbalance of travel distance from waste sources to the nearest TPS, using the p-dispersion method to maximize the travel distance value from waste sources to the nearest TPS facility. The study determined good location of TPS by p-dispersion method, then compared it with previous research using p-median and p-center method. The research was conducted with the help of software Lingo 11. Data processing has been done resulting in minimum travel time of at least 9 minutes with selected polling stations as much as 70 TPS. The results of comparison were very different, since the p-dispersion and other methods are very different. The advantages of each method vary depending on the its purpose. The p-median has the goal of minimizing the average travel time. While the p-center has the goal of minimizing the maximum travel time [7].

Ref. [8] conducted a study using the p-dispersion method, which discusses the consequences of frequently finding that waste producers must transport waste on time to avoid risks to the communities around TPS. Thus, the researcher proposes an equity-based waste container allocation to reduce the chances of waste-related disasters. In this paper, a novel approach is introduced, combining the p-center and p-dispersion models. The objective is to derive an optimal configuration of solid waste collection sites within a region, aiming to distribute waste-induced disaster risk evenly among all solid waste producers in the area. The paper presents a location mathematical model designed to minimize the disparity between the maximum and minimum waste-induced disaster risk faced by these waste producers [8].

Ref. [9] conduct a thorough study that examines the trade-offs and computational efficiency of four multi-objective models. These models combine the p-dispersion model with other facility location objectives, specifically focused on siting critical assets, including the p-median, max-cover, p-center, and p-maxian models. To evaluate the effectiveness of these models, the researchers perform a case study in Orlando, Florida. The results indicate that the dispersion/center model yields a gradual trade-off curve, whereas the dispersion/maxian trade-off curve exhibits a more pronounced 'elbow' shape. Furthermore, the center and median multi-objective models require significantly higher computational resources compared to the models employing max cover and p-maxian [9].

Ref. [10] provided a comprehensive presentation of precise calculations and numerical method computations, along with an overview of various studies, types, models, and methods employed by previous researchers to address discrete location problems. The paper delves into the analysis of set covering location problems, maximal covering location problems, p-center location problems, p-median location problems, and fixed charge facility location problems. Additionally, the article offers a concise explanation of several heuristic algorithms utilized for tackling discrete location problems, including the genetic algorithm, particle swarm optimization, and greedy reduction algorithm. The author applies the proposed model and algorithms to determine the optimal temporary disposal sites in Palembang City [10].

The theory of location-allocation is the science that investigates the spatial order of economic activities. Therefore, In their scholarly and scientific research paper, Ref. [11] performed an examination of 90 published articles related to service facility location problems dating from the year 2000 onwards. The authors propose a systematic classification system that centers around 19 fundamental attributes, encompassing key characteristics and descriptive dimensions pertinent to location problems. This taxonomy is formulated from the perspective of operations research and aims to offer valuable support to location scientists and practitioners who are engaged in addressing service facility location problems. Furthermore, the study organizes service facility location problems into distinct categories based on their specific application fields and conducts comprehensive investigations into each trait. Additionally, intriguing comparisons between facility location problems across different application fields are made, and potential avenues for future research are identified [11].

In the research conducted by Ref. [12], a mixed-integer program is formulated, wherein the value of the 0-1 location variables in the distance constraints is reversed to only impose constraints on the distance between pairs of open facilities, thereby maximizing this distance. Additionally, a related problem known as the maxisum dispersion problem, which focuses on maximizing the average separation distance between open facilities, is also formulated and solved. The paper presents computational outcomes for both models, considering the placement of 5 and 10 facilities on a network comprising 25 nodes. Furthermore, a multicriteria approach that combines the dispersion and maxisum problems is explored. The analysis uncovers a notable weak duality connection between the p-dispersion problem and the (p-1)-center problem. Specifically, half of the maximin distance in the p-dispersion problem sets a lower boundary for the minimax distance in the center problem with (p-1) facilities. Given that the p-center problem is commonly addressed using a sequence of set-covering problems, the p-dispersion problem assumes significance in establishing an initial distance for this sequence of covering problems [12].

In summary, the p-dispersion problem involves identifying the optimal locations for p facilities on a network, aiming to maximize the minimum separation distance between any pair of open facilities [12]. Typically, the decision regarding the placement of an activity unit is influenced by various factors, including local raw materials, local demand, transferable inputs, and external demand [13]. It can also be interpreted as the geographical allocation of scarce resources and its impact on activities [14].

III. THE P-DISPERSION PROBEM DEFINITION

This study employs the p-dispersion method, which is utilized to determine the optimal locations, denoted as P, for facilities within a network. The objective is to maximize the minimum separation distance between each pair of selected facilities.

The p-dispersion problem can be described as follows. Given a set of n objects and a matrix of distances between each pair of points, the objective is to choose p points in order to maximize the smallest distance between two chosen objects [15].

The p-dispersion problem finds various applications in facility location, especially when the goal is to scatter the chosen facilities as far apart from each other as possible. For instance, in military defense, scattering helps prevent the simultaneous destruction of multiple facilities in a single enemy attack. Telecommunications use scattering when positioning cell phone antennas or selecting frequencies to minimize interference. Additionally, when choosing the locations for franchise shops, scattering helps minimize competition among them [15].

In some applications, there are n objects described by multiple attributes, and the objective is to choose a diverse sample of p objects. In such cases, distances are computed using a metric that takes into account the attributes. The p-dispersion problem that studied the problem and proposed variants based on different dispersion metrics. The four variants documented in the literature are as follows:

- The maxisum-sum variation seeks to maximize the total sum of distances among all the chosen points.
- The maximin-sum variation aims to maximize the smallest sum of distances from each selected point to all other selected points.
- The maxisum-min variation strives to maximize the sum of the minimum distances from each selected point to its closest selected point.
- The maximin-min variation, often referred to as the max-min p-dispersion problem, the max-min diversity problem, or simply the p-dispersion problem [15], is considered the most classical form of the problem.

The p-dispersion problem is often motivated by military operations, where spatially separating strategic facilities like missile silos helps protect them during attacks. However, it also finds relevance in the context of retail franchises and central place theory. Numerous researchers have explored new techniques to solve dispersion problems. Moreover, the concept of dispersion has been applied to route hazardous materials along dissimilar paths between an origin and a destination [9].

IV. PROBLEM DESCRIPTION

The waste produced by the community requires adequate temporary shelters, but Yogyakarta City is experiencing an imbalance in the expansion of land for temporary shelters. The waste management is one of the joint responsibilities of the Yogyakarta City government and the Provincial Government of the Special Region of Yogyakarta. Based on initial observations, the waste generated by the people of Yogyakarta City goes through several stages before entering the Integrated Waste Disposal Site (TPST). The waste generated by the community is collected at the Temporary Disposal Site (TPS). The location of TPS in the City of Yogyakarta is now causing several problems, one of which is the location of the TPS that is too close to the location of community settlements. For example, in the Krasak sector TPSS location such as the Pengok TPSS which is 1m away from residential areas [4].

To solve this problem, we used a mathematical model of the p-dispersion method in this research. In actual conditions, there are several aspects to consider, including the placement of TPS and the location of waste sources, considering the distance from the waste sources to the TPS and the capacity of each type of available TPS, as illustrated in Fig. 1 and Fig. 2.

A relationship diagram was created to explain the relationship between variables and parameters based on the system in actual conditions, including structural and functional aspects, and the determination or reduction of available TPS facilities based on the p-dispersion method, as shown in Fig. 3.

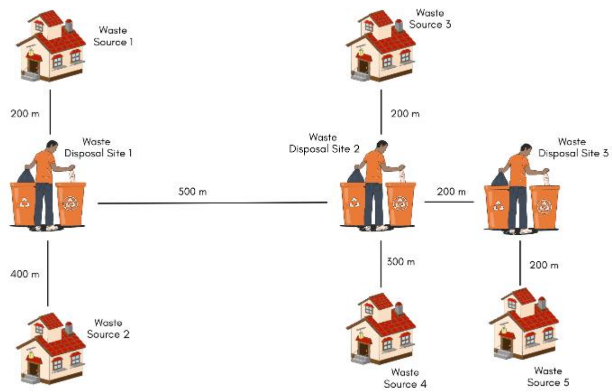

Fig. 1. Illustration of TPS Placement and Waste Sources Based on Real Conditions

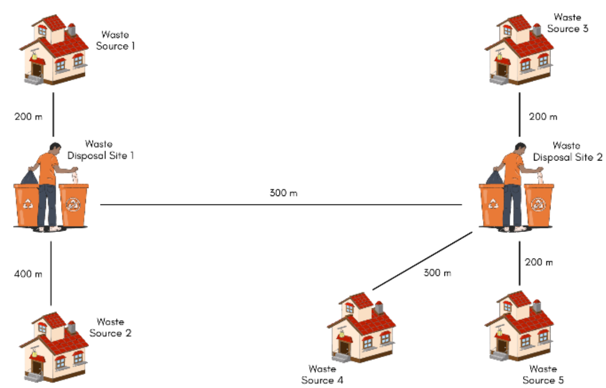

Fig. 2. Illustration of TPS Placement Using the p-dispersion Method

V. RESEARCH METHODS

This research was conducted at TPS Sector Malioboro - Kranggan Yogyakarta by requiring some data such as the number and location of TPS. In addition, data related to amount, location and volume of waste sources.

5.1. P-dispersion method

The method used in this study is the p-dispersion method. p-dispersion is a method used to find the location of facilities p in a network to maximize the minimum separation distance between each pair of open facilities. p-dispersion has a goal of maximizing the minimum value at a time take facilities [7].

Dispersion can be treated as an independent objective in which the primary focus is on maximizing the minimum inter-facility distance between any two facilities. This specific objective can be represented as the p-dispersion problem in discrete network space. Operating under the maximin principle, the p-dispersion problem aims to optimize the 'worst-case' scenario by maximizing the distance between the two nearest facilities, effectively enhancing their spatial separation as much as possible [15].

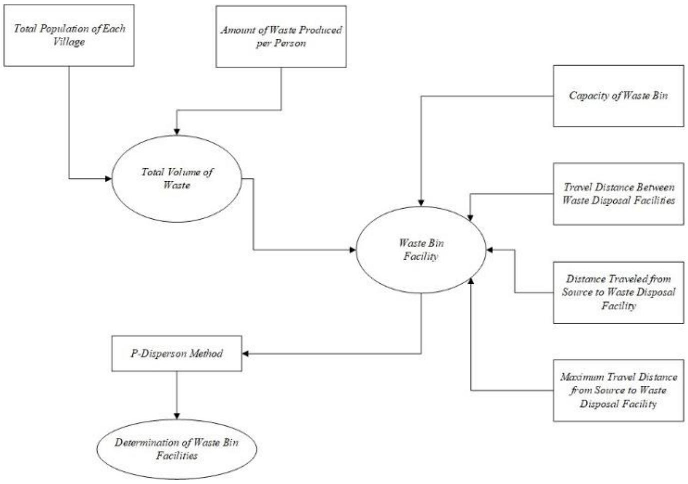

Fig. 3. Variables and Parameters Relationship Diagram Based on the P-Dispersion Method

5.2. Mathematical model

The mathematical model of the p-dispersion problem is formulated as follows:

- Objective Function

This research aims to maximize the minimum travel distance between available TPS facilities in the Malioboro-Kranggan sector, considering the distance from the waste source and TPS capacity.

$$\text{Maximize } W \quad (1)$$

- Constraints

TPS Travel Distance. This function maximises the minimum travel distance between each available TPS facility.

$$W + (m - D_{kk})X_{ka} + (m - D_{kk})X_{kb} \leqslant 2m - D_{kk}$$
$$\forall\, k \in K,\ ka \neq kb \quad (2)$$

The number of Available TPS. This function aims to determine the number of available TPS facilities to be placed and dispersed.

$$\Sigma k \in K\ X_k = p \quad (3)$$

Waste Source Serviceability. The waste source comes from the population in each neighbourhood in the Malioboro-Kranggan sector, and each waste source can only be served by one available TPS facility.

$$\Sigma i \in I\ Y_{ik} >= 1\ \forall\, i \in I \quad (4)$$

TPS Capacity. TPS has a waste storage capacity that can accommodate waste from the waste sources in the Malioboro-Kranggan sector.

$$\Sigma i \in I\ V_i Y_{ik} \leq C_k X_k,\ \forall\, k \in K \quad (5)$$

Maximum Disposal Distance. The maximum disposal distance is determined by the maximum travel distance for someone to dispose of waste (waste source) to the TPS facility without exceeding the maximum distance.

$$\{D_{k(i)}\} \cdot Y_{ik} \leq D_{max} \cdot X_k,\ \forall\, k \in K \quad (6)$$

- Decision Variables.

$$X_k\ \{0,1\}\ \forall\, k \in K \quad (7)$$
$$Y_{ik}\ \{0,1\}\ \forall\, i \in I,\ k \in K \quad (8)$$
$$X_{ka}\ \{0,1\}\ \forall\, k \in K \quad (9)$$
$$X_{kb}\ \{0,1\}\ \forall\, k \in K \quad (10)$$

Model Notation

The mathematical model used in this research is represented using the following notation:

- Sets:

I = {1,2,..., i} Represents the set of indices for waste sources from the community

K = {1,2,...,k} Represents the set of indices for alternative TPS locations

E = {ka,kb∈E, ka ≠ kb} Represents the set of directed edges

- Parameters:

C_k = Capacity of TPS facility at index k (m^3/day)

V_i = volume of waste generated by the population at index I (m^3/day)

P = Number of TPS facilities to be placed

D_{ik} = Travel distance between waste source point at index i to available alternative TPS location at index k (minutes)

D_{max} = Total maximum travel distance as a fulfilment limit (minutes)

D_{kk} = Total travel distance between alternative TPS location at index ka to other alternative TPS location at index kb (minutes)

- Decision Variables:

X_k = (takes the value 1 if facility at index k is selected as a location for waste source storage and 0 otherwise)

Y_{ik} = (takes the value 1 if waste source at index i can be fulfilled by the facility at index k, and 0 otherwise)

5.3. Study area and data

The study area for this research is the city of Yogyakarta, particularly the Maliobro-Kranggan sector. The database used to create the models is made up of data corresponding to the daily generation of solid waste by locality (m^3/day).

The data collected is waste source, waste volume, the number of TPS, location of TPS, TPS capacity, and distance of the facility.

5.4. Algorithm

The p-dispersion algorithm is presented in Fig. 4.

Algorithm 1 p-dispersion algorithm

Inputs:
$I = \{1, 2, \dots, i\}$ ▷ Indices for waste sources from the community
$K = \{1, 2, \dots, k\}$ ▷ Indices for alternative TPS locations
$E = \{(ka, kb) \in E \mid ka \neq kb\}$ ▷ Directed edges
Ck ▷ Capacity of TPS facility at index k (m3/day)
Vi ▷ Volume of waste generated by the population at index I (m3/day)
P ▷ Number of TPS facilities to be placed
Dik ▷ Travel distance between waste source point at index i to available alternative TPS location at index k (minutes)
$Dmax$ ▷ Total maximum travel distance as a fulfillment limit (minutes)
Dkk ▷ Total travel distance between alternative TPS location at index ka to other alternative TPS location at index kb (minutes)
Decision Variables:
$Xk \in \{0, 1\} \quad \forall k \in K$ ▷ Takes the value 1 if facility at index k is selected as a location for waste source storage, and 0 otherwise
$Yik \in \{0, 1\} \quad \forall i \in I, k \in K$ ▷ Takes the value 1 if waste source at index i can be fulfilled by the facility at index k, and 0 otherwise
Objective Function:
$maximize \quad W$
Constraints:
for $i \in I$ **do**
  $\sum_{k \in K} Yik = 1$ ▷ Amount of trash that can be served
end for
for $k \in K$ **do**
  $\sum_{i \in I} Vi \cdot Yik \leq Ck \cdot Xk$ ▷ Total TPS capacity
end for
for $(i, k) \in E$ **do**
  $Dik \cdot Yik \leq Dmax \cdot Xk$ ▷ Maximum disposal distance
end for
$\sum_{k \in K} Xk \leq P$ ▷ Number of facilities available
for $(ka, kb) \in E$ **do**
  $W + (m - Dkk) \cdot Xka + (m - Dkk) \cdot Xkb \leq 2 \cdot m - Dkk$ ▷ Distance between facilities
end for
Binary Constraints:
for $(i, ka) \in E$ **do**
  $Yik \in \{0, 1\}$ ▷ Binary constraint for Yik
end for
for $k \in K$ **do**
  $Xk \in \{0, 1\}$ ▷ Binary constraint for Xk
end for

Fig. 4. P-dispersion Algorithm

5.5. Computational experience

The problem requires a solution for determining TPS locations by determining locations for existing and selected TPS using the help of Lingo 11.0 software. The application setting on Lingo 11.0 are shown on Fig.5. The program on Lingo 11 is as follow:

```
!p-dispersion model;
SETS:
Set_i/1..13/:Vi;
Set_k/1..17/:  ck, Xk;
LINK_ik (set_i, set_k): Dik, Yik;
LINK_kakb (set_k, set_k): Dkk;
ENDSETS
DATA:
!Source waste volume;
Vi = @ole ('D:\TPS Distance Data.xlsx','Vi');
!TPS capacity;
Ck = @ole ('D:\TPS Distance Data.xlsx','Ck');
!Distance from source to TPS;
Dik  = @ole ('D:\TPS Distance Data.xlsx','Dik');
!Distance between facilities;
Dkk = @ole ('D:\TPS Distance Data.xlsx','Dkk');
p = 13 ;
m = 5900 ;
Dmax = 1000 ;
ENDDATA
!Objective function;
max = W;
!Amount of trash that can be served;
@FOR (set_i(i):
(@sum (set_k(k) : Yik))  = 1 ) ;
!Total TPS capacity;
@FOR (SET_k(k):
((@SUm(SET_i(i): Vi(i) * Yik(i,k)))) <= Ck(k) *
Xk(k));
!Maximum disposal distance;
@FOR (LINK_ik(i,k):
Dik(i,k)*Yik(i,k) <= Dmax * Xk(k)) ;
!Number of facilities available;
((@sum (set_k(k) : Xk(k))))  <= p ;
!Distance between facilities;
@for (LINK_kakb  (k,k):
w + M - DKK(k,k)* Xk(k)* Xk (k)<= 2*M - DKK (k,k));
!Decision;
@for (LINK_ik(i,ka) : @bin (Yik)) ;
@for (set_k(_k) : @bin (Xk)) ;
```

Fig. 5. Application setting on Lingo

VI. ANALYSIS AND FINDINGS

The p-dispersion method aims to maximize the smallest separation distance between available waste collection points from one TPS to another. This research also considers the distance from the waste source to the TPS and the capacity of the TPS in terms of accommodating the total volume of waste generated by the source.

The data processing results, summarized and presented in Table II using Lingo 11.0 software application, show the source of waste, selected TPS, TPS capacity, and distance from the source to the facility.

TABLE II
THE DATA PROCESSING RESULT

No	Waste Source	Waste Volume (m^3/day)	Selected TPS	TPS Capacity (m^3/day)	Distance to the facility (m)
1	Kricak	2,508,672	Depo Makam Utaralaya	28	1000
2	Karangwaru	1,836,572	Container Dinsos Karangwaru	20	550
3	Tegalrejo	1,744,264	Container BLPT	20	850
4	Bener	931,728	TPSS RW 4	15	550
5	Bumijo	1,943,356	Container DPUPR	20	750
6	Cokrodiningratan	1,666,432	TPSS Gowongan	17	1000
7	Gowongan	1,515,468	TPS Kleringan	17	900
8	Sosromenduran	1,405,112	TPSS Pasar Senen	17	1000
9	Pringgokusuman	2,309,768	Depo Pringgokusuman	28	1000
10	Ngampilan	1,907,636	TPSS TamanBu daya	20	1000
11	Notoprajan	1,546,676	TPSS Poltabes	17	1000
12	Ngapusan	105,468	LC Pasar Sore	15	1000
13	Prawirodirjan	1,748,964	Container Benteng Vredeburg	20	1000

VII. RESULTS AND DISCUSSION

Based on the processed data using the p-dispersion model with the help of the Lingo 11.0 software application, it is found that 13 out of 17 available TPS were selected. According to Table II, it was found that the following TPS facilities can serve as waste disposal for the respective source of waste from the corresponding neighbourhoods: Depo Makam Utoroloyo for Kricak, Container Dinsos Karangwaru for Karangwaru, Container BLPT for Tegalrejo, TPS RW 4 for Bener, Container DPUPR for Bumijo, TPS Gowongan for Cokrodiningratan, TPS Kleringan for Gowongan, TPS Pasar Senen for Sosromenduran, Depo Pringgokusuman for Pringgokusuman, TPS Taman Budaya for Ngampilan, TPS Poltabes for Notoprajan, Landasan Container Pasar Sore for Ngapusan, and Container Benteng Vredburg for Prawirodirjan, see Fig.6. All the selected TPS facilities have a total capacity of 254 m^3/day, accommodating the total waste volume generated from 13 neighbourhoods, amounting to 221.19328 m^3/day. With the total capacity being more extensive than the total waste volume generated, even with reduced TPS facilities, they can still accommodate all the waste sources in the Malioboro-Kranggan sector.

These findings imply that, even with a reduction in TPS facilities, the selected TPS can accommodate all the waste sources in the Malioboro-Kranggan sector. The placement of waste sources and the selected TPS using the p-dispersion model can effectively optimize the waste disposal process by reducing the number of TPS facilities required while ensuring that all waste generated from the neighbourhoods in the sector can be adequately managed.

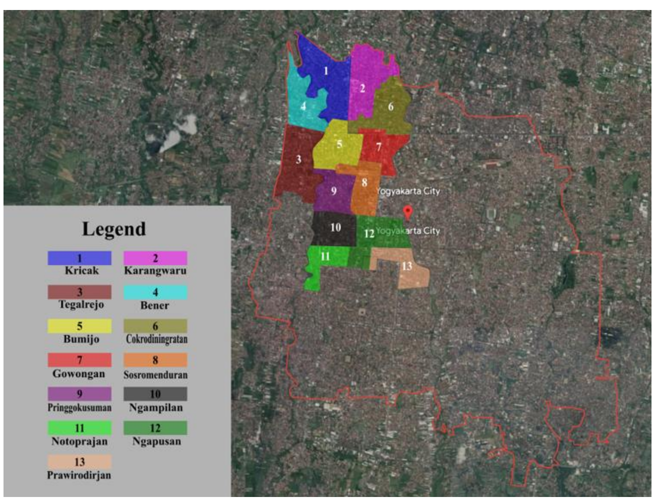

Fig. 6. Optimal TPS in Yogyakarta City

Lingo 11.0 software applications and Google Earth maps in this research demonstrate the potential of using advanced tools and technologies in waste management planning. The p-dispersion model, coupled with optimization software, can provide valuable insights into the optimal placement of waste collection points, considering various factors such as distance, capacity, and waste volume. It helps local authorities and waste management planners make informed decisions to allocate resources efficiently, reduce costs, and improve the overall waste management system.

VIII. IMPLICATIONS FOR WASTE MANAGEMENT PRACTICES

The p-dispersion method aims to maximize the smallest separation distance between available waste collection points. It is also worth noting that the findings of this research can have broader implications for waste management practices in other urban areas facing similar challenges. The methodology and approach used in this study can be replicated and applied in different contexts to optimize waste collection and disposal processes, leading to more sustainable and effective waste management practices.

Waste management planners play a crucial role in developing effective waste collection and disposal systems while aiming to minimize environmental impacts and promote sustainable waste management practices. These planners consider various factors such as distance, capacity, and waste volume to make informed decisions.

- Distance is essential in waste management planning as it affects transportation costs, energy consumption, and emissions. Planners aim to minimize the distance between waste generation sources and disposal facilities to reduce the carbon footprint associated with waste transportation [16].
- Waste volume is another critical factor that waste management planners take into account. By understanding the amount and composition of waste generated, they can develop appropriate waste separation, recycling, and disposal strategies. It helps reduce the amount of waste sent to landfills and maximise resource recovery [17].
- Capacity refers to the ability of waste collection and disposal systems to handle the amount of waste generated. Waste management planners analyze the current and projected waste volumes to ensure that the infrastructure and facilities are adequately sized to accommodate the waste generated by the population [18].

These factors allow waste management planners to optimize waste collection and disposal systems. By implementing efficient and sustainable practices, such as promoting recycling and composting, waste management planners can minimize the environmental impacts of waste generation and disposal [19].

In summary, waste management planners consider factors such as distance, capacity, and waste volume to make informed decisions that improve waste collection and disposal systems, reduce environmental impacts, and promote sustainable waste management practices.

IX. CONCLUSION

Based on the results of this research using the p-dispersion method with the assistance of Lingo 11.0 software, it was found that there was a reduction in the number of temporary waste collection point facilities with the selection of 13 out of 17 available TPS units. With a total capacity of 306 m^3/day, these 13 selected TPS units will serve as waste disposal facilities for 13 neighbourhoods in the Malioboro-Kranggan sector, generating a total waste volume of 221.19328 m^3/day. The selected TPS facilities include Depo Makam Utoroloyo, Container Dinsos Karangwaru, Container BLPT, TPSS RW 4 Bener, Container DPUPR, Depo Pringgokusuman, TPSS Gowongan, TPSS Kleringan, TPSS Pasar Senen, TPSS Taman Budaya, TPSS Poltabes, Container Vrederburg, and LC Pasar Sore. Based on the processing results, the objective value obtained was 5900, indicating that the ideal minimum separation distance between TPS facilities is 5900 meters. These findings can serve as a reference for the relevant authorities, such as the Department of Environmental Health, in allocating and placing TPS facilities in the Malioboro-Kranggan sector to minimize environmental pollution caused by closely located TPS facilities.

The results of this research using the p-dispersion model with the help of Lingo 11.0 software application demonstrate the approach's effectiveness in optimizing waste collection and disposal processes in the Malioboro-Kranggan sector. The selected TPS facilities were found to have sufficient capacity to accommodate all the waste generated from the neighbourhoods in the sector, even with a reduction in the number of TPS facilities. The findings highlight the potential of advanced tools and technologies in waste management planning and provide valuable insights for local authorities and planners to improve waste management practices in urban areas. Further research and application of similar methodologies in other contexts can contribute to more sustainable and effective waste management practices globally.

LIST OF ABBREVIATIONS

TPS	Tempat Pembuangan Sementara (Waste Collection Points or Temporary Disposal Sites).
SIPSN	The National Waste Management Information System.
DLH	The Environmental Agency of Yogyakarta City.
TPA	Tempat Pembuangan Akhir (Waste Disposal Site)
TPSS	Tempat Pengumpulan Sampah Sementara (Temporary Waste Collection Point)
LC	Loading Center
TPST	Tempat Pembuangan Sampah Terpadu (Integrated Waste Disposal Site)

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