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| WORD COUNT | 5767 | TIME SUBMITTED | 22-JUN-2024 10:58AM |
| | | PAPER ID | 109781144 |

# Determining the Best Location for COVID-19 Vaccine Distribution in Palembang Using the Set Covering Problem Model and Greedy Heuristic Algorithm

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**Abstract**

Optimizing the location of public health facilities is crucial to ensure public accessibility. Palembang City uses public health facilities for COVID-19 vaccine distribution and administration. This study identified the best location for COVID-19 vaccine distribution in Palembang City by implementing the Set Covering Problem (SCP) model and solving it with the Greedy Heuristic Algorithm. The SCP model consists of the Set Covering Location Problem (SCLP) model and the p-Centre Location Problem (p-CLP) and considers the separating distance between vaccine distribution sites located in each sub-district of Palembang City. The p-CLP model was formulated, and the Greedy Heuristic Algorithm was executed to determine the optimal distribution location for COVID-19 vaccines. The SCLP model successfully identified 27 optimal COVID-19 vaccine locations in Palembang City. These locations were subsequently used to formulate the p-CLP model. The p-CLP model's solution and the application of the Greedy Heuristic Algorithm yielded 27 optimal vaccine sites, which include Ariodillah Health Centre, Naga Swidak Health Centre, Sako Health Centre, Bukitsangkal Health Centre, Sei Lincah Health Centre, Kenten Health Centre, Kalidoni Health Centre, Pakjo Health Centre, Sei Baung Health Centre, Merdeka Health Centre, OPI Health Centre, Sosial Health Centre, Talang Betutu Health Centre, Myria Hospital, Sukarami Health Centre, Keramasan Health Centre, Karya Jaya Health Centre, 7 Ulu Health Centre, Sabokingking Health Centre, Charitas Hospital, Dr. Mohammad Hasan Hospital, Siti Khadijah Hospital, Bunda Hospital, Bunda Noni Hospital, Pelabuhan Kelas II Palembang Health Office, Tiara Fatrin Hospital, and Alang-Alang Lebar Health Centre.

**Keywords:** *Location, Vaccine, Set Covering Problem, Set Covering Location Problem, p-Center Location Problem, Greedy Heuristic Algorithm.*

## A. INTRODUCTION

Coronavirus disease 2019, commonly known as COVID-19, is an infectious disease caused by the SARS-CoV-2 virus. The first cases were reported in China in December 2019. Amidst its highly contagious nature, the disease has affected 6,045,043 people across 34 provinces and 510 districts and cities as of 2021 (Chung et al., 2021). This paper aims to identify the most suitable location for distributing COVID-19 vaccines in Palembang, the capital of South Sumatra Province.

Palembang is divided into 18 administrative sub-districts and 107 urban settlements, encompassing a total area of 400.61 km$^2$. It shares borders with Banyuasin Regency to the north, east, and west, and Muara Enim Regency to the south. Demographic changes and population growth influence the development of

Palembang City. Fast, transparent, effective, and accountable public services are critical for the city's growth and progress (Antoni et al., 2021). Compared to other cities and districts in South Sumatra Province, Palembang City has the highest population density (Devi et al., 2016). The government of Palembang City is taking measures to prevent the spread of COVID-19, such as conducting campaigns to promote healthy living, participating in the vaccination movement, and identifying the most suitable locations for administering COVID-19 vaccines.

Vaccination is intended to establish herd immunity, ensuring that individuals can maintain their productivity in performing daily activities. The vaccination process consists of four stages: dose 1, dose 2, booster 1, and booster 2. Various vaccines are available, such as Sinovac, AstraZeneca, Moderna, Pfizer, and Sinopharm. Vaccination sites in Palembang are in central and auxiliary health centres, government or private clinics, government or private hospitals, health service units, and malls. There are 43 vaccination locations located in Palembang and spread out throughout 14 sub-districts (Dewi & Bustan, 2021).

Optimization problems related to location and allocation involve the Set Covering Problem (SCP) model (Octarina et al., 2022). The application of the SCP model can be observed in tackling real-world issues, such as determining the optimal route for garbage collection vehicles to the collection point, distributing machines for designated tasks, and allocating job roles to individuals (Brimkov et al., 2019; Daskin & Maass, 2019; Kwon et al., 2020; Octarina et al., 2022; Octarina et al., 2022; Xu & Li, 2018). The SCP model maximizes the number of facility locations that can efficiently cater to all requirements. The SCP model comprises diverse model groups, specifically the Set Covering Location Problem (SCLP), Maximum Covering Location Problem (MCLP), p-Centre Location Problem (p-CLP), and p-Median Problem that interrelate (Javid et al., 2017). SCLP optimizes facility placements to serve all demand points in a distribution system issue model (Octarina et al., 2022). MCLP is designed to identify the most significant demand coverage within a standard time frame using a specified number of p facilities. According to Syakina & Nurdiati (2021), the objective function of MCLP is to maximize the number of facilities acquired within a specific period.

One algorithm for solving the SCP is the Greedy Heuristic Algorithm. It determines the best facility to construct at each step (Bangun et al., 2022). As per Amarilies et al. (2020), the Greedy Heuristic Algorithm is the most suitable method to acquire solutions for the SCLP model and the p-CLP issue. The Greedy Heuristic Algorithm can be implemented in a sequence of steps, first identifying high-demand candidates and then identifying facilities capable of providing the required replacements, with the caveat that more than one facility is allocated (Katayama, 2019). This algorithm selects the optimal replacement option after the best possible swap. Additionally, it considers the removal of each selected candidate and substitution with unselected substitutes (Bangun et al., 2023).

Previous research on location determination using SCP has advanced significantly. Sitepu et al. (2022) proposed an optimization solution for the covering-based model in emergency room (ER) settings. The study identified five emergency

room locations: Alang-Alang Lebar, Gandus, Ilir Barat I, Ilir Barat II, and Kertapati sub-districts. Sitepu et al. (2019) optimized the locations ER in Palembang City using the SCP model, resulting in six ER serving eight sub-districts. The ER are in Ilir Timur II, Kalidoni, Sako, Seberang Ulu II, Sematang Borang, and Sukarami sub-districts. According to Bangun et al. (2022), the Greedy Heuristic Algorithm is valuable for finding optimal solutions to large-scale problems. This study examines the SCP modelling of COVID-19 vaccine distribution locations. Subsequently, it implements the greedy heuristic algorithm to determine the optimum COVID-19 vaccine location in Palembang City.

## B. METHODS

The stages carried out in this research are:

1. Measure the distance of each COVID-19 vaccine location in Palembang using Google Maps and present it as a data table.
2. Defining variables and parameters for the SCLP model and p-CLP for determining the location of the COVID-19 vaccine in Palembang City.
3. Formulate the SCP model, including the SCLP model and the p-CLP.
4. Determine the solution of the two SCP models with the help of LINGO 13.0 software.
5. Solving SCP with the Greedy Heuristic Algorithm.
6. Analyze the results of the SCP model with LINGO 13.0 and the Greedy Heuristic Algorithm.

## C. RESULTS AND DISCUSSION

This section examines the research data, determining the quantity and whereabouts of COVID-19 vaccine distribution in Palembang City, formulating the SCLP model and the p-CLP as the SCP model, and implementing the Greedy Heuristic Algorithm to solve the SCP. The dataset comprises a roster of sub-districts, the names of the COVID-19 vaccine dispensary outlets in Palembang City, and the intervening distance separating each depot. Information on the COVID-19 vaccine distribution sites was procured from the Palembang City Health Office, which surveyed and collated the data based on location points in each sub-district of Palembang City. Table 1 displays the classification of COVID-19 vaccine distribution sites by sub-district.

In the Ilir Timur 1 sub-district, for instance, there are three health centres, specifically Ariodillah Health Centre, Dempo Health Centre, and Talang Ratu Health Centre, as well as three hospitals: Charitas Hospital, YK Madira Hospital, and Sriwijaya Hospital. The number of vaccine distribution locations decreases here, with the Alang-Alang Lebar sub-district having only one COVID-19 vaccine distribution location, namely the Alang-Alang Lebar Health Centre.

**Table 1. List of COVID-19 Vaccine Distribution Sites in Palembang City**

| No | Sub-District | COVID-19 Vaccine Distribution Sites |
|---|---|---|
| 1 | Ilir Timur I | Ariodillah Health Centre |
| | | Charitas Hospital |
| | | Dempo Health Centre |
| | | Talang Ratu Health Centre |
| | | YK Madira Hospital |
| | | Sriwijaya Hospital |
| 2 | Plaju | Naga Swidak Hospital |
| 3 | Sako | Sako Health Centre |
| | | Multiwahana Health Centre |
| 4 | Kalidoni | Bukitsangkal Health Centre |
| | | Sei Lincah Health Centre |
| | | Kenten Health Centre |
| | | Kalidoni Health Centre |
| 5 | Kemuning | Dr. Mohammad Hasan Hospital |
| | | Bhayangkara Hasan Hospital |
| 6 | Ilir Barat I | Kampus Health Centre |
| | | Pakjo Health Centre |
| | | Siti Khadijah Health Centre |
| | | Bunda Hospital |
| | | Graha Mandiri Hospital |
| | | MMC Hospital |
| | | Bunda Noni Hospital |
| | | Padang Selasa Health Centre |
| | | Sei Baung Health Centre |
| 7 | Bukit Kecil | Merdeka Health Centre |
| 8 | Jakabaring | OPI Health Centre |
| 9 | Sukarami | Sosial Health Centre |
| | | Talang Betutu Health Centre |
| | | Myria Health Centre |
| | | Pelabuhan Kelas II Palembang Health Office |
| | | Sukarami Health Centre |
| | | Ar Rasyid Hospital |
| 10 | Kertapati | Keramasan Health Centre |
| | | Karya Jaya Health Centre |
| 11 | Seberang Ulu II | Taman Bacaan Health Centre |
| 12 | Seberang Ulu I | 7 Ulu Health Centre |
| | | Bari Hospital |
| 13 | Ilir Timur II | Boom Baru Health Centre |
| | | Sabokingking Health Centre |
| | | 11 Ilir Health Centre |

| | | |
|---|---|---|
| | | 5 Ilir Health Centre<br>Tiara Fatrin Hospital |
| 14 | Alang-Alang Lebar | Alang-Alang Lebar Health Centre |

The variable definitions of the name of the COVID-19 vaccine distribution location and the variable names of sub-districts in Palembang City can be seen in Table 2-Table 4, respectively.

**Table 2. Variable Definition for COVID-19 Vaccination Distribution Locations in Palembang City**

| Variable | Location | Variable | Location |
|---|---|---|---|
| $y_1$ | Ariodillah Health Centre | $y_{23}$ | Padang Selasa Health Centre |
| $y_2$ | Charitas Hospital | $y_{24}$ | Sei Baung Health Centre |
| $y_3$ | Dempo Health Centre | $y_{25}$ | Merdeka Health Centre |
| $y_4$ | Talang Ratu Health Centre | $y_{26}$ | OPI Health Centre |
| $y_5$ | YK Madira Hospital | $y_{27}$ | Sosial Health Centre |
| $y_6$ | Sriwijaya Hospital | $y_{28}$ | Talang Betutu Health Centre |
| $y_7$ | Naga Swidak Health Centre | $y_{29}$ | Myria Hospital |
| $y_8$ | Sako Health Centre | $y_{30}$ | Pelabuhan Kelas II Palembang Health Office |
| $y_9$ | Multiwahana Health Centre | $y_{31}$ | Sukarami Health Centre |
| $y_{10}$ | Bukitsangkal Health Centre | $y_{32}$ | Ar Rasyid Hospital |
| $y_{11}$ | Sei Lincah Health Centre | $y_{33}$ | Kramasan Health Centre |
| $y_{12}$ | Kenten Health Centre | $y_{34}$ | Karya Jaya Health Centre |
| $y_{13}$ | Kalidoni Health Centre | $y_{35}$ | Taman Bacaan Health Centre |
| $y_{14}$ | Dr. Mohammad Hoesin Health Centre | $y_{36}$ | 7 Ulu Health Centre |
| $y_{15}$ | Bhayangkara Hasan Hospital | $y_{37}$ | Bari Hospital |
| $y_{16}$ | Kampus Health Centre | $y_{38}$ | Boom Baru Health Centre |
| $y_{17}$ | Pakjo Health Centre | $y_{39}$ | Sabongkingking Health Centre |
| $y_{18}$ | Siti Khadijah Health Centre | $y_{40}$ | 11 Ilir Health Centre |
| $y_{19}$ | Bunda Hospital | $y_{41}$ | 5 Ilir Health Centre |
| $y_{20}$ | Graha Mandiri Hospital | $y_{42}$ | Tiara Fatrin Hospital |
| $y_{21}$ | MMC Hospital | $y_{43}$ | Alang-Alang Lebar Hospital |
| $y_{22}$ | Bunda Noni Hospital | | |

**Table 3. Variable Definition of Sub-District in Palembang**

| Variable | Sub-District |
|---|---|
| $z_1$ | Ilir Timur I Sub-District |
| $z_2$ | Plaju Sub-District |
| $z_3$ | Sako Sub-District |
| $z_4$ | Kalidoni Sub-District |
| $z_5$ | Kemuning Sub-District |
| $z_6$ | Ilir Barat I Sub-District |
| $z_7$ | Bukit Kecil Sub-District |
| $z_8$ | Jakabaring Sub-District |
| $z_9$ | Sukarami Sub-District |
| $z_{10}$ | Kertapati Sub-District |
| $z_{11}$ | Seberang Ulu II Sub-District |
| $z_{12}$ | Seberang Ulu I Sub-District |
| $z_{13}$ | Ilir Timur II Sub-District |
| $z_{14}$ | Alang-Alang Lebar Sub-District |

Table 2 explains that $y_1$ represents Ariodillah Health Centre, $y_2$ represents Charitas Hospital, $y_3$ represents Dempo Health Centre, until $y_{43}$ represents Alang-Alang Lebar Health Centre. Table 3 states that $z_1$ represents Ilir Timur I Sub-District, $z_2$ represents Plaju Sub-District, and so on until $z_{15}$ represents Alang-Alang Lebar Sub-District.

**Table 4. Parameter and The Value of Parameter**

| Parameter | Name of Sub-District | The Value of Parameter |
|---|---|---|
| $p_1$ | Ilir Timur I Sub-District | 6 |
| $p_2$ | Plaju Sub-District | 1 |
| $p_3$ | Sako Sub-District | 2 |
| $p_4$ | Kalidoni Sub-District | 4 |
| $p_5$ | Kemuning Sub-District | 2 |
| $p_6$ | Ilir Barat I Sub-District | 9 |
| $p_7$ | Bukit Kecil Sub-District | 1 |
| $p_8$ | Jakabaring Sub-District | 1 |
| $p_9$ | Sukarami Sub-District | 6 |
| $p_{10}$ | Kertapati Sub-District | 2 |
| $p_{11}$ | Seberang Ulu II Sub-District | 1 |
| $p_{12}$ | Seberang Ulu I Sub-District | 2 |
| $p_{13}$ | Ilir Timur II Sub-District | 5 |
| $p_{14}$ | Alang-Alang Lebar Sub-District | 1 |

Table 4 describes the parameters and parameter values used in the model. $p_1$ defines Ilir Timur I Sub-District with a value of 6, which means that there are 3 Health Centres and 3 Hospitals located in Ilir Timur I Sub-District, $p_2$ defines Plaju Sub-District with a value of 1, which means that there is only 1 Healh Centre located in Plaju Sub-District, until $p_{14}$ defines Alang-Alang Lebar Sub-District with a value of 1,

which means that there is 1 Health Centre located in Alang-Alang Lebar Sub-District.

Data on the distance between COVID-19 vaccine distribution sites in Palembang City was obtained by directly measuring the site on January 15, 2022, using Google Maps. According to Article 18 of the Law on the Implementation of COVID-19 Vaccination, the Regency/City Health Office and the Provincial Health Office shall gradually collect data and determine the implementing health service facilities, as well as determine the distribution of COVID-19 vaccines, supporting equipment, and logistical tools that can be used to implement COVID-19 vaccination. Permenpera/No.32/Permen/M/2006 states that the ideal distance standard for health service facilities of community health centres is 2 km.

***The SCLP Model Formulation***

The SCLP model formulation for COVID-19 Vaccine Distribution Locations in Palembang City is in the form of:

Minimize $Z_{SCLP} = \sum_{j=1}^{43} y_j$ (1.1)

Subject to

$y_1 + y_2 + y_4 + y_5 + y_6 + y_{14} + y_{15} + y_{17} + y_{18} + y_{19} \geq 1$ (1.2)

$y_1 + y_2 + y_3 + y_5 + y_{14} + y_{16} + y_{24} + y_{26} + y_{42} \geq 1$ (1.3)

$y_2 + y_3 + y_{40} \geq 1$ (1.4)

$y_1 + y_4 + y_{17} \geq 1$ (1.5)

$y_1 + y_2 + y_5 + y_{24} + y_{42} \geq 1$ (1.6)

$y_1 + y_6 + y_{15} + y_{17} \geq 1$ (1.7)

$y_7 + y_{35} \geq 1$ (1.8)

$y_8 \geq 1$ (1.9)

$y_9 + y_{10} \geq 1$ (1.10)

$y_9 + y_{10} + y_{38} + y_{40} + y_{41} \geq 1$ (1.11)

$y_{11} \geq 1$ (1.12)

$y_{12} \geq 1$ (1.13)

$y_{13} \geq 1$ (1.14)

$y_1 + y_2 + y_{14} + y_{15} + y_{17} + y_{24} \geq 1$ (1.15)

$y_1 + y_6 + y_{14} + y_{15} + y_{17} + y_{18} + y_{19} \geq 1$ (1.16)

$y_2 + y_{16} + y_{18} + y_{19} + y_{24} \geq 1$ (1.17)

$y_1 + y_4 + y_6 + y_{14} + y_{15} + y_{17} + y_{18} + y_{19} + y_{20} \geq 1$ (1.18)

$y_1 + y_{15} + y_{16} + y_{17} + y_{18} + y_{19} + y_{20} + y_{24} \geq 1$ (1.19)

$y_{17} + y_{18} + y_{19} + y_{20} \geq 1$ (1.20)

$y_{21} + y_{27} \geq 1$ (1.21)

$y_{22} + y_{23} \geq 1$ (1.22)

$y_2 + y_5 + y_{14} + y_{16} + y_{18} + y_{19} + y_{24} \geq 1$ (1.23)

$y_{25} \geq 1$ (1.24)

$y_{26} \geq 1$ (1.25)

$y_{21} + y_{27} \geq 1$ (1.26)

$y_{28} \geq 1$ (1.27)

$y_{30} \geq 1$ (1.28)

$y_{31} \geq 1$ (1.29)
$y_{29} + y_{32} \geq 1$ (1.30)
$y_{33} \geq 1$ (1.31)
$y_{34} \geq 1$ (1.32)
$y_{36} \geq 1$ (1.33)
$y_{27} + y_{37} \geq 1$ (1.34)
$y_{10} + y_{38} + y_{40} \geq 1$ (1.35)
$y_{39} \geq 1$ (1.36)
$y_3 + y_{10} + y_{38} + y_{40} + y_{42} \geq 1$ (1.37)
$y_{10} + y_{41} + y_{42} \geq 1$ (1.38)
$y_2 + y_5 + y_{40} + y_{41} + y_{42} \geq 1$ (1.39)
$y_{43} \geq 1$ (1.40)
$y_1, y_2, y_3, \dots, y_{43} \in \{0,1\}$ (1.41)

Model (1.1) aims to minimize the number of COVID-19 vaccine distribution locations in Palembang City while meeting all demand points. Constraints (1.2) to (1.40) outline the requirements for each COVID-19 vaccine distribution location in Palembang City, with at least one demand needing to be fulfilled. Constraint (1.41) specifies that variables $y_1$ to $y_{43}$ are binary. The SCLP model was implemented using LINGO software, and the results are presented in Table 5.

**Table 5. Optimal Solution of SCLP Model**

| ***Solver Status*** | |
|---|---|
| *Model Class* | PILP |
| *State* | *Global Optimal* |
| *Objective* | 21 |
| *Infeasibility* | 0 |
| *Iterations* | 0 |
| ***Extended Solver Status*** | |
| *Solver Type* | *Branch and Bound* |
| *Best Objective* | 21 |
| *Objective Bound* | 21 |
| *Steps* | 0 |
| *Active* | 0 |
| *Update Interval* | 2 |
| *GMU (K)* | 34 |
| *ER (sec)* | 1 |

The variable value from solving the SCLP model using LINGO 13.0 is either 0 or 1. A value of 0 indicates that no facilities are located at the given location, while a value of 1 indicates that facilities are present. There are 21 variables worth 1, namely hospitals and health centres with variables $y_2, y_8, y_{10}, y_{11}, y_{12}, y_{13}, y_{17}, y_{23}, y_{26}, y_{27}, y_{28}, y_{30}, y_{31}, y_{32}, y_{33}, y_{34}, y_{35}, y_{36}, y_{39}$, and $y_{43}$. This indicates the candidate locations for the facilities are:

1. Charitas Hospital

2. Sako Health Centre
3. Bukitsangkal Health Centre
4. Sei Lincah Health Centre
5. Kenten Health Centre
6. Kalidoni Health Centre
7. Pakjo Health Centre
8. Padang Selasa Health Centre
9. Merdeka Health Centre
10. OPI Health Centre
11. Sosial Health Centre
12. Talang Betutu Health Centre
13. Pelabuhan Kelas II Palembang Health Centre
14. Sukarami Health Centre
15. Ar Rasyid Health Centre
16. Kramasan Health Centre
17. Karya Jaya Health Centre
18. Taman Bacaan Health Centre
19. 7 Ulu Health Centre
20. Sabongkingking Health Centre
21. Alang-Alang Lebar Health Centre

***The p-CLP Model Formulation***

The p-CLP model is formulated using the selected candidates from solving the SCLP model. The objective of this model is to identify a strategic location for COVID-19 vaccine distribution in Palembang City that can meet the demand of all points. Table 6 shows the variable definitions of the selected COVID-19 vaccine distribution locations in Palembang City.

**Table 6. Candidate Locations of Selected Hospitals and Health Centres**

| Variable | Candidate Location | Variable | Candidate Location |
|---|---|---|---|
| $y_2$ | Charitas Hospital | $y_{28}$ | Talang Betutu Health Centre |
| $y_8$ | Sako Health Centre | $y_{30}$ | Pelabuhan Kelas II Health Office |
| $y_{10}$ | Bukitsangkal Health Centre | $y_{31}$ | Sukarami Health Centre |
| $y_{11}$ | Sei Lincah Health Centre | $y_{32}$ | Ar Rasyid Hospital |
| $y_{12}$ | Kenten Health Centre | $y_{33}$ | Kramasan Health Centre |
| $y_{13}$ | Kalidoni Health Centre | $y_{34}$ | Karya Jaya Health Centre |
| $y_{17}$ | Pakjo Health Centre | $y_{35}$ | Taman Bacaan Health Centre |
| $y_{23}$ | Padang Selasa Health Centre | $y_{36}$ | 7 Ulu Health Centre |
| $y_{25}$ | Merdeka Health Centre | $y_{39}$ | Sabokingking Health Centre |
| $y_{26}$ | OPI Health Centre | $y_{43}$ | Alang-Alang Lebar Health Centre |
| $y_{27}$ | Sosial Health Centre | | |

The p-CLP model is as follows:

$$Z_{p-Center} = \min L \quad (2.1)$$

Subject to

$$\sum_{j\in J} z_{ij} = 1, i \in \{1,2,\dots,14\} \text{ and } j \in \{2,8,10,11,12,13,17,23,25,26,27,28,30,31,32,33,34,35,36,39,43\} \quad (2.2)$$

$$\sum_{j\in J} y_j = 21,\ j \in \{2,8,10,11,12,13,17,23,25,26,27,28,30,31,32,33,34,35,36,39,43\} \quad (2.3)$$

$$1900z_{1,2} + 11000z_{1,8} + 7900z_{1,10} + 12000z_{1,11} + 6200z_{1,12} + 9300z_{1,13} + 2800z_{1,17} + 3800z_{1,23} + 3700z_{1,25} + 12000z_{1,26} + 4000z_{1,27} + 14000z_{1,28} + 11000z_{1,30} + 8000z_{1,31} + 5900z_{1,32} + 9200z_{1,33} + 12000z_{1,34} + 6500z_{1,35} + 5700z_{1,36} + 6700z_{1,39} + 10000z_{1,43} \le L \quad (2.4)$$

$$6800z_{2,2} + 13000z_{2,8} + 11000z_{2,10} + 10000z_{2,11} + 9900z_{2,12} + 8000z_{2,13} + 10000z_{2,17} + 8100z_{2,23} + 5700z_{2,25} + 9800z_{2,26} + 12000z_{2,27} + 22000z_{2,28} + 19000z_{2,30} + 16000z_{2,31} + 13000z_{2,32} + 7500z_{2,33} + 12000z_{2,34} + 1600z_{2,35} + 4200z_{2,36} + 6400z_{2,39} + 18000z_{2,43} \le L \quad (2.5)$$

$$9200z_{3,2} + 2300z_{3,8} + 1300z_{3,10} + 7700z_{3,11} + 2300z_{3,12} + 4900z_{3,13} + 9600z_{3,17} + 13000z_{3,23} + 11000z_{3,25} + 19000z_{3,26} + 6300z_{3,27} + 14000z_{3,28} + 8800z_{3,30} + 11000z_{3,31} + 13000z_{3,32} + 15000z_{3,33} + 18000z_{3,34} + 9900z_{3,35} + 11000z_{3,36} + 6500z_{3,39} + 15000z_{3,43} \le L \quad (2.6)$$

$$6900z_{4,2} + 6600z_{4,8} + 4400z_{4,10} + 4200z_{4,11} + 5200z_{4,12} + 60z_{4,13} + 8900z_{4,17} + 9600z_{4,23} + 7600z_{4,25} + 15000z_{4,26} + 9300z_{4,27} + 19000z_{4,28} + 14000z_{4,30} + 15000z_{4,31} + 12000z_{4,32} + 13000z_{4,33} + 16000z_{4,34} + 6400z_{4,35} + 7300z_{4,36} + 3000z_{4,39} + 16000z_{4,43} \le L \quad (2.7)$$

$$6300z_{5,2} + 6300z_{5,8} + 3600z_{5,10} + 9800z_{5,11} + 1800z_{5,12} + 7100z_{5,13} + 4800z_{5,17} + 8600z_{5,23} + 8600z_{5,25} + 15000z_{5,26} + 1800z_{5,27} + 13000z_{5,28} + 7700z_{5,30} + 6400z_{5,31} + 6000z_{5,32} + 12000z_{5,33} + 14000z_{5,34} + 8100z_{5,35} + 8900z_{5,36} + 7900z_{5,39} + 11000z_{5,43} \le L \quad (2.8)$$

$$4800z_{6,2} + 14000z_{6,8} + 12000z_{6,10} + 16000z_{6,11} + 9800z_{6,12} + 13000z_{6,13} + 5100z_{6,17} + 1800z_{6,23} + 3900z_{6,25} + 14000z_{6,26} + 7600z_{6,27} + 18000z_{6,28} + 15000z_{6,30} + 12000z_{6,31} + 9500z_{6,32} + 12000z_{6,33} + 7700z_{6,34} + 9400z_{6,35} + 6700z_{6,36} + 9700z_{6,39} + 11000z_{6,43} \le L \quad (2.9)$$

$$2700z_{7,2} + 12000z_{7,8} + 11000z_{7,10} + 11000z_{7,11} + 9500z_{7,12} + 9200z_{7,13} + 4700z_{7,17} + 1600z_{7,23} + 1600z_{7,25} + 11000z_{7,26} + 7200z_{7,27} + 17000z_{7,28} + 14000z_{7,30} + 11000z_{7,31} + 9100z_{7,32} + 8900z_{7,33} + 9300z_{7,34} + 7100z_{7,35} + 5400z_{7,36} + 7700z_{7,39} + 12000z_{7,43} \le L \quad (2.10)$$

$$31000z_{8,2} + 41000z_{8,8} + 38000z_{8,10} + 33000z_{8,11} + 36000z_{8,12} + 31000z_{8,13} + 35000z_{8,17} + 32000z_{8,23} + 30000z_{8,25} + 24000z_{8,26} + 36000z_{8,27} + 51000z_{8,28} + 48000z_{8,30} + 45000z_{8,31} + 38000z_{8,32} + 30000z_{8,33} + 29000z_{8,34} + 25000z_{8,35} + 29000z_{8,36} + 29000z_{8,39} + 44000z_{8,43} \le L \quad (2.11)$$

$$8500z_{9,2} + 11000z_{9,8} + 11000z_{9,10} + 16000z_{9,11} + 10000z_{9,12} + 13000z_{9,13} + 6900z_{9,17} + 11000z_{9,23} + 11000z_{9,25} + 18000z_{9,26} + 6100z_{9,27} + 8800z_{9,28} + 3400z_{9,30} + 230z_{9,31} + 2500z_{9,32} + 21000z_{9,33} + 17000z_{9,34} + 14000z_{9,35} + 12000z_{9,36} + 15000z_{9,39} + 5100z_{9,43} \le L \quad (2.12)$$

$$16000z_{10,2} + 27000z_{10,8} + 24000z_{10,10} + 22000z_{10,11} + 23000z_{10,12} + 20000z_{10,13} + 18000z_{10,17} + 16000z_{10,23} + 15000z_{10,25} + 13000z_{10,26} + 21000z_{10,27} + 30000z_{10,28} + 26000z_{10,30} + 24000z_{10,31} + 25000z_{10,32} + 8600z_{10,33} + 7700z_{10,34} + 15000z_{10,35} + 12000z_{10,36} + 18000z_{10,39} + 22000z_{10,43} \le L \quad (2.13)$$

$$5300z_{11,2} + 11000z_{11,8} + 9100z_{11,10} + 8500z_{11,11} + 8300z_{11,12} + 6500z_{11,13} + 10000z_{11,17} + 7600z_{11,23} + 5300z_{11,25} + 9400z_{11,26} + 10000z_{11,27} + 22000z_{11,28} + 19000z_{11,30} + 16000z_{11,31} + 13000z_{11,32} + 7500z_{11,33} + 12000z_{11,34} + 1600z_{11,35} + 4200z_{11,36} + 6400z_{11,39} + 19000z_{11,43} \le L \quad (2.14)$$

$$5000z_{12,2} + 14000z_{12,8} + 12000z_{12,10} + 12000z_{12,11} + 9900z_{12,12} + 9600z_{12,13} + 8600z_{12,17} + 6300z_{12,23} + 3900z_{12,25} + 8200z_{12,26} + 9800z_{12,27} + 20000z_{12,28} + 17000z_{12,30} + 14000z_{12,31} + 12000z_{12,32} + 4700z_{12,33} + 8900z_{12,34} + 4000z_{12,35} + 1500z_{12,36} + 7500z_{12,39} + 15000z_{12,43} \le L \quad (2.15)$$

$$4000z_{13,2} + 7700z_{13,8} + 5600z_{13,10} + 5000z_{13,11} + 4900z_{13,12} + 2900z_{13,13} + 7700z_{13,17} + 6800z_{13,23} + 4800z_{13,25} + 12000z_{13,26} + 8000z_{13,27} + 19000z_{13,28} + 14000z_{13,30} + 15000z_{13,31} + 11000z_{13,32} + 9300z_{13,33} + 14000z_{13,34} + 3600z_{13,35} + 4400z_{13,36} + 2000z_{13,39} + 15000z_{13,43} \le L \quad (2.16)$$

$$11000z_{14,2} + 15000z_{14,8} + 15000z_{14,10} + 19000z_{14,11} + 14000z_{14,12} + 16000z_{14,13} + 8200z_{14,17} + 10000z_{14,23} + 12000z_{14,25} + 21000z_{14,26} + 9000z_{14,27} + 9100z_{14,28} + 7300z_{14,30} + 4400z_{14,31} + 5400z_{14,32} + 19000z_{14,33} + 15000z_{14,34} + 16000z_{14,35} + 15000z_{14,36} + 16000z_{14,39} + 30z_{14,43} \le L \quad (2.17)$$

$$z_{ij} \le y_j, i \in \{1,2,\dots,14\} \text{ and } j \in \{2,8,10,11,12,13,17,23,25,26,27,28,30,31,32,33,34,35,36,39,43\} \quad (2.18)$$

$$z_{ij} \in \{0,1\},\ i \in \{1,2,\dots,14\} \text{ and } j \in \{2,8,10,11,12,13,17,23,25,26,27,28,30,31,32,33,34,35,36,39,43\} \quad (2.19)$$

$y_j \in \{0,1\}\, j \in \{2,8,10,11,12,13,17,23,25,26,27,28,30,31,32,33,34,35,36,39,43\}$ (2.20)

$L \geq 0$ (2.21)

The objective function (2.1) minimize the distance between the demand point and the allocated facility. Constraint (2.2) specifies that each demand point can only be covered by one facility. The constraint (2.3) specifies the number of facilities to be built. Constraints (2.4-2.17) specify the maximum demand distance. Constraint (2.18) indicates that demand points are only covered by open facilities. Constraints (2.19)-(2.21) define the constraint domain. Table 7 shows the LINGO 13.0 optimum solution of the p-CLP model is 24,000 with a GMU of 101K and an ER of 0 second. The minimum distance between requests in Palembang City sub-districts to hospitals and health centres is 24,000 metres.

**Table 7. Optimal Solution of p-CLP Model**

| ***Solver Status*** | |
|---|---|
| *Model Class* | *MILP* |
| *State* | *Global Optimal* |
| *Objective* | 24000 |
| *Infeasibility* | 0 |
| *Iterations* | 0 |
| ***Extented Solver Status*** | |
| *Solver Type* | *Branch and Bound* |
| *Best Objective* | 24000 |
| *Objective Bound* | 24000 |
| *Steps* | 0 |
| *Active* | 0 |
| *Update Internal* | 2 |
| *GMU (K)* | 101 |
| *ER (sec)* | 0 |

Based on Table 7, the optimum distance of COVID-19 vaccine distribution locations in Palembang City is 24,000 meter with optimal solutions $z_{1,2} = z_{2,35} = z_{3,10} = z_{4,13} = z_{5,27} = z_{6,23} = z_{7,23} = z_{8,26} = z_{9,31} = z_{10,34} = z_{11,35} = z_{12,36} = z_{13,39} = z_{14,43} = 1$ which mean:

1. The demand in the Ilir Timur I Sub-District ($z_1$) will be located at Charitas Hospital ($y_2$)
2. The demand in the Plaju Sub-District ($z_2$) will be located at Taman Bacaan Health Centre ($y_{35}$)
3. The demand in the Sako Sub-District ($z_3$) will be located at Bukitsangkal Health Centre ($y_{10}$)
4. The demand in the Kalidoni Sub-District ($z_4$) will be located at Kalidoni Health Centre ($y_{13}$)
5. The demand in the Kemuning Sub-District ($z_5$) will be located at Sosial Health Centre ($y_{27}$)
6. The demand in the Ilir Barat I Sub-District ($z_6$) will be located at Padang Selasa Health Centre ($y_{23}$)

7. The demand in the Bukit Kecil Sub-District ($z_7$) will be located at Padang Selasa Health Centre ($y_{23}$)
8. The demand in the Jakabaring Sub-District ($z_8$) will be located at OPI Health Centre ($y_{26}$)
9. The demand in the Sukarami Sub-District ($z_9$) will be located at Sukarami Health Centre ($y_{31}$)
10. The demand in the Kertapati Sub-District ($z_{10}$) will be located at Karya Jaya Health Centre ($y_{34}$)
11. The demand in the Seberang Ulu II Sub-District ($z_{11}$) will be located at Taman Bacaan Health Centre ($y_{35}$)
12. The demand in the Seberang Ulu I Sub-District ($z_{12}$) will be located at 7 Ulu Health Centre ($y_{36}$)
13. The demand in the Ilir Timur II Sub-District ($z_{13}$) will be located at Sabokingking Health Centre ($y_{39}$)
14. The demand in the Alang-Alang Lebar Sub-District ($z_{14}$) will be located at Alang-Alang Lebar Health Centre ($y_{43}$)

***Implementation of The Greedy Heuristic Algorithm in Solving SCLP***

The distribution of COVID-19 vaccines in Palembang City is addressed through the Greedy Heuristic Algorithm, which utilizes distance data initialized to 0 or 1. This information is presented in Table 8. The coefficient constraint value of 1 indicates that COVID-19 vaccine distribution locations in Palembang City are less than 2,000 meters apart, while 0 shows more than 2,000 meters apart.

**Table 8. Objective Function of The SCLP Model**

| **Location** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter $q_i$** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Location** | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| **Parameter $q_i$** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

The orange row states the location of the COVID-19 vaccine distribution in Palembang City. The blue row states the parameter $q_i$, where $q_i$is the objective function coefficient at each $i$ = 1, 2, 3, ..., 43, which are all worth 1.

Iteration 1

Step 1

In step 1 if $q_i = 0, \forall i, y_i = 1$, where $q_i$ is the objective function coefficient, $i$ = 1, 2, 3,…, 43. Next eliminate all constraints where $y_i$ has a coefficient of 1. In that step it does not apply because all values of $q_i$ in the objective function are greater than 0.

Step 2

In step 2 if $q_i > 0, \forall i$ and $y_i$ does not have a coefficient of 1 on any of the remaining constraints then $x_i = 0$. In this step first calculate $d_i$, where $d_i$ is the number of constraints $y_i$ with coefficient 1.

If there is no constraint $y_i$ = 0, so this step is also not applicable.

Step 3

On the remaining variables, then calculate $\frac{q_i}{d_i}$ where $d_i$ is the number of constraints $y_i$ with coefficient 1. Select the minimum $\frac{q_i}{d_i}$ variable and the set $y_i$ has coefficient 1.

Step 4

If there are no more constraints, all remaining sets of variables 0 are stopped, otherwise repeat Step (1).

The calculation process continues until the 27th iteration. The optimal solution from the Greedy Heuristic algorithm is yaitu $y_1 = y_2 = y_7 = y_8 = y_{10} = y_{11} = y_{12} = y_{13} = y_{14} = y_{17} = y_{18} = y_{19} = y_{22} = y_{24} = y_{25} = y_{26} = y_{27} = y_{28} = y_{29} = y_{30} = y_{31} = y_{33} = y_{34} = y_{36} = y_{39} = y_{42} = y_{43} = 1$ which means that the optimal COVID-19 vaccine distribution location can be seen in Table 9.

**Table 9. Optimal Location of The Greedy Heuristic Algorithm**

| No | Optimal Result of Greedy Heuristic Algorithm |
|---|---|
| 1. | Ariodillah Health Centre |
| 2. | Charitas Hospital |
| 3. | Naga Swidak Health Centre |
| 4. | Sako Health Centre |
| 5. | Bukitsangkal Health Centre |
| 6. | Sei Lincah Health Centre |
| 7. | Kenten Health Centre |
| 8. | Kalidoni Health Centre |
| 9. | Dr. Mohammad Hoesin Hospital |
| 10. | Pakjo Health Centre |
| 11. | Siti Khadijah Hospital |
| 12. | Bunda Hospital |
| 13. | Bunda Noni Hospital |
| 14. | Sei Baung Helath Centre |
| 15. | Merdeka Health Centre |
| 16. | OPI Health Centre |
| 17. | Sosial Health Centre |
| 18. | Talang Betutu Health Centre |
| 19. | Myria Hospital |
| 20. | Pelabuhan Kelas II Health Office |
| 21. | Sukarami Health Centre |
| 22. | Kramasan Health Centre |
| 23. | Karya Jaya Health Centre |
| 24. | 7 Ulu Health Centre |
| 25. | Sabongkingking Health Centre |
| 26. | Tiara Fatrin Hospital |
| 27. | Alang-Alang Lebar Health Centre |

The completion of the SCP model and the Greedy Heuristic Algorithm obtained the optimal distribution location of the COVID-19 vaccine in the sub-districts of Ilir Timur I, Plaju, Sako, Kalidoni, Kemuning, Ilir Barat I, Bukit Kecil, Jakabaring,

Sukarami, Kertapati, Seberang Ulu I, Ilir Timur II, and Alang-Alang Lebar, so it is necessary to recommend the distribution location of the COVID-19 vaccine in other sub-districts in Palembang City.

## D. CONCLUSIONS

From the discussion and results of determining the optimal location for COVID-19 vaccine distribution in Palembang City, it can be concluded that the SCLP model and the p-CLP model both produce 27 optimal vaccine distribution locations. However, there are differences in locations in several sub-districts. The study recommends the Greedy Heuristic Algorithm as the optimal solution for locating COVID-19 vaccine distribution locations in Palembang City.

## ACKNOWLEDGEMENT

The research/publication of this article was funded by DIPA of Public Service Agency of Universitas Sriwijaya 2022. SP DIPA-023.17.2.677515/2022, on December 13, 2021. In accordance with the Dean's Decree Number: 0245/UN9.FMIPA/TU.SK/2022, on May 18, 2022.

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