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DETERMINING THE OPTIMAL TEMPORARY WASTE DISPOSAL SITES IN THE ALANG-ALANG LEBAR SUB-DISTRICT PALEMBANG USING THE P-CENTRE LOCATION PROBLEM AND P-MEDIAN PROBLEM MODELS

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ABSTRACT

The rapid development of Palembang City comes with an increase in population and a proportionate increase in waste. Providing Temporary Waste Disposal Sites (TWDS) with ideal locations is one way to address the waste problem in Palembang City. The location of the existing TWDS could be more regular and optimal. The problem of determining the optimal TWDS location can be solved by optimization science, as classified in the Set Covering Problem (SCP) model. The SCP model is divided into the p-Center Location Problem and p-Median Problem models. This study aims to determine the optimal locations for TWDS in the Alang-Alang Lebar Sub-District, Palembang City, by comparing the results of the p-Center Location Problem and p-Median Problem models. Initially, the Alang-Alang Lebar Sub-District had 33 TWDS. After formulating the Set Covering Location Problem and Maximal Covering Location Problem models, we obtain the optimal solution, which we then solve using the p-Center Location Problem and p-Median Problem models. Based on the results and discussion, the optimal TWDS can meet the demand of each village in the Alang-Alang Lebar Sub-District. The p-Center Location Problem and p-Median Problem models produce the same optimal TWDS, namely TWDS Pramuka 2 Street and around, TWDS Colonel Sulaiman Amin Street, TWDS Talang Kelapa Ujung, and TWDS Beside Soekarno Hatta Street. This study recommends using both models to determine the optimal TWDS.

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1. INTRODUCTION

The swift expansion of urban areas in Indonesia corresponds with the rise in population and is directly proportional to the amount of waste produced. However, the government must provide adequate facilities and infrastructure to address these issues, resulting in suboptimal services and a decline in environmental quality, particularly regarding waste management. The definition of waste can be found in Law No. 18 of 2012 [1]. The community refers to solid material from daily human activities or natural processes as waste [2]. The waste issue in Palembang City is a significant problem that must be addressed. According to the Head of the Palembang City Environment and Hygiene Office (EHO), the total daily waste production in Palembang City was 1,180 metric tons in 2022. Based on a population of 1.6 million people in Palembang City, it is assumed that 0.7 kilograms of waste are produced daily. Although this figure decreased by 1.67% from the previous year, it did not decrease significantly [3].

Alang-Alang Lebar Sub-District is one of Palembang City's sub-districts facing a waste problem. This new sub-district was established due to the expansion of the Palembang city area in 2007. According to the Palembang City Solid Waste Detail Engineering Design (DED) in 2013, the Alang-Alang Lebar Sub-District has numerous illegal waste disposal points. This problem may be due to its direct adjacency to Banyuasin Regency and its status as a new residential development area, which needs to be managed appropriately. In addition, the location could be better, and the waste collection system in the area needs to be improved, which causes garbage to accumulate [4]. One solution to the waste problem is using Temporary Waste Disposal Sites (TWDS). These waste storage areas are routinely transported to the Final Disposal Site (FDS) [5]. EHO Palembang City has handled waste problems by providing various locations with adequate waste stations. However, waste disposal sites must be optimally located to prevent excessive stockpiling.

Location optimization is more significant optimization problem [6]. Optimization involves maximizing or minimizing a function to obtain the best or maximum results [7]. The Set Covering Problem (SCP) is a widely used optimization problem in various industrial applications, such as scheduling, manufacturing, service planning, and location problems [8]-[9]. SCP comprises Covering-Based Problem (CBP) and Median-Based Problem models [10]. The SCP model comprises the Set Covering Location Problem (SCLP) model, Maximal Covering Location Problem (MCLP), p-Centre Location Problem, and p-Median Problem [11]. These models aim to minimize the number of facilities required to cover all clients or maximize the number of clients covered by a given number of facilities. The p-Centre Location Problem and p-Median Problem models can utilize the optimal solutions of SCLP and MCLP [12]. A comparison will be made between the optimal solutions of the two models.

SCLP aims to minimize the number of waste stations while ensuring users can access them within a specific distance or time [8]. However, the SCLP has a significant drawback as it requires the coverage of all customers, even if many waste sites need to be utilized more or less [13]. The MCLP is used to overcome these drawbacks. MCLP selects a subset of waste stations to be opened while maximizing the total demand of covered customers, with a constraint on the number of waste stations [14]. The p-Center Location problem aims to minimize the maximum distance between each customer and the assigned facility [15]. In contrast, the p-Median Problem seeks to determine the optimal location of facilities and assigned customers to minimize the total transportation cost and distance between customers and facilities [16]. This problem aims to reduce the distance between TWDS and villages in the Alang-Alang Lebar Sub-District using the p-Centre Location Problem. In contrast, the p-Median Problem minimizes the distance between urban villages in the Alang-Alang Lebar Sub-District and TWDS [17].

Previous research related to the problem of determining the location has been conducted [3], [14], [18]–[22]. [23] employed the SCP model to determine the optimal location and number of fire stations. [24] discussed optimizing the Hospital Emergency Room (HER) location in Palembang City using the SCLP, MCLP, and p-Median Problem models. Similarly, [8] explored the optimization of the location of TWDS in the Seberang Ulu I Sub-District of Palembang City, formulating the SCLP and p-Median Problem models. [3] We also considered the Covering-Based Problem model in determining the optimal location of TWDS in Sukarami Sub-District, Palembang City. In light of the background above, this research was conducted to compare the results of the p-Center Location Problem model with those of the p-Median Problem in determining the optimal location of TWDS in the Alang-Alang Lebar Sub-District of Palembang City.

2. RESEARCH METHODS

The steps taken in this research are

a. Data on the distance between TWDS in each village in the Alang-Alang Lebar Sub-District will be collected and presented in tables.
b. Measuring the distance traveled between TWDS in Alang-Alang Lebar Sub-District with the help of Google Maps.
c. Defining TWDS and village data variables in the Alang-Alang Lebar Sub-District.
d. Formulate the Covering Based Problem model as follows:
   1. The SCLP model uses **Equation (1)** as the objective function and **Constraints (2)-(3)**.
   2. The MCLP model uses **Equation (4)** as the objective function and **Constraints (5)-(8)**.
   3. The p-Centre Location Problem model uses **Equation (9)** as the objective function and **Constraints (10)-(16)**.
e. Formulate the Median Based Problem model using the p-Median Problem model using **Equation (17)** as the objective function and **Constraints (18)-(20)**.
f. Analyze the final results of the p-Center Location Problem and p-Median Problem models.
g. Mapping the optimal locations of TWDS in the Alang-Alang Lebar Sub-District using Google Earth.

Based on the data of TWDS in the Alang-Alang Lebar Sub-District obtained from DLHK Palembang City in 2022, there are eight additional TWDS after retracing, which are spread across four villages. The data can be seen in **Table 1**.

Table 1. List of the Names of TWDS in the Alang-Alang Lebar Sub-District

No	Name of Village	Name of TWDS
1	Srijaya	• TWDS Peristiwa Street and Surroundings • TWDS Srijaya Street around Bala Putra Dewa Museum • TWDS Pramuka 2 Street and Surroundings • TWDS Pulai Street • TWDS Mahmil Street • TWDS Kol. H. Burlian Street (Near JPO KM. 5 Bus Stop) • TWDS Taman Sari Street Near LRT RSUD Prov. Sumsel Station • TWDS Taman Sari Ujung Street • TWDS in front of Indomaret Kol. H. Burlian 1 • TWDS M. Husin Street • TWDS HBR Motik Street in front of Bougenville Complex • TWDS Raflesia Raya Street and Surroundings • TWDS Pancasila Street
2	Karya Baru	• TWDS Kolonel Sulaiman Amin Street • TWDS Pengadilan Tinggi Street • TWDS Minangkabau Street • TWDS Rama Raya Street
3	Talang Kelapa	• TWDS Beside Soekarno Hatta Street • TWDS Kolonel Sulaiman Amin Street around Pemda Jamik Al Muhajirin Complex • TWDS Bungur Raya Street (behind Maskarebet Hall) • TWDS Talang Kelapa Ujung • TWDS PMD Talang Kelapa Street Right and Left • TWDS Lebung Permai Street (Around Griya Interbiz Housing) • TWDS SMA Negeri 22 Palembang • TWDS Hasanudin Street (Near Griya Hero Housing and Surrounding)
4	Alang – Alang Lebar	• TWDS Hasanudin Street around Bumi Indah Sembaja Complex • TWDS Musholah Street • TWDS Jepang Street • TWDS Barokah VI Street • TWDS Bumi Mas Street • TWDS Lorong Alang-Alang Lebar Market • TWDS KM 12 Market • TWDS KM 12 Alang-Alang Lebar Bus Station

Based on Table 1, there are 13 TWDS in the Srijaya Village, 4 TWDS in the Karya Baru Village, 8 TWDS in the Talang Kelapa Village, and 8 TWDS in the Alang–Alang Lebar Village. The definition of village variables in the Alang-Alang Lebar Sub-District can be seen in Table 2. The notation used in defining the variable of villages in the Alang-Alang Lebar Sub-District is $I_{n,}$ where $n = 1, 2, 3, 4$.

Table 2. Definition of the Variable of Villages in the Alang-Alang Lebar Sub-District

Variable	Definition of Variable
I_1	Srijaya Village
I_2	Karya Baru Village
I_3	Talang Kelapa Village
I_4	Alang – Alang Lebar Village

Table 2 defines I_1 as Srijaya Village, I_2 as Karya Baru Village, I_3 as Talang Kelapa Village, and I_4 as Alang-Alang Lebar Village. Then, the definition of each TWDS can be seen in Table 3. The variable used to define each TWDS is K_n where $n = 1, 2, 3, \dots, 33$.

Table 3. Definition of the Variable of TWDS in the Alang-Alang Lebar Sub-District

Variable	Definition of Variables
K_1	TWDS Peristiwa Street and Surroundings
K_2	TWDS Srijaya Street around Bala Putra Dewa Museum
K_3	TWDS Pramuka 2 Street and Surroundings
K_4	TWDS Pulai Street
K_5	TWDS Mahmil Street
K_6	TWDS Kol. H. Burlian Street (Near JPO KM.5 Bus Stop)
K_7	TWDS Taman Sari near LRT RSUD Prov. Sumsel Station
K_8	TWDS Taman Sari Ujung Street
K_9	TWDS in front of Indomaret Kol. H. Burlian 1
K_{10}	TWDS M. Husin Street
K_{11}	TWDS HBR Motik Street in front of Bougenville Complex
K_{12}	TWDS Raflesia Raya Street and Surroundings
K_{13}	TWDS Pancasila Street
K_{14}	TWDS Kolonel Sulaiman Amin Street
K_{15}	TWDS Pengadilan Tinggi Street
K_{16}	TWDS Minangkabau Street
K_{17}	TWDS Rama Raya Street
K_{18}	TWDS Beside Soekarno Hatta Street
K_{19}	TWDS Kolonel Sulaiman Amin around Pemda Jamik Al Muhajirin Complex
K_{20}	TWDS Bungur Raya Street (behind Maskarebet Hall)
K_{21}	TWDS Talang Kelapa Ujung
K_{22}	TWDS PMD Talang Kelapa Street Right and Left
K_{23}	TWDS Lebung Permai Street (Around Griya Interbiz Housing)
K_{24}	TWDS SMA Negeri 22 Palembang
K_{25}	TWDS Hasanudin (Near Griya Hero Housing and Surroundings)
K_{26}	TWDS Hasanudin Street around Bumi Indah Sembaja Complex
K_{27}	TWDS Musholah Street
K_{28}	TWDS Jepang Street
K_{29}	TWDS Barokah VI Street
K_{30}	TWDS Bumi Mas Street
K_{31}	TWDS Lorong Alang-Alang Lebar Market
K_{32}	TWDS KM 12 Market
K_{33}	TWDS KM 12 Alang-Alang Lebar Bus Station

From Table 3, K_1 defines TWDS Peristiwa Street and Surroundings, K_2 defines TWDS Srijaya Street around Bala Putra Dewa Museum, and so un unti K_{33} defines TWDS KM 12 Alang-Alang Lebar Bus Station.

2.1 Covering-Based Problem

The Covering-Based Problem (CBP) is a mathematical model that aims to fulfill service and satisfaction requirements. This model ensures that the demand location must cover the demand within a specific range or travel period from the facility that serves it [11]. The CBP consists of several models, including the following:

a. Set Covering Location Problem

SCLP aims to minimize the number of facilities constructed or the total location cost while ensuring that the resulting network can still meet the demand levels. This problem determines the number and location of facilities required to cover all demand points within a specified range or traveling period of open facilities serving demand **[11]**. The SCLP model can be mathematically expressed as follows.

$$\text{Minimize } Z_{SCLP} = \sum_{j \in Q} K_j \tag{1}$$

Subject to

$$\sum_{j \in Q} K_j \geq 1 \tag{2}$$

$$K_j \in \{0,1\}, \quad j \in Q \tag{3}$$

Definition of notation:

Z_{SCLP} = Objective function value of SCLP model

Q = The index set of facility location

Decision Variable:

$$K_j = \begin{cases} 1; \text{if the facility is located in the } j \text{ location} \\ 0; \text{if the facility is not located in the } j \text{ location} \end{cases}$$

Equation (1) minimizes the number of locations. **Constraint (2)** ensures that one facility is selected at each demand point. **Constraint (3)** states that all decision variables are binary numbers.

b. Maximal Covering Location Problem

MCLP aims to maximize the demand covered within a specific service distance by placing a specified number of facilities **[14]**. Mathematically, the MCLP model can be written as follows.

$$\text{Maximize } Z_{MCLP} = \sum_{i \in P} L_i \tag{4}$$

Subject to

$$\sum_{j \in Q} K_j = p \tag{5}$$

$$L_i \leq \sum_{j \in Q} K_j \tag{6}$$

$$L_i \in \{0,1\}, \quad i \in P \tag{7}$$

$$K_j \in \{0,1\}, \quad j \in Q \tag{8}$$

Definition of notation:

Z_{MCLP} = Objective function value of MCLP model

P = The index set of demand location

p = The number of facility locations which will be built

Decision Variable:

$$L_i = \begin{cases} 1; \text{if the facility which located at } i \in P \text{ is covered} \\ 0; \text{if the facility which located at } i \in P \text{ is not covered} \end{cases}$$

The objective function is maximized at each demand location by **Equation (4)**. **Constraint (5)** stipulates that a total of p facilities are situated at each demand location. **Constraint (6)** indicates that open facilities are solely responsible for covering the demand location. **Constraints (7)** and **Constraints (8)** stipulate that the solution is binary.

c. p-Center Location Problem

p-Center Location Problem is the minimum solution consisting of a set of p points to minimize the maximum distance between the demand point and the nearest point of the set **[25]**. Mathematically, the p-Centre Location Problem model can be written as follows.

$$\text{Minimize } Z_{p-center} = N \tag{9}$$

Subject to

$$\sum_{j \in Q} I_{i,j} = 1, \quad i \in P \tag{10}$$

$$\sum_{j \in Q} K_j = p \tag{11}$$

$$\sum_{j \in Q} d_{i,j} I_{i,j} \leq N, \quad i \in P \tag{12}$$

$$I_{i,j} \leq K_j, \quad i \in P, j \in Q \tag{13}$$

$$I_{i,j} \in \{0,1\}, \quad i \in P, j \in Q \tag{14}$$

$$K_j \in \{0,1\}, \qquad j \in Q \tag{15}$$
$$N \geq 0 \tag{16}$$

Definition of notation:

$Z_{p-center}$ = Objective function value of p-Center Location Problem model

$d_{i,j}$ = The distance from the demand location i to facility location j (meter)

Decision variable:

$$K_j = \begin{cases} 1; \text{if the facility is located in the } j \text{ location} \\ 0; \text{if the facility is not located in the } j \text{ location} \end{cases}$$

$$I_{i,j} = \begin{cases} 1; \text{if the demand location } i \text{ is located at facility location } j \\ 0; \text{if the demand location } i \text{ is not located at facility location } j \end{cases}$$

Equation (9) is the objective function in minimizing the maximum distance the demand location will be placed to the nearest open facility. **Constraint (10)** ensures every demand location is fulfilled. **Constraint (11)** indicates the number of facilities to be placed put to p. **Constraint (12)** states that the distance from the demand point to the facility location must be less than the maximum distance. **Constraint (13)** indicates that each demand location can only be placed in an open facility. **Constraints (14)** and **(15)** are binary integer constraints, while **Constraint (16)** indicates that the solution is non-negative.

2.2 Median-Based Problem

A Median-Based Problem is an optimization problem related to distance-based allocation and location problems. In this problem, facilities must be located and assigned to demand points so that each is mapped to one facility, and the weighted distance between all demand points and related facilities is minimized. The model of the Median-Based Problem is the p-Median Problem.

The goal of the p-Median Problem is to find p locations (facilities) among a set of n potential locations, which is the distance from the demand point to the facility location [8]. In short, the p-Median Problem is a facility location problem that determines the optimal location of a fixed number of facilities by minimizing the total cost of serving demand. Mathematically, the p-Median Problem model is formulated as follows.

$$\text{Minimize } Z_{p-Median} = \sum_{i \in P} \sum_{j \in Q} d_{i,j} I_{i,j} \tag{17}$$

Subject to

$$\sum_{j \in Q} I_{i,j} = 1, \forall i \in P \tag{18}$$
$$\sum_{j \in Q} K_j = p \tag{19}$$
$$I_{i,j} \leq K_j, \forall i \in P, \forall j \in Q \tag{20}$$
$$I_{i,j} \in \{0,1\} \tag{21}$$
$$K_j \in \{0,1\}, \quad j \in Q \tag{22}$$

Definition of notation:

$Z_{p-Median}$ = The objective function value of p-Median Problem model

Decision variable:

$$K_j = \begin{cases} 1; \text{if the facility is located in the } j \text{ location} \\ 0; \text{if the facility is not located in the } j \text{ location} \end{cases}$$

$$I_{i,j} = \begin{cases} 1; \text{if the demand location } i \text{ is located at facility location } j \\ 0; \text{if the demand location } i \text{ is not located at facility location } j \end{cases}$$

Equation (17) is the objective function to minimize the distance between the demand point and the nearest allocated facility. **Constraint (18)** shows that each demand point has only one facility. **Constraint (19)** shows that p is the maximum number of facilities. **Constraint (20)** shows that the facility can cover the demand point. **Constraints (21)** and **(22)** are binary integer constraints.

3. RESULTS AND DISCUSSION

3.1 Formulation of the SCLP Model

Formulation of the SCLP model in the Alang-Alang Lebar Sub-District can be seen in **Equation (23)** with **Constraints (24)-(52)**.

$$\text{Minimize } Z_{SCLP} = \sum_{n=1}^{33} K_n \tag{23}$$

Subject to

$$K_1 + K_5 + K_6 + K_7 \geq 1 \tag{24}$$
$$K_2 \geq 1 \tag{25}$$
$$K_3 + K_4 \geq 1 \tag{26}$$
$$K_1 + K_5 + K_7 \geq 1 \tag{27}$$
$$K_1 + K_6 \geq 1 \tag{28}$$
$$K_1 + K_5 + K_7 + K_8 + K_9 \geq 1 \tag{29}$$
$$K_7 + K_8 \geq 1 \tag{30}$$
$$K_7 + K_9 \geq 1 \tag{31}$$
$$K_{10} \geq 1 \tag{32}$$
$$K_{11} + K_{12} \geq 1 \tag{33}$$
$$K_{13} \geq 1 \tag{34}$$
$$K_{14} \geq 1 \tag{35}$$
$$K_{15} \geq 1 \tag{36}$$
$$K_{16} + K_{18} \geq 1 \tag{37}$$
$$K_{17} \geq 1 \tag{38}$$
$$K_{19} \geq 1 \tag{39}$$
$$K_{20} \geq 1 \tag{40}$$
$$K_{21} \geq 1 \tag{41}$$
$$K_{22} \geq 1 \tag{42}$$
$$K_{23} \geq 1 \tag{43}$$
$$K_{24} \geq 1 \tag{44}$$
$$K_{25} \geq 1 \tag{45}$$
$$K_{26} + K_{27} \geq 1 \tag{46}$$
$$K_{26} + K_{27} + K_{29} \geq 1 \tag{47}$$
$$K_{28} \geq 1 \tag{48}$$
$$K_{27} + K_{29} \geq 1 \tag{49}$$
$$K_{30} \geq 1 \tag{50}$$
$$K_{31} + K_{32} + K_{33} \geq 1 \tag{51}$$
$$K_n \in \{0,1\} \text{ where } n = 1, 2, 3, \dots, 33. \tag{52}$$

Equation (23) states the minimum number of TWDS in the Alang-Alang Lebar Sub-District. **Constraints (24)-(51)** are the constraints for each demand points with distance ≤ 500 meter. **Constraint (52)** shows that each variable must be in 0 or 1 value. The value of 0 means that the TWDS will not be settled in location n where $n = 1, 2, 3, \dots, 33$. The value of 1 means otherwise.

Table 4 presents the optimal solution of the SCLP model, obtained using the LINGO 13.0 application. The Solver Status, Model Class, indicates that the solution is Pure Integer Linear Programming (PILP), which signifies that the model is pure integer programming. The state field shows that the resulting solution is globally optimal, with the objective function value being 22. The infeasibility value is 0, indicating that the equation with multiple constraints has produced a feasible solution. The iteration value is 0, indicating that there have been no iterations. The extender solver status shows that the solver type is branch and bound, obtained from the optimal solution of 22 with an interval of 2, Generated Memory Unit (GMU) of 29K, and Elapsed Runtime (ER) of 0 seconds.

Based on **Table 4**, the optimal solutions are $K_1 = K_2 = K_4 = K_7 = K_{10} = K_{12} = K_{13} = K_{14} = K_{15} = K_{17} = K_{18} = K_{19} = K_{20} = K_{21} = K_{22} = K_{23} = K_{24} = K_{25} = K_{27} = K_{28} = K_{30} = K_{33}$, which means there are 22 candidate locations, which can be seen in **Table 5**.

Table 4. Optimal Solution of the SCLP Model

Solver Status	
Model Class	PILP
State	Global Optimal
Objective	22
Infeasibility	0
Iteration	0
Extended Solver Status	
Solver Type	Branch and Bound
Best Objective	22
Objective Bound	22
Steps	0
Active	0
Update Interval	2
GMU (K)	29
ER (sec)	0

Table 5. Optimal TWDS Based on the SCLP Model

No	Optimal TWDS
1	TWDS Peristiwa Street and Surroundings
2	TWDS Srijaya Street around Bala Putra Dewa Museum
3	TWDS Pulai Street
4	TWDS Taman Sari Street near LRT RSUD Prov. Sumsel Station
5	TWDS M. Husin Street
6	TWDS Raflesia Raya Street and Surroundings
7	TWDS Pancasila Street
8	TWDS Kolonel Sulaiman Amin Street
9	TWDS Pengadilan Tinggi Street
10	TWDS Rama Raya Street
11	TWDS Beside Soekarno Hatta Street
12	TWDS Kolonel Sulaiman Amin around Pemda Jamik Al Muhajirin Complex
13	TWDS Bungur Raya Street (behind Maskarebet Hall)
14	TWDS Talang Kelapa Ujung
15	TWDS PMD Talang Kelapa Street Right and Left
16	TWDS Lebung Permai Street (Around Griya Interbiz Housing)
17	TWDS SMA Negeri 22 Palembang
18	TWDS Hasanudin (Near Griya Hero Housing and Surroundings)
19	TWDS Musholah Street
20	TWDS Jepang Street
21	TWDS Bumi Mas Street
22	TWDS KM 12 Alang - Alang Lebar Bus Station

3.2 Formulation of the MCLP Model

This stage formulates the MCLP model using data on TWDS in the Alang-Alang Lebar Sub-District. This MCLP formulation maximizes the demand point with a specified coverage distance. Table 6 lists variable definitions and demand points in the Alang-Alang Lebar Sub-District.

Table 6. Definition of Demand Points in the Alang – Alang Lebar Sub-District

Variable	Demand Point
L_1	Peristiwa Street and Surroundings
L_2	Srijaya Street around Bala Putra Dewa Museum
L_3	Pramuka 2 Street and Surroundings
L_4	Pulai Street
L_5	Mahmil Street
L_6	Kol. H. Burlian Street (Near JPO KM.5 Bus Stop)
L_7	Taman Sari near LRT RSUD Prov. Sumsel Station
L_8	Taman Sari Ujung Street
L_9	In front of Indomaret Kol. H. Burlian 1
L_{10}	M. Husin Street
L_{11}	HBR Motik Street in front of Bougenville Complex
L_{12}	Raflesia Raya Street and Surroundings
L_{13}	Pancasila Street
L_{14}	Kolonel Sulaiman Amin Street
L_{15}	Pengadilan Tinggi Street
L_{16}	Minangkabau Street
L_{17}	Rama Raya Street
L_{18}	Beside Soekarno Hatta Street
L_{19}	Kolonel Sulaiman Amin around Pemda Jamik Al Muhajirin Complex
L_{20}	Bungur Raya Street (behind Maskarebet Hall)
L_{21}	Talang Kelapa Ujung
L_{22}	PMD Talang Kelapa Street Right and Left
L_{23}	Lebung Permai Street (Around Griya Interbiz Housing)
L_{24}	SMA Negeri 22 Palembang
L_{25}	Hasanudin (Near Griya Hero Housing and Surroundings)
L_{26}	Hasanudin Street around Bumi Indah Sembaja Complex
L_{27}	Musholah Street
L_{28}	Jepang Street
L_{29}	Barokah VI Street
L_{30}	Bumi Mas Street
L_{31}	Lorong Alang-Alang Lebar Market
L_{32}	KM 12 Market
L_{33}	KM 12 Alang-Alang Lebar Bus Station

Using the distance data and the data in **Table 5**, the MCLP model is formulated as follows.

$$\text{Maximize } Z_{MCLP} = \sum_{n=1}^{33} L_n \quad (53)$$

Subject to

$$\sum_{n=1}^{33} K_n = 22 \quad (54)$$
$$K_1 + K_5 + K_6 + K_7 \geq L_1 \quad (55)$$
$$K_2 \geq L_2 \quad (56)$$
$$K_3 + K_4 \geq L_3 \quad (57)$$
$$K_3 + K_4 \geq L_4 \quad (58)$$
$$K_1 + K_5 + K_7 \geq L_5 \quad (59)$$
$$K_1 + K_6 \geq L_6 \quad (60)$$
$$K_1 + K_5 + K_7 + K_8 + K_9 \geq L_7 \quad (61)$$
$$K_7 + K_8 \geq L_8 \quad (62)$$
$$K_7 + K_9 \geq L_9 \quad (63)$$
$$K_{10} \geq L_{10} \quad (64)$$
$$K_{11} + K_{12} \geq L_{11} \quad (65)$$
$$K_{11} + K_{12} \geq L_{12} \quad (66)$$
$$K_{13} \geq L_{13} \quad (67)$$
$$K_{14} \geq L_{14} \quad (68)$$
$$K_{15} \geq L_{15} \quad (69)$$
$$K_{16} + K_{18} \geq L_{16} \quad (70)$$
$$K_{17} \geq L_{17} \quad (71)$$
$$K_{16} + K_{18} \geq L_{18} \quad (72)$$
$$K_{19} \geq L_{19} \quad (73)$$

$$K_{20} \geq L_{20} \tag{74}$$
$$K_{21} \geq L_{21} \tag{75}$$
$$K_{22} \geq L_{22} \tag{76}$$
$$K_{23} \geq L_{23} \tag{77}$$
$$K_{24} \geq L_{24} \tag{78}$$
$$K_{25} \geq L_{25} \tag{79}$$
$$K_{26} + K_{27} \geq L_{26} \tag{80}$$
$$K_{26} + K_{27} + K_{29} \geq L_{27} \tag{81}$$
$$K_{28} \geq L_{28} \tag{82}$$
$$K_{27} + K_{29} \geq L_{29} \tag{83}$$
$$K_{30} \geq L_{30} \tag{84}$$
$$K_{31} + K_{32} + K_{33} \geq L_{31} \tag{85}$$
$$K_{31} + K_{32} + K_{33} \geq L_{32} \tag{86}$$
$$K_{31} + K_{32} + K_{33} \geq L_{33} \tag{87}$$
$$K_n \in \{0,1\} \text{ where } n = 1, 2, 3, \dots, 33. \tag{88}$$
$$L_n \in \{0,1\} \text{ where } n = 1, 2, 3, \dots, 33. \tag{89}$$

Based on the formulation of the MCLP model, it can be said that:

1. **Equation (53)** is the objective function to maximize the total demand in the Alang-Alang Lebar Sub-District.
2. **Equation (54)** is the constraint that states there will be 22 facilities to be located.
3. **Constraints (55)-(87)** state the constraint for each demand point.
4. **Constraints (88)** and **(89)** ensure that all solutions are binary, i.e., 0 or 1. If 0 means that the facility location does not occupy the demand location, and if one, it means that the facility occupies the demand location.

The optimal solution for the MCLP model in Alang - Alang Lebar Sub-District using LINGO 13.0 can be seen in **Table 7** and **Table 8**.

Table 7. Optimal Solution of The MCLP Model

Solver Status	
Model Class	PILP
State	Global Optimal
Objective	33
Infeasibility	0
Iteration	0
Extended Solver Status	
Solver Type	Branch and Bound
Best Objective	33
Objective Bound	33
Steps	0
Active	0
Update Interval	2
GMU (K)	38
ER (sec)	0

Table 8. Optimal TWDS based on the MCLP Model

No	Optimal TWDS
1	TWDS Peristiwa Street and Surroundings
2	TWDS Srijaya Street around Bala Putra Dewa Museum
3	TWDS Pramuka 2 Street and Surroundings
4	TWDS Taman Sari Street near LRT RSUD Prov. Sumsel Station
5	TWDS M. Husin Street
6	TWDS Raflesia Raya Street and Surroundings
7	TWDS Pancasila Street
8	TWDS Kolonel Sulaiman Amin Street
9	TWDS Pengadilan Tinggi Street
10	TWDS Rama Raya Street
11	TWDS Beside Soekarno Hatta Street
12	TWDS Kolonel Sulaiman Amin around Pemda Jamik Al Muhajirin Complex
13	TWDS Bungur Raya Street (behind Maskarebet Hall)
14	TWDS Talang Kelapa Ujung
15	TWDS PMD Talang Kelapa Street Right and Left
16	TWDS Lebung Permai Street (Around Griya Interbiz Housing)
17	TWDS SMA Negeri 22 Palembang
18	TWDS Hasanudin (Near Griya Hero Housing and Surroundings)
19	TWDS Musholah Street
20	TWDS Jepang Street
21	TWDS Bumi Mas Street
22	TWDS KM 12 Market

3.3 Formulation of the p-Center Location Problem Model

The p-Centre Location Problem model uses data on the location of TWDS obtained from solving the MCLP model and data on demand points in the Alang - Alang Lebar Sub-District. Table 9 shows the location of the selected candidate TWDS where K_1 states TWDS Peristiwa Street and Surroundings, K_2 states TWDS Srijaya Street around the Bala Putra Dewa Museum, K_3 states TWDS Pramuka 2 Street and Surroundings to K_{32} states TWDS KM 12 Market.

Table 9. Selected Candidate Locations of TWDS

Variable	Location
K_1	TWDS Peristiwa Street and Surroundings
K_2	TWDS Srijaya Street around Bala Putra Dewa Museum
K_3	TWDS Pramuka 2 Street and Surroundings
K_7	TWDS Taman Sari near LRT RSUD Prov. Sumsel Station
K_{10}	TWDS M. Husin Street
K_{12}	TWDS Raflesia Raya Street and Surroundings
K_{13}	TWDS Pancasila Street
K_{14}	TWDS Kolonel Sulaiman Amin Street
K_{15}	TWDS Pengadilan Tinggi Street
K_{17}	TWDS Rama Raya Street
K_{18}	TWDS Beside Soekarno Hatta Street
K_{19}	TWDS Kolonel Sulaiman Amin around Pemda Jamik Al Muhajirin Complex
K_{20}	TWDS Bungur Raya Street (behind Maskarebet Hall)
K_{21}	TWDS Talang Kelapa Ujung
K_{22}	TWDS PMD Talang Kelapa Street Right and Left
K_{23}	TWDS Lebung Permai Street (Around Griya Interbiz Housing)
K_{24}	TWDS SMA Negeri 22 Palembang
K_{25}	TWDS Hasanudin (Near Griya Hero Housing and Surroundings)
K_{27}	TWDS Musholah Street
K_{28}	TWDS Jepang Street
K_{30}	TWDS Bumi Mas Street
K_{32}	TWDS KM 12 Market

Table 10 explains that $d_{1,1}$ is the distance between Srijaya Village (I_1) to TWDS Peristiwa Street and Surroundings (K_1) which is 1100 metres. $d_{2,2}$ is the distance between Karya Baru Village (I_2) to TWDS Srijaya Street around Bala Putra Dewa Museum (K_2) which is 8300 metres. $d_{3,3}$ is the distance between Karya Baru Village (I_3) to TWDS Pramuka 2 Street and Surroundings (K_3) which is 1900 metres and $d_{4,32}$ is the distance between Karya Baru Village (I_4) to TWDS KM 12 Market (K_{32}) which is 5300 metres.

Table 10. Distance Data between the Village and TWDS in the Alang-Alang Lebar Sub-District

$d_{i,j}$	1	2	3	7	10	12	13	14	15	17	18
1	1100	600	190	1400	3100	7300	4700	10000	4600	6300	6300
2	7300	8300	8400	4900	2100	1700	2300	850	2800	4500	1700
3	10800	9000	1900	8400	6300	4800	4900	5000	5900	5100	3800
4	7800	8700	8800	5400	5700	2300	1900	3500	2900	2500	700

$d_{i,j}$	19	20	21	22	23	24	25	27	28	30	32
1	5900	7300	9500	7800	12700	9100	9200	7200	7400	9900	9500
2	1600	3700	5100	2900	7800	4200	4300	5300	5600	5000	6000
3	4800	3800	1100	2300	2600	1600	2900	3900	5600	3600	4600
4	3300	1400	3900	2200	7100	3500	1900	3800	2500	4300	5300

The formulation of p-Center Location Problem is as follows:

Minimize N (90)

Subject to

$$I_{1,1} + I_{1,2} + I_{1,3} + I_{1,7} + I_{1,10} + I_{1,12} + I_{1,13} + I_{1,14} + I_{1,15} + I_{1,17} + I_{1,18} + I_{1,19} + I_{1,20} + I_{1,21} + I_{1,22} + I_{1,23} + I_{1,24} + I_{1,25} + I_{1,27} + I_{1,28} + I_{1,30} + I_{1,32} = 1 \quad (91)$$

$$I_{2,1} + I_{2,2} + I_{2,3} + I_{2,7} + I_{2,10} + I_{2,12} + I_{2,13} + I_{2,14} + I_{2,15} + I_{2,17} + I_{2,18} + I_{2,19} + I_{2,20} + I_{2,21} + I_{2,22} + I_{2,23} + I_{2,24} + I_{2,25} + I_{2,27} + I_{2,28} + I_{2,30} + I_{2,32} = 1 \quad (92)$$

$$I_{3,1} + I_{3,2} + I_{3,3} + I_{3,7} + I_{3,10} + I_{3,12} + I_{3,13} + I_{3,14} + I_{3,15} + I_{3,17} + I_{3,18} + I_{3,19} + I_{3,20} + I_{3,21} + I_{3,22} + I_{3,23} + I_{3,24} + I_{3,25} + I_{3,27} + I_{3,28} + I_{3,30} + I_{3,32} = 1 \quad (93)$$

$$I_{4,1} + I_{4,2} + I_{4,3} + I_{4,7} + I_{4,10} + I_{4,12} + I_{4,13} + I_{4,14} + I_{4,15} + I_{4,17} + I_{4,18} + I_{4,19} + I_{4,20} + I_{4,21} + I_{4,22} + I_{4,23} + I_{4,24} + I_{4,25} + I_{4,27} + I_{4,28} + I_{4,30} + I_{4,32} = 1 \quad (94)$$

$$K_1 + K_2 + K_3 + K_7 + K_{10} + K_{12} + K_{13} + K_{14} + K_{15} + K_{17} + K_{18} + K_{19} + K_{20} + K_{20} + K_{21} + K_{22} + K_{23} + K_{24} + K_{25} + K_{27} + K_{28} + K_{30} + K_{32} = 22 \quad (95)$$

$$1100I_{1,1} + 600I_{1,2} + 190I_{1,3} + 1400I_{1,7} + 3100I_{1,10} + 7300I_{1,12} + 4700I_{1,13} + 10000I_{1,14} + 4600I_{1,15} + 6300I_{1,17} + 6300I_{1,18} + 5900I_{1,19} + 7300I_{1,20} + 9500I_{1,21} + 7800I_{1,22} + 12700I_{1,23} + 9100I_{1,24} + 9200I_{1,25} + 7200I_{1,27} + 7400I_{1,28} + 9900I_{1,30} + 5300I_{1,32} \le N \quad (96)$$

$$7300I_{2,1} + 8300I_{2,2} + 8400I_{2,3} + 4900I_{2,7} + 2100I_{2,10} + 1700I_{2,12} + 2300I_{2,13} + 850I_{2,14} + 2800I_{2,15} + 4500I_{2,17} + 1700I_{2,18} + 1600I_{2,19} + 3700I_{2,20} + 5100I_{2,21} + 2900I_{2,22} + 7800I_{2,23} + 4200I_{2,24} + 4300I_{2,25} + 5300I_{2,27} + 5600I_{2,28} + 5000I_{2,30} + 6000I_{2,32} \le N \quad (97)$$

$$10800I_{3,1} + 9000I_{3,2} + 1900I_{3,3} + 8400I_{3,7} + 6300I_{3,10} + 4800I_{3,12} + 4900I_{3,13} + 5000I_{3,14} + 5900I_{3,15} + 5100I_{3,17} + 3800I_{3,18} + 4800I_{3,19} + 3800I_{3,20} + 1100I_{3,21} + 2300I_{3,22} + 2600I_{3,23} + 1600I_{3,24} + 2900I_{3,25} + 3900I_{3,27} + 5600I_{3,28} + 3600I_{3,30} + 4600I_{3,32} \le N \quad (98)$$

$$7800I_{4,1} + 8700I_{4,2} + 8800I_{4,3} + 5400I_{4,7} + 5700I_{4,10} + 2300I_{4,12} + 1900I_{4,13} + 3500I_{4,14} + 2900I_{4,15} + 2500I_{4,17} + 700I_{4,18} + 3300I_{4,19} + 1400I_{4,20} + 3900I_{4,21} + 2200I_{4,22} + 7100I_{4,23} + 3500I_{4,24} + 1900I_{4,25} + 3800I_{4,27} + 2500I_{4,28} + 4300I_{4,30} + 5300I_{4,32} \le N \quad (99)$$

$$I_{1,1}, I_{2,1}, I_{3,1}, I_{4,1} \le K_1 \quad (100)$$

$$I_{1,2}, I_{2,2}, I_{3,2}, I_{4,2} \le K_2 \quad (101)$$

$$I_{1,3}, I_{2,3}, I_{3,3}, I_{4,3} \le K_3 \quad (102)$$

$$I_{1,7}, I_{2,7}, I_{3,7}, I_{4,7} \le K_7 \quad (103)$$

$$I_{1,10}, I_{2,10}, I_{3,10}, I_{4,10} \le K_{10} \quad (104)$$

$$I_{1,12}, I_{2,12}, I_{3,12}, I_{4,12} \le K_{12} \quad (105)$$

$$I_{1,13}, I_{2,13}, I_{3,13}, I_{4,13} \le K_{13} \quad (106)$$

$$I_{1,14}, I_{2,14}, I_{3,14}, I_{4,14} \leq K_{14} \quad (107)$$
$$I_{1,15}, I_{2,15}, I_{3,15}, I_{4,15} \leq K_{15} \quad (108)$$
$$I_{1,17}, I_{2,17}, I_{3,17}, I_{4,17} \leq K_{17} \quad (109)$$
$$I_{1,18}, I_{2,18}, I_{3,18}, I_{4,18} \leq K_{18} \quad (110)$$
$$I_{1,19}, I_{2,19}, I_{3,19}, I_{4,19} \leq K_{19} \quad (111)$$
$$I_{1,20}, I_{2,20}, I_{3,20}, I_{4,20} \leq K_{20} \quad (112)$$
$$I_{1,21}, I_{2,21}, I_{3,21}, I_{4,21} \leq K_{21} \quad (113)$$
$$I_{1,22}, I_{2,22}, I_{3,22}, I_{4,22} \leq K_{22} \quad (114)$$
$$I_{1,23}, I_{2,23}, I_{3,23}, I_{4,23} \leq K_{23} \quad (115)$$
$$I_{1,24}, I_{2,24}, I_{3,24}, I_{4,24} \leq K_{24} \quad (116)$$
$$I_{1,25}, I_{2,25}, I_{3,25}, I_{4,25} \leq K_{25} \quad (117)$$
$$I_{1,27}, I_{2,27}, I_{3,27}, I_{4,27} \leq K_{27} \quad (118)$$
$$I_{1,28}, I_{2,28}, I_{3,28}, I_{4,28} \leq K_{28} \quad (119)$$
$$I_{1,30}, I_{2,30}, I_{3,30}, I_{4,30} \leq K_{30} \quad (120)$$
$$I_{1,32}, I_{2,32}, I_{3,32}, I_{4,32} \leq K_{32} \quad (121)$$
$$I_{i,j} \in \{0,1\}, i = 1,2,3,4, j = 1,2,3,7,10,12,13,14,15,17,18,19,20,21,22,23,24,25,27,28,30,32 \quad (122)$$
$$K_1, K_2, K_3, K_7, K_{10}, K_{12}, K_{13}, K_{14}, K_{15}, K_{17}, K_{18}, K_{19}, K_{20}, K_{21}, K_{22}, K_{23}, K_{24}, K_{25}, K_{27}, K_{28}, K_{30}, K_{32} \in \{0,1\} \quad (123)$$
$$N \geq 0 \quad (124)$$

Based on the formulation in **Equations (91)-(96)** and **Constraints (97)-(126)** can be explained as follows:

1. **Equation (91)** is the minimum distance between the Village point and the TWDS in the Alang - Alang Lebar Sub-District.
2. **Equation (92)** limits the demand point in Village 1, namely Srijaya Village.
3. **Equation (93)** is a constraint for the demand point in Village 2, namely Karya Baru Village.
4. **Equation (94)** is the constraint for the demand point in Village 3, Talang Kelapa Village.
5. **Equation (95)** is the constraint for the demand point in Village 4, which is Alang-Alang Lebar Village.
6. **Equation (96)** is the number of facility location placements.
7. **Constraints (97)** to **(100)** are constraints for facility location demand.
8. **Constraints (101)** to **(123)** are constraints for demand at locations according to the optimal TWDS results of the MCLP model.
9. **Constraints (124)** and **(125)** state that each variable in the p-Centre Location Problem model is binary.
10. **Constraint (126)** indicates that the maximum traveling distance cannot be negative.

The optimal solution of the p-Center Location Problem can be seen in **Table 11**. Based on **Table 11**, the optimum distance location of TWDS in the Alang-Alang Lebar Sub-District is 1100 meter, with the optimal solutions are $I_{1,3} = I_{2,14} = I_{3,21} = I_{4,18} = 1$, which mean:

1. The demand in Srijaya Village (I_1) will be located at TWDS Pramuka 2 Street and Surroundings (K_3).
2. The demand in Karya Baru Village (I_2) will be located at TWDS Kolonel Sulaiman Amin Street (K_{14}).
3. The demand in Talang Kelapa Village (I_3) will be located at TWDS Talang Kelapa Ujung (K_{21}).
4. The demand in Alang–Alang Lebar Village (I_4) will be located at TWDS beside Soekarno Hatta Street (K_{18}).

Table 11. Optimal Solution of the p-Center Location Problem Model

Solver Status	
Model Class	MILP
State	Global Optimum
Objective	1100
Infeasibility	0
Iteration	2
Extended Solver Status	
Solver Type	Branch and Bound
Best Objective	1100
Objective Bound	1100
Steps	0
Active	0
Update Interval	2
GMU (K)	45
ER (sec)	0

3.4 Formulation of the p-Median Problem Model

This stage formulates the p-Median Problem model using data on the location of TWDS obtained from solving the MCLP model and data on demand points in the Alang-Alang Lebar Sub-District. The location of the selected TWDS can be seen in **Table 8**. The formulation of the p-Median Problem model is as follows:

Minimize

$$Z_{p-Median} = 1100I_{1,1} + 600I_{1,2} + 190I_{1,3} + 1400I_{1,7} + 3100I_{1,10} + 7300I_{1,12} + 4700I_{1,13} + 10000I_{1,14} + 4600I_{1,15} + 6300I_{1,17} + 6300I_{1,18} + 5900I_{1,19} + 7300I_{1,20} + 9500I_{1,21} + 7800I_{1,22} + 12700I_{1,23} + 9100I_{1,24} + 9200I_{1,25} + 7200I_{1,27} + 7400I_{1,28} + 9900I_{1,30} + 9500I_{1,32}+7300I_{2,1} + 8300I_{2,2} + 8400I_{2,3} + 4900I_{2,7} + 2100I_{2,10} + 1700I_{2,12} + 2300I_{2,13} + 850I_{2,14} + 2800I_{2,15} + 4500I_{2,17} + 1700I_{2,18} + 1600I_{2,19} + 3700I_{2,20} + 5100I_{2,21} + 2900I_{2,22} + 7800I_{2,23} + 4200I_{2,24} + 4300I_{2,25} + 5300I_{2,27} + 5600I_{2,28} + 5000I_{2,30} + 6000I_{2,32} + 10800I_{3,1} + 9000I_{3,2} + 1900I_{3,3} + 8400I_{3,7} + 6300I_{3,10} + 4800I_{3,12} + 4900I_{3,13} + 5000I_{3,14} + 5900I_{3,15} + 5100I_{3,17} + 3800I_{3,18} + 4800I_{3,19}+3800I_{3,20} + 1100I_{3,21} + 2300I_{3,22} + 2600I_{3,23} + 1600I_{3,24} + 2900I_{3,25} + 3900I_{3,27} + 5600I_{3,28} + 3600I_{3,30} + 4600I_{3,32} + 7800I_{4,1} + 8700I_{4,2} + 8800I_{4,3} + 5400I_{4,7} + 5700I_{4,10} + 2300I_{4,12} + 1900I_{4,13} + 3500I_{4,14} + 2900I_{4,15} + 2500I_{4,17} + 700I_{4,18} + 3300I_{4,19} + 1400I_{4,20} + 3900I_{4,21} + 2200I_{4,22} + 7100I_{4,23} + 3500I_{4,24} + 1900I_{4,25} + 3800I_{4,27} + 2500I_{4,28} + 4300I_{4,30} + 5300I_{4,32} \quad (125)$$

Subject to

$$I_{1,1} + I_{1,2} + I_{1,3} + I_{1,7} + I_{1,10} + I_{1,12} + I_{1,13} + I_{1,14} + I_{1,15} + I_{1,17} + I_{1,18} + I_{1,19} + I_{1,20} + I_{1,21} + I_{1,22} + I_{1,23} + I_{1,24} + I_{1,25} + I_{1,27} + I_{1,28} + I_{1,30} + I_{1,32} = 1 \quad (126)$$

$$I_{2,1} + I_{2,2} + I_{2,3} + I_{2,7} + I_{2,10} + I_{2,12} + I_{2,13} + I_{2,14} + I_{2,15} + I_{2,17} + I_{2,18} + I_{2,19} + I_{2,20} + I_{2,21} + I_{2,22} + I_{2,23} + I_{2,24} + I_{2,25} + I_{2,27} + I_{2,28} + I_{2,30} + I_{2,32} = 1 \quad (127)$$

$$I_{3,1} + I_{3,2} + I_{3,3} + I_{3,7} + I_{3,10} + I_{3,12} + I_{3,13} + I_{3,14} + I_{3,15} + I_{3,17} + I_{3,18} + I_{3,19} + I_{3,20} + I_{3,21} + I_{3,22} + I_{3,23} + I_{3,24} + I_{3,25} + I_{3,27} + I_{3,28} + I_{3,30} + I_{3,32} = 1 \quad (128)$$

$$I_{4,1} + I_{4,2} + I_{4,3} + I_{4,7} + I_{4,10} + I_{4,12} + I_{4,13} + I_{4,14} + I_{4,15} + I_{4,17} + I_{4,18} + I_{4,19} + I_{4,20} + I_{4,21} + I_{4,22} + I_{4,23} + I_{4,24} + I_{4,25} + I_{4,27} + I_{4,28} + I_{4,30} + I_{4,32} = 1 \quad (129)$$

$$K_1 + K_2 + K_3 + K_7 + K_{10} + K_{12} + K_{13} + K_{14} + K_{15} + K_{17} + K_{18} + K_{19} + K_{20} + K_{20} + K_{21} + K_{22} + K_{23} + K_{24} + K_{25} + K_{27} + K_{28} + K_{30} + K_{32} = 22 \quad (130)$$

$$I_{1,1} + I_{2,1} + I_{3,1} + I_{4,1} \leq K_1 \quad (131)$$

$$I_{1,2} + I_{2,2} + I_{3,2} + I_{4,2} \leq K_2 \quad (132)$$

$$I_{1,3} + I_{2,3} + I_{3,3} + I_{4,3} \leq K_3 \quad (133)$$

$$I_{1,7} + I_{2,7} + I_{3,7} + I_{4,7} \leq K_7 \quad (134)$$

$$I_{1,10} + I_{2,10} + I_{3,10} + I_{4,10} \leq K_{10} \quad (135)$$

$$I_{1,12} + I_{2,12} + I_{3,12} + I_{4,12} \leq K_{12} \quad (136)$$

$$I_{1,13} + I_{2,13} + I_{3,13} + I_{4,13} \leq K_{13} \quad (137)$$
$$I_{1,14} + I_{2,14} + I_{3,14} + I_{4,14} \leq K_{14} \quad (138)$$
$$I_{1,15} + I_{2,15} + I_{3,15} + I_{4,15} \leq K_{15} \quad (139)$$
$$I_{1,17} + I_{2,17} + I_{3,17} + I_{4,17} \leq K_{17} \quad (140)$$
$$I_{1,18} + I_{2,18} + I_{3,18} + I_{4,18} \leq K_{18} \quad (141)$$
$$I_{1,19} + I_{2,19} + I_{3,19} + I_{4,19} \leq K_{19} \quad (142)$$
$$I_{1,20} + I_{2,20} + I_{3,20} + I_{4,20} \leq K_{20} \quad (143)$$
$$I_{1,21} + I_{2,21} + I_{3,21} + I_{4,21} \leq K_{21} \quad (144)$$
$$I_{1,22} + I_{2,22} + I_{3,22} + I_{4,22} \leq K_{22} \quad (145)$$
$$I_{1,23} + I_{2,23} + I_{3,23} + I_{4,23} \leq K_{23} \quad (146)$$
$$I_{1,24} + I_{2,24} + I_{3,24} + I_{4,24} \leq K_{24} \quad (147)$$
$$I_{1,25} + I_{2,25} + I_{3,25} + I_{4,25} \leq K_{25} \quad (148)$$
$$I_{1,27} + I_{2,27} + I_{3,27} + I_{4,27} \leq K_{27} \quad (149)$$
$$I_{1,28} + I_{2,28} + I_{3,28} + I_{4,28} \leq K_{28} \quad (150)$$
$$I_{1,30} + I_{2,30} + I_{3,30} + I_{4,30} \leq K_{30} \quad (151)$$
$$I_{1,32} + I_{2,32} + I_{3,32} + I_{4,32} \leq K_{32} \quad (152)$$
$$I_{i,j} \in \{0,1\}, i = 1,2,3,4, j = 1,2,3,7,10,12,13,14,15,17,18,19,20,21,22,23,24,25,27,28,30,32 \quad (153)$$
$$K_1, K_2, K_3, K_7, K_{10}, K_{12}, K_{13}, K_{14}, K_{15}, K_{17}, K_{18}, K_{19}, K_{20}, K_{21}, K_{22}, K_{23}, K_{24}, K_{25}, K_{27}, K_{28}, K_{30}, K_{32} \in \{0,1\} \quad (154)$$

Based on the p-Median Problem model formulation, **Equations (125)-(131)** and **Constraints (132)-(154)** can be explained as follows:

1. **Equation (125)** is an objective function that aims to minimize the total demand in the Alang-Alang Lebar Sub-District.
2. **Equation (126)** states the constraint for the demand at the location I_1.
3. **Equation (127)** states the constraint for demand at location I_2.
4. **Equation (136)** states the constraint for demand at location I_3.
5. **Equation (129)** states the constraint for demand at location I_4.
6. **Equation (130)** states the number of TWDS.
7. **Constraints (131)** to **(152)** state the constraints for demand at locations based on the optimal TWDS resulting from the MCLP model.
8. **Constraints (153)** and **(154)** show the constraints of each variable in the p-Median Problem model are binary, namely zero or one. **Constraint (153)** is zero if the demand point at location i is not placed at facility location j where $i = 1, 2, 3, 4$ and j = 1, 2, 3, 7, 10, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 30, 32. It is one if the demand point location i is placed at the facility location j. **Constraint (156)** is zero if the facility is not placed at location i where $i = 1, 2, 3, 4$ and j = 1, 2, 3, 7, 10, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 30, 32. It is one if the facility is placed at location i.

Table 12 shows the optimal solution generated from the p-Median Problem model.

Table 12. Optimal Solution of the p-Median Problem Model

Solver Status	
Model Class	MILP
State	Global Optimal
Objective	2840
Infeasibility	0
Iteration	0
Extended Solver Status	
Solver Type	Branch an Bound
Best Objective	2840
Objective Bound	2840
Steps	0
Active	0
Update Interval	2
GMU (K)	74
ER (sec)	0

Based on the solution of the p-Median Problem model, the optimal distance of TWDS in the Alang-Alang Lebar Sub-District is 2840 meter. The optimal solutions are $I_{1,3} = I_{2,14} = I_{3,21} = I_{4,18} = 1$, which mean:

1. The demand in Srijaya Village (I_1) will be located at TWDS Pramuka 2 Street and Surroundings (K_3).
2. The demand in Karya Baru Village (I_2) will be located at TWDS Kolonel Sulaiman Amin Street (K_{14}).
3. The demand in Talang Kelapa Village (I_3) will be located at TWDS Talang Kelapa Ujung (K_{21}).
4. The demand in Alang – Alang Lebar Village (I_4) will be located at TWDS beside Soekarno Hatta Street (K_{18}).

3.5 Analysis of the p-Center Location Problem and the p-Median Problem Model Results

The p-Center Location Problem and p-Median Problem model formulations result in the optimal locations of TWDS that should be placed in the Alang-Alang Lebar Sub-District Palembang. Table 13 and Table 14 summarize the optimal TWDS based on the solutions of the p-Centre Location Problem and p-Median Problem models, respectively.

Table 13. Optimal Location of TWDS in the Alang-Alang Lebar Sub-District based on the p-Center Location Problem Model

No.	Demand Location	Facility Location
1	Srijaya Village	TWDS Pramuka 2 Street and Surroundings
2	Karya Baru Village	TWDS Kolonel Sulaiman Amin Street
3	Talang Kelapa Village	TWDS Talang Kelapa Ujung
4	Alang – Alang Lebar Village	TWDS beside Soekarno Hatta Street

Table 14. Optimal Location of TWDS in the Alang-Alang Lebar Sub-District based on the p-Median Problem Model

No.	Demand Location	Facility Location
1	Srijaya Village	TWDS Pramuka 2 Street and Surroundings
2	Karya Baru Village	TWDS Kolonel Sulaiman Amin Street
3	Talang Kelapa Village	TWDS Talang Kelapa Ujung
4	Alang – Alang Lebar Village	TWDS beside Soekarno Hatta Street

The p-Center Location Problem and p-Median Problem model formulations provide solutions that can meet the demand in each village in the Alang - Alang Lebar Sub-District, namely TWDS Pramuka 2 Street and Surroundings, TWDS Kolonel Sulaiman Amin Street, TWDS Talang Kelapa Ujung, and TWDS beside Soekarno Hatta Street. However, some TWDS placements are outside the village, namely TWDS beside

Soekarno Hatta Street. The p-Center Location Problem and p-Median Problem models can determine the optimal TWDS to the nearest demand place. The mapping of the optimal location of TWDS for each village in the Alang-Alang Lebar Sub-District can be seen in **Figure 1**.

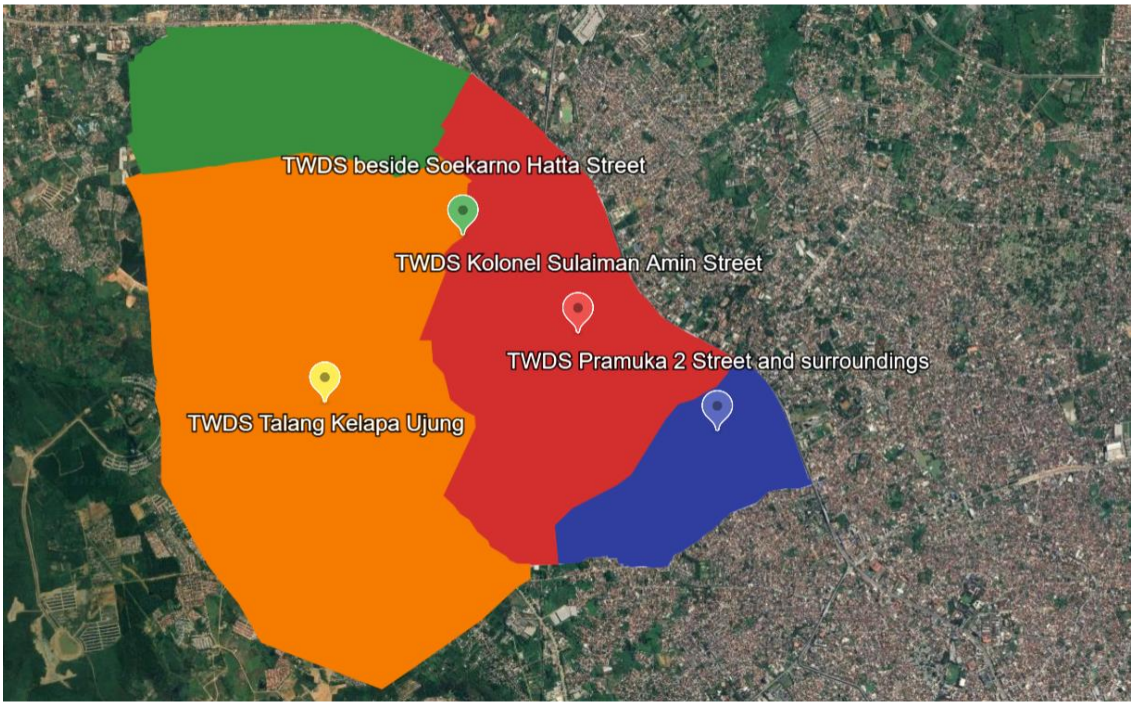

Figure 1. Optimal location of TWDS in the Alang-Alang Lebar Sub-District

Figure 1 shows the map of the optimal TWDS based on villages in the Alang-Alang Lebar Sub-District. The optimal TWDS in Srijaya Village is TWDS Pramuka 2 Street and Surroundings. The optimal TWDS in Karya Baru Village is TWDS Kolonel Sulaiman Amin Street. The Optimal TWDS in Talang Kelapa Village is TWDS Talang Kelapa Ujung, and the last TWDS beside Soekareno Hatta Street is the optimal TWDS in Alang-Alang Lebar Village.

4. CONCLUSIONS

The results and discussion of determining the optimal TWDS in the Alang-Alang Lebar Sub-District of Palembang City with the SCLP, MCLP, p-Center Location Problem, and p-Median Problem models have led to the following conclusions:

1. The SCLP model produces 22 optimal TWDS, as shown in **Table 5**.
2. The MCLP model produces 22 optimal TWDS, as shown in **Table 8**.
3. The p-Center Location Problem and p-Median Problem models produce the same 4 optimal TWDS: TWDS Pramuka 2 Street and Surroundings, TWDS Kolonel Sulaiman Amin Street, TWDS Talang Kelapa Ujung, and TWDS beside Soekarno Hatta Street. This research proposes the solution of the p-Centre Location Problem and p-Median Problem models.

The formulation of the p-Centre Location Problem and p-Median Problem models is highly dependent on the solutions of the SCLP and MCLP models. Therefore, for further research, it is necessary to develop a model that can provide solutions in the form of additional TWDS in each neighborhood to cover all demand areas.

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