

Optimization of Public Health Centers Location in Bandar Lampung Using Integer Linear Programming

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Article Information	ABSTRACT
Article History Received : June 07, 2025 Revised : June 23, 2025 Published : July 10, 2025 Keywords: <i>Branch and bound; LINGO; Optimization; Integer linear programming; Set covering problem.</i>	Public health centers are the primary healthcare services that play an essential role in public health services. Therefore, adequate facilities are needed to ensure that every individual receives proper healthcare services. Bandar Lampung City, the capital of Lampung Province, has a population of approximately 1,100,109 people. According to data from BPS (Statistics Indonesia), Bandar Lampung has a high life expectancy rate in Lampung, reaching 74.53%. To further improve this percentage, efforts are being made to ensure the equitable distribution of healthcare facilities across all regions of Bandar Lampung. This study aims to determine the optimal locations and number of public health centers in Bandar Lampung. Optimization is carried out using integer linear programming with the objective function of minimizing the number of public health centers while considering travel time and the maximum patient capacity each public health center can accommodate. The optimization model is formulated based on the set covering problem model and solved using the branch and bound method with LINGO software. The results indicate that the optimal number of public health centers needed to achieve an equitable distribution in Bandar Lampung is 43, covering 20 districts. This number is expected to fulfill the goal of ensuring equitable access to healthcare services through public health centers in Bandar Lampung.

INTRODUCTION

Bandar Lampung City, the capital of Lampung Province, continues to experience an increase in population every year. According to data from the Central Bureau of Statistics (BPS) of Lampung Province, in 2023, the population reached approximately 1,100,109 people with an area of 183.77 km² (Saksono, 2023). This condition increases the demand for equitable and easily accessible healthcare services.

The Head of the Lampung Health Office (Dinkes), Edwin Rusli, stated that the primary goal of healthcare development is to improve the quality of public health, as indicated by an increase in life expectancy (Suryanto, 2024). The average life expectancy rate in Bandar Lampung is recorded at 74.53%, calculated based on mortality cases in each age group (BPS, 2023). To achieve this goal, various preventive measures are being implemented to reduce both the risk of diseases and mortality rates, with a strong emphasis on preventive actions.

As primary healthcare service facilities, public health centers are crucial in maintaining public and individual health. With a focus on preventive services and health promotion, public health centers should ideally be available in every district. According to data from BPS Lampung

Province, there are currently 31 public health centers across 20 districts in Bandar Lampung City (Saksono, 2023). However, to provide optimal services, the number and locations of public health centers need to be strategically planned to serve the community effectively and efficiently. If the number and distribution of public health centers are unbalanced, healthcare services risk becoming less effective in reaching the population.

Due to the importance of proper public health center distribution, efforts are needed to optimize their locations so that healthcare facilities are distributed according to the community's needs based on population density and area size. Various factors, such as geographical conditions, land area, basic infrastructure, and the socio-economic conditions of a region, influence public access to public health centers. To achieve this optimization, the Set Covering Problem (SCP) approach can be applied. SCP, formulated in the form of Integer Linear Programming (ILP), aims to minimize the number of required facilities while ensuring that all demand areas remain covered. The optimization of facility location selection in operations research using the SCP model can be applied to solve various problems related to facility location determination across different fields (Idayani, 2022). This problem can be solved using LINGO software, which is designed to find optimal solutions in linear programming, especially in cases involving numerous variables.

According to Irnanda et al. (2022), optimization is finding the best value (minimum or maximum) of a function within a specific context. Integer programming is a linear program with the requirement that its decision variables must be integers (Irnanda et al., 2022). One of the most commonly used methods in integer programming is the branch and bound algorithm, which is effective in solving integer problems and has become a standard approach in solving ILP (T. Bakhtiar & Hanum, 2022; Taha, 2015).

Several previous studies have applied the SCP approach to determine the optimal location of public facilities. One such study was conducted by Sitepu et al. (2018), which focused on optimizing the location of hospital Emergency Rooms (IGD) in Palembang using the SCP model. Idayani et al. (2020) used SCP to determine the locations of fire stations in Situbondo Regency, considering fire incidents and travel time. Alizadeh & Nishi (2020) present an extension of the Covering Location Problem (CLP) as a hybrid covering model that utilizes the Set Covering Location Problems (SCLP) and Maximal Covering Location Problems (MCLP). Philip et al. (2021) used the SCP model to determine the number and location of the bus stops with high demand by identifying the location of trip generation. F. Bakhtiar et al. (2022) optimized the number and location of droppoints using SCP model at the Jetis branch of the logistics company and determined the shortest distribution route. Idayani et al. (2023) applied SCP to determine the locations of student service centers for Universitas Terbuka across Indonesia by considering the number of students in each province. Rizkiansyah et al. (2024) used SCP to optimize the temporary warehouse facility location in the Cianjur earthquake of 2022. Furthermore, Idayani (2025) applies the SCP approach to determine the optimal locations of public health centers by analyzing four scenarios considering travel time and district boundaries.

There has been no research that discusses optimizing the location of health centers in Bandar Lampung that use SCP. Based on this background, this study aims to determine the optimal locations and number of public health centers in Bandar Lampung City by considering travel time, district boundaries, and population size. Optimization is conducted using integer linear programming to minimize the number of public health centers while taking into account travel time and the maximum patient capacity that can be served. The integer linear programming model, formulated based on actual data, will be solved using the branch and bound method with the assistance of LINGO software.

RESEARCH METHODS

Several steps are conducted to finish this study, i.e., research objective definition and literature review, data collection and processing, formulation model, solving model, conclusion and recommendations. All the research stages are illustrated in Figure 1.

1. The initial step in this study is to define the research objective, which is to optimize the location of public health centers. Next, a literature review is conducted to understand how to solve the SCP, which is part of ILP, using the branch and bound method with the assistance of LINGO software.
2. The second step is data collection and processing. Data used in this study include population size, travel time between districts, district boundaries, public health centers locations, and disease incidence rates in Bandar Lampung City. Data is collected using documentation techniques from websites (<https://bandarlampungkota.bps.go.id/id>) and Google Maps (<https://www.google.com/maps>). The next step is to conduct the data processing by organizing, analyzing, and interpreting data so that it can be used in the next step, model formulation.
3. The third step is model formulation. An optimization model is formulated using the SCP model based on the collected data to determine the locations and number of public health centers.
4. The fourth step is model completion. This model is solved using the branch and bound method with the assistance of LINGO software, which is capable of handling large-scale and complex ILP problems. LINGO features a solver that supports flexible modeling with more than 30 constraints (Team, 2024, 2025).
5. The last step is concluding and making suggestions. Once the model is solved, the optimization results are analyzed to draw conclusions and provide recommendations for future research.

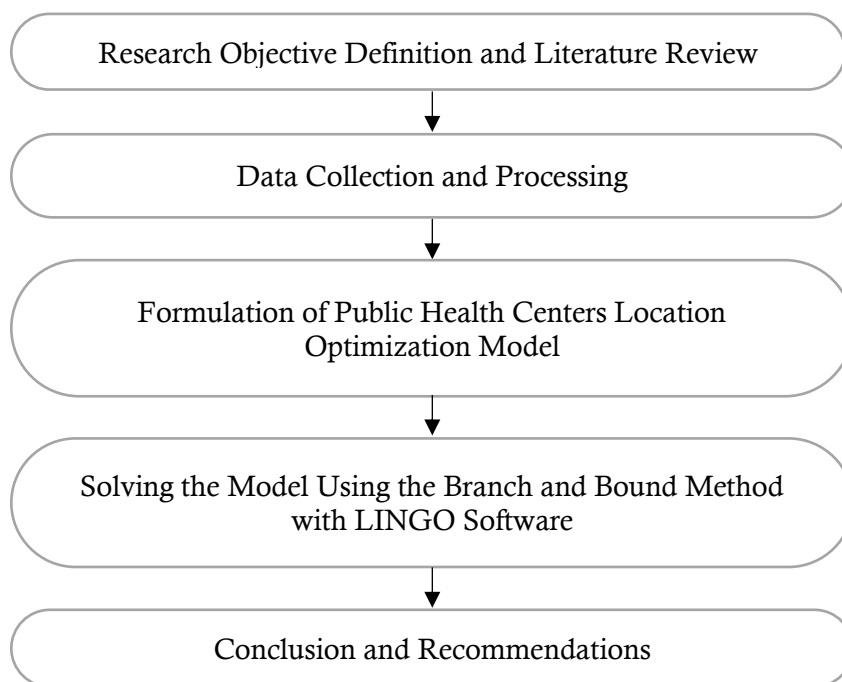


Figure 1. Research stages

RESULTS AND DISCUSSION

Optimization Model

The model formulation is based on the SCP model to minimize the objective function while ensuring that all community needs are met. In this study, the model is developed by considering several aspects, including population size, patient travel time to public health centers,

district boundaries, the minimum capacity of public health centers, and government policies that require at least one public health centers in each district. In general, the model formulation is structured as follows (Aktaş et al., 2013).

Objective function

$$\min \sum_{j \in J} x_j \quad (1)$$

subject to

$$\sum_{j \in N_i} r x_j \geq \sum_{i \in I} f_i, \quad \forall i \in I \quad (2)$$

$$x_j \geq 1, \quad \forall j \in J \quad (3)$$

$$x_j \in \{0,1\}, \quad \forall j \in J \quad (4)$$

where

i, I = demand nodes (district) index and set, $I = 1, 2, \dots, n$;

j, J = candidate nodes (public health center candidate) index and set, $J = 1, 2, \dots, m$;

x_j = binary decision variable (1 if a public health center is opened in node j , 0 otherwise);

r = public health center capacity;

f_i = demand (population multiplied by morbidity rate);

N_i = nodes j set within the standard time S of node, $N_i = \{j | d_{ij} \leq S\}$;

d_{ij} = traveling time or the (shortest) distance between nodes i and j ;

S = time or distance standard for a public health center at node j to be eligible to serve node i ;

Objective Function

The objective function in equation (1) aims to minimize the number of public health centers while still providing optimal healthcare services to the community. This objective function includes the decision variable x_j or $j \in J$, which is a binary decision variable. The set J represents the candidate districts that may serve as public health centers locations. The variable x_j takes the value of 1 if a public health centers is established in district j and 0 otherwise. In Bandar Lamoung City, there are 20 districts, so the set J is defined as $J = 1, 2, 3, \dots, 20$, where x_1 = Teluk Betung Barat, x_2 = Teluk Betung Timur, x_3 = Teluk Betung Selatan, x_4 = Bumi Waras, x_5 = Panjang, x_6 = Tanjung Karang Timur, x_7 = Kedamaian, x_8 = Teluk Betung Utara, x_9 = Tanjung Karang Pusat, x_{10} = Enggal, x_{11} = Tanjung Karang Barat, x_{12} = Kemiling, x_{13} = Langkapura, x_{14} = Kedaton, x_{15} = Rajabasa, x_{16} = Tanjung Senang, x_{17} = Labuhan Ratu, x_{18} = Sukarame, x_{19} = Sukabumi, and x_{20} = Way Halim. Thus, the objective function can be written as

$$\min \sum_{j=1}^{20} x_j \quad (5)$$

Constraint Functions

The first constraint (2) represents the demand constraint for public health centers. The number of public health centers established must be greater than or equal to the demand. The demand f_i represents the population in the district i experiencing health complaints that affect daily activities, making the district a potential candidate for a public health centers location.

The demand for each district is calculated by multiplying the district's population by the morbidity rate of Bandar Lampung City in 2023, which was 11.60% (Saksono, 2023). The morbidity rate, also known as the sickness rate, is a parameter used to measure public health based on the percentage of the population experiencing health complaints and showing symptoms of specific diseases.

By considering travel time and district boundaries, both conditions must be met for x_j to take a value of 1. Thus, $x_j = 1$ if the travel time is less than or equal to 30 minutes and the district shares a boundary with district x_i . However, if either of these conditions is not met, then $x_j = 0$ (see Table 1).

Table 1. Table Binary Decision Variable x_j

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}
x_1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
x_2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x_3	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
x_4	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
x_5	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
x_6	0	0	0	0	0	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1
x_7	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	1	1
x_8	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
x_9	0	0	1	0	0	1	0	1	1	1	1	0	0	1	0	0	0	0	0	0
x_{10}	0	0	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
x_{11}	1	0	1	0	0	0	0	0	1	0	1	1	1	1	0	0	1	0	0	0
x_{12}	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0
x_{13}	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0	0	0
x_{14}	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	0	1
x_{15}	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0
x_{16}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
x_{17}	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0	1
x_{18}	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1
x_{19}	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0
x_{20}	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	1	0	1

Additionally, the capacity of the public health centers, denoted as r is another key factor in determining the number and location of facilities in each district. The minimum capacity of a public health center is 100 visits per day (Budiman et al., 2017). Since the capacity is uniform, the right-hand side of the equation can be simplified by dividing $\sum_{i \in I} f_i$ by r over a month (30 days). Thus, constraint (2) can be expanded into 20 constraints, formulated as follows.

$$x_1 + x_2 + x_3 + x_{11} + x_{12} \geq 10,72 \quad (6)$$

$$x_1 + x_2 + x_3 \geq 4,94 \quad (7)$$

$$x_1 + x_2 + x_3 + x_4 + x_8 + x_9 + x_{11} \geq 13,54 \quad (8)$$

$$x_3 + x_4 + x_5 + x_7 + x_8 + x_{10} \geq 11,68 \quad (9)$$

$$x_4 + x_5 + x_7 + x_{19} \geq 10,04 \quad (10)$$

$$\vdots \quad \vdots \quad \vdots$$

$$x_6 + x_7 + x_{14} + x_{16} + x_{17} + x_{18} + x_{20} \geq 15,10 \quad (25)$$

The second constraint is based on the Minister of Health of the Republic of Indonesia Regulation No. 43 of 2019, which mandates the establishment of at least one public health center in each district. Under certain conditions, more than one public health center may be established

within a single district (Regulation of the Minister of Health of the Republic of Indonesia Number 43 of 2019 about Public Health Centers, 2019).

Thus, constraint (3) ensures that the number of public health center in each district is at least one. When expanded, this results in 20 constraints, formulated as follows:

$$x_1 \geq 1 \quad (26)$$

$$x_2 \geq 1 \quad (27)$$

$$\vdots \quad \vdots \quad \vdots$$

$$x_{20} \geq 1 \quad (40)$$

The Optimal Solution

The optimization model for public health centers location was solved using the branch and bound method with the help of LINGO software, considering district boundaries and travel time. Both conditions must be met for x_j to be 1. However, if one or both conditions are not satisfied, then $x_j = 0$. The optimization results can be seen in Figure 2. The results indicate that the optimal solution, or the objective function value, is 43, meaning that the efficient allocation of public health centers locations and numbers, while considering travel time limits and population, results in 43 public health centers distributed across 20 districts in Bandar Lampung. The total number of variables in the model is 21, with 41 constraints. The solution was obtained after 30 iterations performed by the solver to determine the optimal solution. The time required by LINGO to complete the computation and find the optimal result was 0.04 seconds, demonstrating that the computation process was highly efficient (see Figure 2).

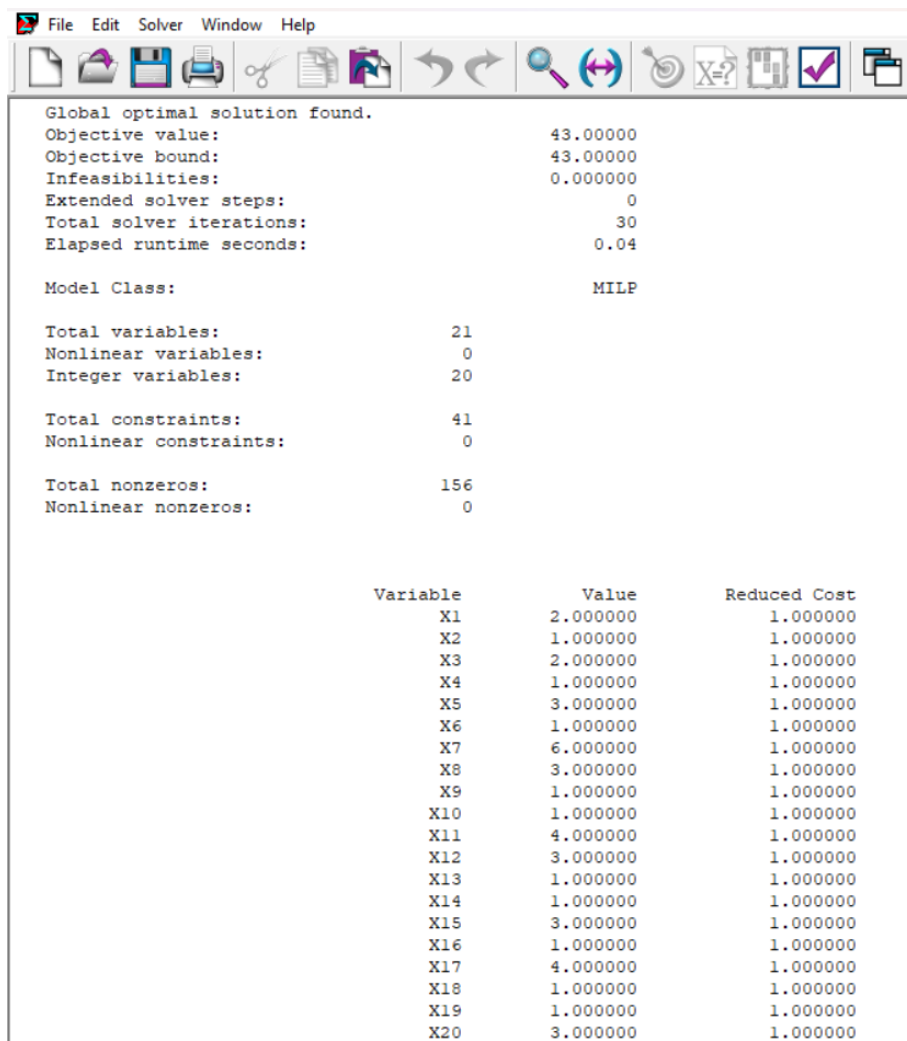


Figure 2. Optimization results using LINGO software

The highest proposed the public health centers number is six in Kedamaian District (x_7). The highest proposed the public health centers number is six in Kedamaian District Bumi Waras (x_4), Panjang (x_5), Tanjung Karang Timur (x_6), Teluk Betung Utara (x_8), Enggal (x_{10}), Sukarame (x_{18}), Sukabumi (x_{19}), and Way Halim (x_{20}). This strategic placement allows Kedamaian to accommodate healthcare service demand in surrounding districts, reducing travel time for healthcare access in the region. Additionally, Tanjung Karang Barat (x_{11}) and Labuhan Ratu (x_{17}). This aims to improve the distribution of healthcare services and ensure that the travel time for the community becomes more efficient while facilitating access to healthcare facilities. In Kemiling District, which has the largest population in Bandar Lampung City, the current number of community health centers is already optimal, namely three units. Although the population is large, these three health centers are considered sufficient to meet the needs because their locations are strategic, and the average travel time is still within the optimal limit.

Unlike Sukabumi and Sukarame Districts, which also have a large population after Kemiling. Previously, these two districts had three community health centers, but after optimization, the number was reduced to one. This reduction was made because the community's access in these two districts to health centers in neighboring districts, such as Way Halim, Kedamaian, and Panjang, was considered adequate.

This is supported by adequate road infrastructure, allowing the community to access healthcare facilities within a reasonable travel time, both within the district and in neighboring districts. Currently, there are 31 community health centers in Bandar Lampung City (see Table 2), but their distribution is still considered uneven across districts, making healthcare services not yet fully optimal.

Table 2. Comparison of Public Health Centers Number

District	Population	Number of Public Health Centers (Current)	Number of Public Health Centers (Optimization Result)
Teluk Betung Barat	38.527	1	2
Teluk Betung Timur	49.926	2	1
Teluk Betung Selatan	39.359	1	2
Bumi Waras	58.169	1	1
Panjang	74.858	1	3
Tanjung Karang Timur	38.542	1	1
Kedamaian	53.457	1	6
Teluk Betung Utara	50.587	2	3
Tanjung Karang Pusat	50.326	2	1
Enggal	25.752	1	1
Tanjung Karang Barat	63.194	2	4
Kemiling	86.300	3	3
Langkapura	43.372	1	1
Kedaton	52.388	1	1
Rajabasa	55.958	1	3
Tanjung Senang	62.402	1	1
Labuhan Ratu	48.208	1	4
Sukarame	67.138	3	1
Sukabumi	73.178	3	1
Way Halim	68.468	2	3
Total	1.100.109	31	43

The study result is in accordance with previous studies (Faisi et al., 2021; Idayani, 2025; Idayani et al., 2020, 2023; Sitepu et al., 2022), which show that the optimal number of facilities is greater than the current number of facilities. According to previous observations and documentation, this result indicates that the current number of facilities is insufficient to serve existing demand. Although the number of suggested facilities is greater, this number is the smallest number that can be suggested because the model

formulated aims to minimize the objective function. In other words, the costs incurred for development are also minimal. It can be said that the number of facilities suggested or obtained from completing the model is the minimum number, but it can still meet demand or serve the sick community. The location determined is also optimal because it is based on the population.

In Sitepu et al. (2018), the optimization model is formulated only based on travel time but uses four covering problem models. Idayani (2025) compares four models that differ in whether they consider travel time and/or district boundaries. Faisi et al. (2021) did not consider population or demand, only considering travel time with a simple linear programming optimization model. Idayani et al. (2020) considered travel time and population. In comparison, this study considers travel time, district boundaries, and population size as demand. Many factors need to be considered when building a health center, which can affect the quality of health center services. So, in further research, an optimization model can be developed by considering the capacity of health workers, especially in remote areas. In addition, in terms of model completion, many mathematical applications, not only LINGO, can be used. So in further research, it can also be compared how to solve the model using other applications, such as POM QM for Windows, LINDO, MPL, or Solver in Microsoft Excel.

Although the optimization model in this study still needs to be developed, the study's results can be used by the city government to consider the development of health facilities in Bandar Lampung City. The number and location of the recommended health centers can increase the effectiveness and reach of health center services because they have been designed based on travel time, sub-district boundaries, and population.

CONCLUSION

The problem of determining the location and number of health centers can be solved using integer linear programming with minimal cost by considering travel time and district boundaries. The optimal number of community health centers consists of 43 across 20 districts to meet the community's healthcare needs while considering travel time and district boundaries. In the next studies, the model can be developed by considering the capacity of health workers, especially for rural areas. In addition, the solution can be found by other applications, i.e., POM QM for Windows, LINDO, MPL, or Solver in Microsoft Excel. The local government can consider using the results of this study in developing health facilities in Bandar Lampung City, so that development is well-planned and in accordance with the needs of the community, so that it can serve the community as a whole at minimal cost.

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