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Use of the Discrete Facility Location Model in Optimizing the Number and Location of Fire Stations: A Case Study

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Abstract

This article discusses the application of discrete facility location model in optimizing the number and location of fire stations in Pekanbaru City. This quantitative model uses three basic discrete facility location models: the location set covering problem (LSCP), maximum covering location problem and the p-median problem. The mathematical model in this problem is solved using the LINGO 18.0. Computational results show that this discrete facility location model can determine the minimum number of fire stations, location of fire stations, maximum fire stations services and the allocation of each subdistrict to the fire stations.

Keywords: *Discrete facility location model, location set covering problem, maximum covering location problem, p-median problem*

1. INTRODUCTION

The facility location problem is part of the location problem in optimization. The optimal location of facilities and the allocation of demand for facilities are important issues, because they take into account costs (Bolouri et al. [3]). Optimization problems usually have some specified constraints, such as time and distance. The facility location problem model is widely applied in everyday life, such as in selecting or determining the location of airports, bus stops, fire stations, warehouses and other facilities (Current et al. [6]).

Daskin and Maass [7] classify discrete facility location models into three models: location set covering problem (LSCP), maximum covering location problem (MCLP), and p-median problem. LSCP aims to minimum the number of facilities that can serve all demand points within a predetermined distance or time (Toregas et al. [12]). MCLP aims to optimize facility coverage or maximum service coverage within standard time with a predetermined number of facilities (Church and Revelle [5]) As well as the p-median problem to minimum total travel time (Hakimi [9]). The following previous research discusses determining facility locations using this model. The use of the LSCP, MCLP, and p-median problem models is used to determine the optimal location of the emergency unit in Palembang City (Sitepu et al. [11]). Determining the optimal location and number of fire stations in urban areas using a Point of Interests (POIs) based model with the location-allocation method in Zhengzhou City (Chen et al. [4]).

The fires that occurred disturbed the comfort and safety of residents, and caused many economic, psychological, social losses and so on. Many people lose their lives due to various accidents such as fire. Improper deployment of fire stations can be considered as one of the reason (Davoodi [8]). Fires that occur are usually caused by various things such as electrical short circuits and stove explosions.

The response time to fire notifications in Indonesia is no more than 15 (fifteen) minutes as regulated in the Minister of Public Works Regulation No. 20 of 2009 concerning Technical Provisions for Fire Management in Urban Areas. This response time starts from receiving a call/report of a fire incident somewhere until arriving at the scene with equipment that has been prepared and ready for spraying operations. The service area in each fire management area is not more than 7.5 km (Menteri Pekerjaan Umum [10]).

The Pekanbaru City Government is trying its best to handle the fires that occur by building fire and rescue stations equipped with fire fighting facilities. From the results of an interview with one of the fire station operators in Pekanbaru City, currently all areas in

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The Pekanbaru City Government is trying its best to handle the fires that occur by building fire and rescue stations equipped with fire fighting facilities. From the results of an interview with one of the fire station operators in Pekanbaru City, currently all areas in Pekanbaru City cannot be reached within standard time by the existing fire stations, namely 9 fire stations. To build an optimal fire station, appropriate methods are needed so that areas far from the fire station can be reached efficiently and fire station coverage can be optimized so as to minimum the impact of fire.

In this article, the author uses the Location Set Covering Problem (LSCP), Maximum Covering Location Problem (MCLP), and p-median problem models in determining the optimal location, number and coverage of fire stations in Pekanbaru City, the calculations of which are carried out using an application LINGO 18.0. The QGIS application was also used to determine the midpoint on the Pekanbaru City map which was used as a reference point for calculating the time between each subdistrict. In part two the discrete facility location model is explained, in part three there is a discussion of the problem of the number and location of fire stations using the LSCP, MCLP and p-median problem models. Next, section four explains the conclusions of this article.

2. RESEARCH METHOD

2.1 Discrete Facility Location Model at Fire Station

The discrete facility location model is related to determining the best facility location from given candidate location so as to minimum total costs and increase customer satisfaction (Ulukan and Demircioğlu [13]). These problem models include three basic types: Location Set Covering Problem (LSCP) model, Maximal Covering Location Problem (MCLP) model, and p-median problem model.

2.1.1 Location Set Covering Problem (LSCP) Model

Location Set Covering Problem introduced by Toregas et al. [12] aims to minimum the location of facilities that can meet all demand points within a predetermined distance or time. The general formula for minimizing the number of facilities is as follows (Yeh and Chen [14]):

$$\min z = \sum_{j \in J} x_j, \tag{1}$$

subject to

$$\sum_{j \in N_i} x_j \geq 1, \qquad \forall i \in I, \tag{2}$$

$$x_j \in \{0,1\}, \qquad \forall j \in J. \tag{3}$$

where

I ≔ set of demand points,
J ≔ set of candidate facility locations,
N_i ≔ set of candidate locations for facility j that can serve request point i in standard time S, $N_i = \{j | d_{ij} \leq S\}$, where d_{ij} is the time required between location i and location j,
$x_j \coloneqq \begin{cases} 1 & \text{if facility is built at location } j, \\ 0 & \text{otherwise.} \end{cases}$

Objective function (1) is to minimize the number of facility locations. Constraint (2) ensures that every i-th request point can be served in standard time by at least one facility. Constraint (3) states that the decision variable is binary.

2.1.2 Maximum Covering Location Problem (MCLP) Model

MCLP aims to maximum service coverage within standard time with a predetermined number of facilities (Church and Revelle [5]). The MCLP model can be written as follows (Yeh and Chen [14]):

$$\max z = \sum_{i \in I} a_i y_i, \tag{4}$$

subject to

$$\sum_{j \in N_i} x_j \geq y_i, \qquad \forall i \in I, \tag{5}$$

$$\sum_{j \in J} x_j \geq p, \tag{6}$$

$$x_j \in \{0,1\}, \qquad \forall j \in J, \tag{7}$$

$$y_i \in \{0,1\}, \qquad \forall i \in I. \tag{8}$$

where

I := set of demand points,
J := set of candidate facility locations,
p := number of facilities to be opened,
a_i := weight or population to be served at request point i,
N_i := set of candidate locations for facility j that can serve request point i in standard time S, $N_i = \{j | d_{ij} \leq S\}$, where d_{ij} is the time required between location i and location j,

$$x_j := \begin{cases} 1 & \text{if facility is built at location } j, \\ 0 & \text{otherwise.} \end{cases}$$

$$y_i := \begin{cases} 1 & \text{if demand point } i \text{ is satisfied,} \\ 0 & \text{otherwise.} \end{cases}$$

Objective function (4) maximizes the scope of facilities opened by considering standard time. Constraint (5) ensures that at least one facility must be located within the specified standard time so that it can serve each demand point i. Constraint (6) states that the number of facilities allocated is limited by the p value. Constraints (7) and (8) state that the decision variables are binary.

2.1.3 Model *p*-Median Problem

The p-median problem was introduced by Hakimi [9] when considering the optimal location of switching centers in a communications network. The application of the p-median problem model is carried out to determine the allocation of each demand point to the facility location obtained from the LSCP model, with the objective function of the p-median problem model being to minimum the distance or travel time between the facility location and the demand point. The p-median problem model can be written generally as follows (Bangun et al. [2]):

$$\min z = \sum_{i \in I} \sum_{j \in J} d_{ij} y_{ij}, \tag{9}$$

subject to

$$\sum_{j \in J} y_{ij} = 1, \quad \forall i \in I \tag{10}$$

$$\sum_{j \in J} x_j = p, \tag{11}$$

$$y_{ij} \leq x_j, \qquad \forall i \in I, \qquad \forall j \in J, \tag{12}$$

$$x_j \in \{0,1\}, \qquad \forall j \in J, \tag{13}$$

$$y_{ij} \in \{0,1\}, \quad \forall i \in I, \qquad \forall j \in J, \tag{14}$$

where

z := scalar value of decision making criteria or objective function,
I := set of demand points,
J := set of facility locations,
p := number of facilities,
d_{ij} := time between the i-th request point and the j-th facility location
$x_j := \begin{cases} 1 & \text{if the facility is located at the } j\text{-th location,} \\ 0 & \text{otherwise.} \end{cases}$
$y_{ij} := \begin{cases} 1 & \text{if the request at the } i\text{-th location is allocated to the } j\text{-th facility,} \\ 0 & \text{otherwise.} \end{cases}$

The objective function (9) is to minimize the total time between the demand point and the facility location. Constraint (10) states that each request point i must be served by one facility j. Constraint (11) states that p is a limit on the number of facility locations. Constraint (12) states that the facility can only serve demand points within its coverage area. Constraint (13) and constraint (14) state that the problem is a binary number.

3. RESULTS AND DISCUSSION

In Pekanbaru City there are 15 subdistricts and 83 urban villages Badan (Badan Pusat Statistik [1]). Definitions of decision variables taken from many subdistricts are denoted by x_j as the candidate location for the fire station and y_i as the demand point in can be seen in Table 1. Parameters and Parameter Values for each subdistrict in Pekanbaru City are shown in Table 2. The parameter values in Table 2 are obtained from many urban village of each subdistrict which are denoted by a_i as the weight of the demand points. Because there are 15 subdistricts in Pekanbaru City, $i, j = 1, 2, \ldots, 15$.

Table 1. Variable definitions for each subdistrict

Variable	Variable	Subdistrict
$\boldsymbol{x_1}$	y_1	Binawidya
$\boldsymbol{x_2}$	y_2	Bukit Raya
$\boldsymbol{x_3}$	y_3	Kulim
$\boldsymbol{x_4}$	y_4	Lima Puluh
$\boldsymbol{x_5}$	y_5	Marpoyan Damai
$\boldsymbol{x_6}$	y_6	Payung Sekaki
$\boldsymbol{x_7}$	y_7	Pekanbaru Kota
$\boldsymbol{x_8}$	y_8	Rumbai Barat
$\boldsymbol{x_9}$	y_9	Rumbai
$\boldsymbol{x_{10}}$	y_{10}	Rumbai Timur
$\boldsymbol{x_{11}}$	y_{11}	Sail
$\boldsymbol{x_{12}}$	y_{12}	Senapelan
$\boldsymbol{x_{13}}$	y_{13}	Sukajadi
$\boldsymbol{x_{14}}$	y_{14}	Tuah Madani
$\boldsymbol{x_{15}}$	y_{15}	Tenayan Raya

Table 2. Parameters and parameter values for each subdistrict

Parameter	Subdistrict	Parameter value
a_1	Binawidya	5
a_2	Bukit Raya	5
a_3	Kulim	5
a_4	Lima Puluh	4
a_5	Marpoyan Damai	6
a_6	Payung Sekaki	6
a_7	Pekanbaru Kota	6
a_8	Rumbai Barat	6
a_9	Rumbai	6
a_{10}	Rumbai Timur	5
a_{11}	Sail	3
a_{12}	Senapelan	6
a_{13}	Sukajadi	7
a_{14}	Tuah Madani	5
a_{15}	Tenayan Raya	8

From the results of an interview with one of the fire station operators in Pekanbaru City and in Minister of Public Works Regulation No. 20 of 2009, the time required for a fire truck from the fire station to the incident location is ≤ 15 minutes from receiving the call/report to arriving at the incident location at a distance of 7.5 km (Menteri Pekerjaan Umum [10]). This travel time is calculated from the midpoint of one subdistrict to the midpoint of another subdistrict using Google Maps which can be seen in Table 3. Travel time is notated as d_{ij} where i, j =1,2,...,15 are the subdistricts in Pekanbaru City. It is assumed that the travel time in this study is when the road conditions are busy/congested and applies at all times, so that existing obstacles are ignored, such as traffic jams, damaged roads, several traffic signs, the number of fire trucks and other obstacles. And the route chosen is the closest route and can be passed by fire trucks.

Table 3. Time between each subdistrict in Pekanbaru City (in minutes)

d_{ij}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	24	38	22	20	10	18	34	19	42	17	16	14	11	40
2	28	0	22	23	18	29	19	45	36	44	17	21	19	25	32
3	41	23	0	30	33	41	28	54	47	54	26	32	29	41	21
4	24	19	29	0	24	17	8	32	23	31	9	8	12	29	27
5	21	17	34	25	0	21	20	41	28	43	19	21	18	19	39
6	12	26	39	18	22	0	20	24	10	36	20	10	12	17	42
7	18	13	28	10	18	15	0	30	21	28	6	7	6	23	29
8	35	41	53	31	41	25	31	0	17	39	33	25	30	39	56
9	20	31	43	22	28	10	24	16	0	33	25	15	18	26	46
10	45	40	52	32	46	38	31	41	33	0	33	30	33	51	53
11	20	14	24	8	19	19	7	35	24	32	0	11	8	25	28
12	19	18	31	8	20	9	9	24	15	28	11	0	7	23	31
13	17	16	30	11	17	11	8	29	19	32	9	6	0	21	32
14	14	24	40	27	21	16	23	39	25	49	23	23	20	0	44
15	41	32	21	28	39	40	27	53	45	54	27	31	30	44	0

Table 4 is the binary decision variable x_j which is obtained if the travel time in Table 3 is ≤ 15 minutes. A value of 1 means that the travel time from the request point (subdistrict) to the candidate fire station location is ≤ 15 minutes. A value of 0 means that the travel time from the request point (subdistrict) to the candidate fire station location is > 15 minutes.

Table 4. Binary decision variable x_j

d_{ij}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	0	0	1	0	0	0	1	1	1	0	0
5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0
7	0	1	0	1	0	1	1	0	0	0	1	1	1	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
11	0	1	0	1	0	0	1	0	0	0	1	1	1	0	0
12	0	0	0	1	0	1	1	0	1	0	1	1	1	0	0
13	0	0	0	1	0	1	1	0	0	0	1	1	1	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

3.1 Location Set Covering Problem (LSCP) Model Formulation

To minimum the number of fire station locations in Pekanbaru City, the LSCP model is used. Based on equation (1), constraints (2), (3), and the binary decision variable x_j in Table 4, the LSCP model formulation is obtained as follows:

$$\min z = \sum_{j \in J} x_j, \tag{15}$$

subject to

$$\sum_{j \in N_i} x_j \geq 1, \qquad i = 1,2,\dots,15, \qquad (16)\text{-}(30)$$

$$x_j \in \{0,1\}, \qquad j = 1,2,\dots,15. \tag{31}$$

The objective function (15) minimums the number of fire station locations. Constraints (16)-(30) are limitations for each demand point (subdistrict). Constraint (31) states that the decision variable is binary valued.

From the model above using LINGO 18.0, the optimal solution 8 is obtained with $x_1 = x_2 = x_3 = x_5 = x_8 = x_{10} = x_{12} = x_{15} = 1$ which means that fire stations should be built in 8 locations as follows, namely as follows: Binawidya Subdistrict, Bukit Raya Subdistrict, Kulim Subdistrict, Marpoyan Damai Subdistrict, Rumbai Barat Subdistrict, Rumbai Timur Subdistrict, Senapelan Subdistrict, and Tenayan Raya Subdistrict.

Figure 1 shows a comparison map of the coverage of existing fire stations and fire stations that should be built using the LSCP model. Currently with 9 existing fire stations, many areas cannot be served with ≤ 15 minutes

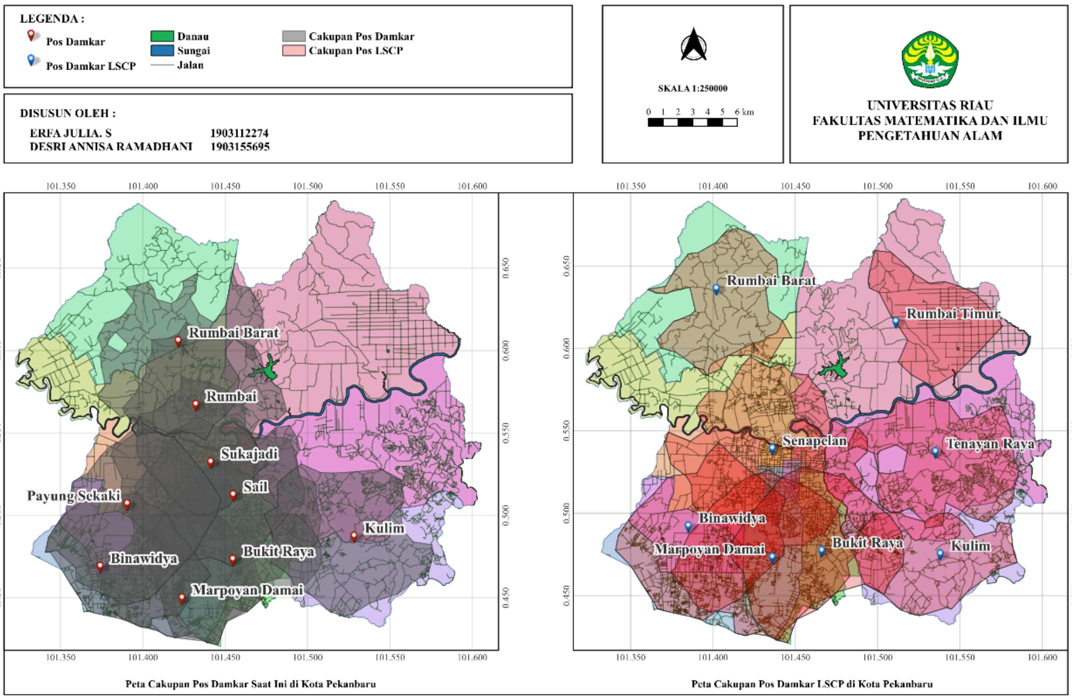

Figure 1. Map of fire stations area coverage in Pekanbaru City

3.2 LSCP Sensitivity Analysis using MCLP

LSCP sensitivity analysis was carried out using MCLP which aims to see that the location and coverage of the selected fire stations are maximum in serving demand points when the number of fire stations to be built is limited. In the sensitivity analysis, 3 other alternatives were tried to see the location of the selected station, namely 6, 7 and 8 stations.

When 5 fire stations are to be built (p =6), based on equation model (4), Table 2, constraints (5), (6), (7), (8), and Table 4 to maximum demand for fire station services, The MCLP model formulation is obtained as follows:

$$\max z = \sum_{i \in I} a_i y_i, \tag{32}$$

subject to

$$\sum_{j \in N_i} x_j \geq y_i, \qquad \forall i \in I, \qquad (33)\text{-}(47)$$

$$\sum_{j \in J} x_j \geq 6, \tag{48}$$

$$x_j \in \{0,1\}, \qquad j = 1,2, \ldots, 15, \tag{49}$$

$$y_i \in \{0,1\}, \qquad i = 1,2, \ldots, 15. \tag{50}$$

Objective function (32) maximums the number of demand points (subdistrict). Constraints (33)-(47) are limitations for each demand point (subdistrict). Constraint (48) is the number of alternative fire station locations. Constraints (49) and (50) state that the decision variable is binary valued.

By using the LINGO 18.0 application, an objective value of 73 was obtained. The optimal solution for the location of the fire station obtained was $x_1 = x_5 = x_8 = x_{10} = x_{12} = x_{15} = 1$ and the demand point $y_2 = y_3 = 0$ which means the fire station was built in 6 locations and there are 2 subdistricts that cannot be served.

When 7 fire stations are to be built (p =7), The MCLP model formulation is as follows:

$$\max z = \sum_{i \in I} a_i y_i,$$

subject to

$$\sum_{j \in N_i} x_j \geq y_i, \qquad \forall i \in I,$$

$$\sum_{j \in J} x_j \geq 7,$$

$$x_j \in \{0,1\}, \qquad j = 1,2,\dots,15,$$

$$y_i \in \{0,1\}, \qquad i = 1,2,\dots,15.$$

By using the LINGO 18.0 application, an objective value of 78 was obtained. The optimal solution for the location of the fire station obtained was $x_1 = x_3 = x_5 = x_8 = x_{10} = x_{12} = x_{15} = 1$ and the demand point $y_2 = 0$ which means the fire station was built in 7 locations and there is 1 subdistrict that cannot be served.

When 8 fire stations are to be built (p =8), The MCLP model formulation is as follows:

$$\max z = \sum_{i \in I} a_i y_i,$$

subject to

$$\sum_{j \in N_i} x_j \geq y_i, \qquad \forall i \in I,$$

$$\sum_{j \in J} x_j \geq 8,$$

$$x_j \in \{0,1\}, \qquad j = 1,2,\dots,15,$$

$$y_i \in \{0,1\}, \qquad i = 1,2,\dots,15.$$

By using the LINGO 18.0 application, an objective value of 83 was obtained. The optimal solution for the location of the fire station obtained was $x_1 = x_3 = x_5 = x_8 = x_{10} = x_{12} = x_{15} = 1$ which means that the fire station was built in the following 8 locations: Binawidya Subdistrict , Bukit Raya Subdistrict, Kulim Subdistrict, Marpoyan Damai Subdistrict, Rumbai Barat Subdistrict, Rumbai Timur Subdistrict, Senapelan Subdistrict, and Tenayan Raya Subdistrict. So, if 8 fire stations are to be built, then all subdistricts in Pekanbaru City can be served.

3.3 p-Median Problem Model at the Fire Station in Pekanbaru City

The p-median problem model in this fire station problem uses the solution results obtained from the previous LSCP model as data on the number and location of fire stations, namely the p parameter value. The parameter value p =8 is used to constrain the number of fire stations. The variable notation y_i is the location of the demand point (subdistrict) in Pekanbaru City and the variable notation x_j is the candidate location for the fire station selected from the results of the LSCP model. The decision variable notation used in the p-median problem model is y_{ij}. The notation y_{ij} can be defined if y_{ij} has a value of 1 which is defined as allocating demand point (subdistrict) i to selected fire station j with $i = 1,2,\ldots,15$ and $j = 1,2,3,5,8,10,12,15$.

Based on equation (2.4) and with the travel time data contained in Table 3 and constraints (2.5) to (2.9), the objective function and constraints for this fire station problem are as follows.:

$$\min z = \sum_{i \in I} \sum_{j \in J} d_{ij} y_{ij}, \tag{51}$$

subject to

$$\sum_{j \in J} y_{ij} = 1, \quad \forall i \in I \qquad (52)\text{-}(66)$$

$$\sum_{j \in J} x_j = 8, \tag{67}$$

$$y_{ij} \le x_j \qquad \forall i \in I, \qquad \forall j \in J \qquad (68)\text{-}(75)$$

$$x_j \in \{0,1\}, \qquad j = 1,2,3,5,8,10,12,15, \tag{76}$$

$$y_{ij} \in \{0,1\}, \qquad i = 1,2, \ldots 15, \qquad j = 1,2,3,5,8,10,12,15. \tag{77}$$

The objective function (51) minimums the total travel time between the request point (subdistrict) and the fire station. Constraints (52)-(66) are limits for each demand point (subdistrict). Constraint (67) states the limit on the number of fire stations. Constraints (68)-(75) ensure that the demand point (subdistrict) corresponds to the optimal fire station of the LSCP solution. Constraints (76)-(77) state that each variable has a binary value.

Solving the p-median model problem was carried out using the LINGO 18.0 application. The results of this research are recommendations for planning the allocation of demand points to fire station facilities to obtain allocations from each subdistrict in Pekanbaru City to the selected candidate fire station locations as a result of the LSCP model. It was found that the minimum total travel time from the request point (subdistrict) to the nearest fire station from the LSCP model was 71 minutes with the optimal solution $y_{1,1} = y_{2,2} = y_{3,3} = y_{4,12} = y_{5,5} = y_{6,12} = y_{7,12} = y_{8,8} = y_{9,12} = y_{10,10} = y_{11,12} = y_{12,12} = y_{13,12} = b_{14,1} = y_{15,15} = 1$, which means that:

(i) Demand in Binawidya Subdistrict (y_1) are allocated to the fire station location in Kulim Subdistrict (x_1).
(ii) Demand in Bukit Raya Subdistrict (y_2) are allocated to the fire station location in Bukit Raya Subdistrict (x_2).
(iii) Demand in Kulim Subdistrict (y_3) are allocated to the fire station location in Kulim Subdistrict (x_3).
(iv) Demand in Limapuluh Subdistrict (y_4) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(v) Demand in Marpoyan Damai Subdistrict (y_5) are allocated to the fire station location in Marpoyan Damai Subdistrict (x_5).
(vi) Demand in Payung Sekaki Subdistrict (y_6) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(vii) Demand in Pekanbaru Kota Subdistrict (y_7) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(viii) Demand in Rumbai Barat Subdistrict (y_8) are allocated to the fire station location in Rumbai Barat Subdistrict (x_8).

(ix) Demand in Rumbai Subdistrict (y_9) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(x) Demand in Rumbai Timur Subdistrict (y_{10}) are allocated to the fire station location in Rumbai Timur Subdistrict (x_{10}).
(xi) Demand in Sail Subdistrict (y_{11}) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(xii) Demand in Senapelan Subdistrict (y_{12}) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(xiii) Demand in Sukajadi Subdistrict (y_{13}) are allocated to the fire station location in Senapelan Subdistrict (x_{12}).
(xiv) Demand in Tuah Madani Subdistrict (y_{14}) are allocated to the fire station location in Binawidya Subdistrict (x_1).
(xv) Demand in Tenayan Raya Subdistrict (y_{15}) are allocated to the fire station location in Tenayan Raya Subdistrict (x_{15}).

4. CONCLUSIONS

Based on the results of the discussion, using the LINGO 18.0 application, a solution was obtained for the LSCP model in determining the location and number of fire and rescue stations in Pekanbaru City, namely 8 fire and rescue stations as follows: Binawidya Subdistrict, Bukit Raya Subdistrict, Kulim Subdistrict, Marpoyan Damai Subdistrict, Rumbai Barat Subdistrict, Rumbai Timur Subdistrict, Senapelan Subdistrict, and Tenayan Raya Subdistrict. To maximum fire station services, the MCLP model is used. Of the several alternative locations with the MCLP model, the fire station cannot serve all subdistricts. When the optimal number of stations from the LSCP model is 8 stations, the results obtained are the same 8 fire station locations using the LSCP model. And from these 8 fire stations, all demand points, namely 83 urban villages in 15 subdistricts in Pekanbaru City, can be served maximum. Based on the results of the p-median problem model, it can be seen that with the number of eight fire stations obtained from the results of the previous LSCP and MCLP models, we can allocate each demand point (subdistrict) to the nearest fire station because this model solution minimums the total driving travel time from the fire station. Thus, using the discrete facility location model can provide an optimal solution.

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REFERENCES

1. Badan Pusat Statistik, 2021, Peraturan Badan Pusat Statistik. Retrieved from https://www.bps.go.id/
2. Bangun, P. B. J., Octarina, S., Aniza, R., Hanum, L., Puspita, F. M., and Supadi, S. S., 2022, Set Covering Model Using Greedy Heuristic Algorithm to Determine The Temporary Waste Disposal Sites in Palembang. *Science and Technology Indonesia*, **Volume :** 7 pp 98–105.
3. Bolouri, S., Vafaeinejad, A., Alesheikh, A. A., and Aghamohammadi, H., 2018, The ordered capacitated multi-objective location-Allocation problem for fire stations using spatial optimization. *ISPRS International Journal of Geo-Information*, **Volume :** 7.
4. Chen, M., Wang, K., Yuan, Y., and Yang, C., 2023, A POIs Based Method for Location Optimization of Urban Fire Station: A Case Study in Zhengzhou City. *Fire*, **Volume :** 6.
5. Church, R., and Revelle, C., 1975, The Maximal Covering Faicility Location. *Paper of the Regional Science A ssociation* , **Volume :** 32 pp 101-118.
6. Current, J., Daskin, M., and Schilling, D., 2002, *Discrete Network Location Models. Facility Location: Applications and theory,* **Volume :** 1 pp 81-118.

7. Daskin, M. S., and Maass, K. L., 2015, The p-Median Problem. *Location Science*, pp 21–45.
8. Davoodi, M., 2019, A GIS based Fire Station Site Selection using Network Analysis and Set Covering Location Problem (Case study: Tehran, Iran), pp 433–436.
9. Hakimi, S. L., 1965, Optimum Distribution of Switching Centers in a Communication Network and Some Related Graph Theoretic Problems. *Operations Research*, **Volume :** 13 pp 462–475.
10. Menteri Pekerjaan Umum, 2009, Peraturan Menteri Pekerjaan Umum Nomor 20 Tahun 2009 tentang Pedoman Teknis Manajemen Proteksi Kebakaran di Perkotaan. Jakarta.
11. Sitepu, R., Puspita, F. M., Romelda, S., Fikri, A., Susanto, B., and Kaban, H., 2019, Set covering models in optimizing the emergency unit location of health facility in Palembang. *Journal of Physics: Conference Series*, **Volume :** 1282.
12. Toregas, C., Swain, R., ReVelle, C., and Bergman, L., 1971, The Location of Emergency Service Facilities. *Operations Research*, **Volume :** 19 pp 1363–1373.
13. Ulukan, Z., and Demircioğlu, E., 2015, A Survey of Discrete Facility Location Problems, **Volume :** 9 pp 2487–2492.
14. Yeh, C. H., and Chen, Y. R., 2020, Location Model Analysis of Flood Relief Facilities: A Case