Bi-Objective Benders Decomposition Model for The Optimal Location of Temporary Waste Disposal Site in Ilir Barat I Sub-District Palembang

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Abstract. The increase in population density in the Ilir Barat I (IB-I) sub-district of Palembang has resulted in waste management issues. In response, the government has established a Temporary Waste Disposal Site (TWDS). This study aims to identify the optimal locations for TWDS in the IB-I sub-district by utilizing the Set Covering Problem (SCP). SCP is a subset of optimization problems that aims to solve the optimal location allocation problem. This study's SCP model comprises two sub-models: the Set Covering Location Problem (SCLP) model and the Maximal Covering Location Problem (MCLP) model. As a comparison, the bi-objective benders decomposition model was also formulated in this research. The IB-I sub-district contains 27 TWDS situated across six villages. Based on the results, the optimal solution of the SCLP model was used to formulate the MCLP model. SCP model identified 15 optimal TWDS. The bi-objective benders decomposition model produced 27 optimum TWDS in the IB-I sub-district. Consequently, this research recommends using the bi-objective benders decomposition model to determine the most suitable TWDS. The bi-objective benders decomposition model was employed to address the demand points in six villages of the IB-I sub-district of Palembang.

Keywords: Location Optimization, Set Covering Location Problem, Maximal Covering Location Problem, Bi-Objective Benders Decomposition.

1 Introduction

As the population of Palembang continues to grow, the amount of waste generated also increases. The increase in waste production is a global issue arising from population growth, changing consumer behavior, and lifestyle changes. The population of Palembang City is increasing annually, leading to a rise in the amount of waste. Population density and diverse urban areas pose significant waste management challenges [1]. Ilir Barat I (IB-I) is the most populous of the 18 sub-districts in Palembang City, according to the Central Bureau of Statistics

SICBAS 2023, November 03, Palembang, Indonesia

DOI 10.4108/eai.3-11-2023.2347901

(CBS) of Palembang City. It covers an area of 19.77 km^2 and had a population of 141,949 people in 2021. The sub-district is divided into six urban villages. Waste generation results from the daily activities of residents, and the Padang Selasa market is the largest contributor. The government's waste management efforts have failed to keep pace with the level of waste production, resulting in an unresolved waste problem. The Palembang City Government, led by the Department of Environment and Hygiene (DEH), has established Temporary Waste Disposal Sites (TWDS) to tackle the issue of waste accumulation. The defective placement of TWDS has resulted in landfills due to excessive waste. The TWDS serves as a principal reference point in the field of waste management.

Location optimization is a crucial aspect of the optimization problem [2]. According to [3], optimization is discovering an optimal solution that satisfies specific constraints by maximizing or minimizing the objective value (objective function). An optimization problem can be used to determine the number of locations and facilities required for TWDS, and the Set Covering Problem (SCP) model can solve this problem. The SCP is an integer programming problem that optimizes the number and allocation of facility locations. According to [4], The applications of SCP in everyday life are manifold. They include allocating machines, assigning jobs to workers, optimizing facility locations to achieve optimal results, and setting waste vehicle routes to minimize the distance and cost involved. The Set Covering Location Problem (SCLP) and Maximal Covering Location Problem (MCLP) are models within the broader SCP framework [5]. SCLP forms part of Integer Linear Programming (ILP), which seeks to optimize the selection of location-allocation, identify the best possible solution, and minimize contributing constraints. In contrast, MCLP is a numerical programming model that strives to identify the optimum location for public facilities and maximize demand coverage [6].

The bi-objective benders decomposition model is a tool that effectively addresses location optimization problems, including challenging tasks such as stochastic or non-linear programming [7–10]. The bi-objective benders decomposition model is a highly effective method for resolving Mixed Integer Problems (MIP) by simplifying the original constraints into fewer variables than the main ones [11]. Previous research has been carried out on SCP, specifically addressing public location problems [4,12–18]. In their study, [2] sought to identify the optimal TWDS in the Kemuning sub-district. To this end, they employed a Greedy Reduction Algorithm (GRA) and identified three locations that would serve the needs of six villages. [6] examined the development of an efficient groundwater monitoring system at an oil refinery location using the MCLP model. The obtained research findings can potentially decrease borehole numbers by a significant proportion of 52.72%, particularly within the oil refining and storage zone. [19] tackled the issue of discrete TWDS positioning in Palembang City through heuristic models and algorithms. In a study published in 2022 by [20], the issue of locating TWDS in the Seberang Ulu I sub-district was examined utilizing the p-median method. [20] ultimately led to the proposal of 12 optimized TWDS. Additionally, the authors investigated the optimization of TWDS in the Sukarami sub-district using the GRA. This ultimately led to the recommendation of three optimal TWDS in the Sukarami sub-district.

Based on this background, this study aims to develop the SCP model and bi-objective benders decomposition. The LINGO 18.0 program solves this model to identify the best possible positions for TWDS in the IB-I sub-district.

2 Methods

The research proceeded in the following manner: data on the names of TWDS in the IB-I sub-district were collected from DLHK Palembang City and presented as data tables. TWDS and village data variables in the IB-I sub-district were defined and described. The distance travelled between TWDS was measured using Google Maps. The SCP model was formulated. The SCP model, which comprises the SCLP and MCLP models, is then determined using the LINGO 18.0 application. The bi-objective benders decomposition model is formulated to determine the optimal location of TWDS. The solution of the bi-objective benders decomposition model is then found using the LINGO 18.0 application. The outcomes of the SCP model, specifically the SCLP and MCLP and the bi-objective benders decomposition model, must be analyzed. Based on the results obtained from the SCP model, both the SCLP and MCLP and the bi-objective benders decomposition model, conclusions will be drawn.

3 Results

This section presents the collected data and methodology used to determine the locations and facilities of TWDS for the IB-I sub-district in Palembang City. The models employed in the research were SCLP, MCLP, and the bi-objective benders decomposition model. Table 1 provides a list of the 6 villages and 27 TWDS within IB-I sub-district of Palembang City.

Table 1. List of villages and TWDS in the IB-I sub-district

Name of Villages	Name of TWDS
Bukit Lama	• TWDS PDAM Street Bukit Lama Village • TWDS Sultan Mansyur Street • TWDS Polygon Housing • TWDS Siguntang • TWDS Srijaya Negara Street beside Jaya Sempurna Street • TWDS Srijaya Negara Street Padang Selasa Market
Bukit Baru	• TWDS Demang Lebar Daun Street in front of City Trading Office Bus Stop
26 Ilir D. I	• TWDS Natuna Street beside BPN • TWDS Kapten A. Rivai Street Karya Lane
Lorok Pakjo	• TWDS Bintan Street beside Mandiri Bank • TWDS Illegal beside Five Intersection of DPRD Province in front of Pindang Kuyung Restaurant • TWDS Puncak Sekuning Street • TWDS Aerobik Street in front of DPD GOLKAR Office • TWDS Intersection Kaca Piring Street • TWDS opposite Palembang Square • TWDS beside Financial Office • TWDS Demang Lebar Daun Street in front of Capil Office • TWDS Angkatan 45 Street in front of Sang Merah Putih Street
Demang Lebar Daun	• TWDS Angkatan 45 Street in front of Persatuan Lane • TWDS Angkatan 45 Street opposite Kejora Lane (Harapan Lane)

	• TWDS Angkatan 45 Intersection Harisan Lane • TWDS Demang Lebar Daun Street Brimob Retention Point
Siring Agung	• TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge • TWDS Inspektur Marzuki Street Intersection Pakjo Lane • TWDS Pakjo Children's Prison • TWDS Pakjo Prison Complex • TWDS Anwar Arsad Street in front of Indomaret

The variables of TWDS were defined as p_j, where $j = 1,2,3, \dots ,27$ that can be seen in Table 2.

Table 2. Variable definition of TWDS in the IB-I sub-district

Variable	Definition of Variable
p_1	TWDS PDAM Street Bukit Lama Village
p_2	TWDS Sultan Mansyur Street
p_3	TWDS Polygon Housing
p_4	TWDS Siguntang
p_5	TWDS Demang Lebar Daun Street in front of City Trading Office Bus Stop
p_6	TWDS Srijaya Negara Street beside Jaya Sempurna Street
p_7	TWDS Srijaya Negara Street Padang Selasa Market
p_8	TWDS Natuna Street beside BPN
p_9	TWDS Bintan Street beside Mandiri Bank
p_{10}	TWDS Illegal beside Five Intersection of DPRD Province in front of Pindang Kuyung Restaurant
p_{11}	TWDS Puncak Sekuning Street
p_{12}	TWDS Aerobik Street in front of DPD GOLKAR Office
p_{13}	TWDS Intersection Kaca Piring Street
p_{14}	TWDS opposite Palembang Square
p_{15}	TWDS Kapten A. Rivai Street Karya Lane
p_{16}	TWDS Angkatan 45 Street in front of Sang Merah Putih Street
p_{17}	TWDS Angkatan 45 Street in front of Persatuan Lane
p_{18}	TWDS Angkatan 45 Street opposite Kejora Lane (Harapan Lane)
p_{19}	TWDS Angkatan 45 Street Intersection Harisan Lane
p_{20}	TWDS Demang Lebar Daun Street Brimob Retention Point
p_{21}	TWDS beside Financial Office
p_{22}	TWDS Demang Lebar Daun Street in front of Capil Office
p_{23}	TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge
p_{24}	TWDS Inspektur Marzuki Street Intersection Pakjo Lane
p_{25}	TWDS Pakjo Children's Prison
p_{26}	TWDS Pakjo Prison Complex
p_{27}	TWDS Anwar Arsad Street in front of Indomaret

Table 2 defines p_1 as TWDS PDAM Street Bukit Lama Village, p_2 as TWDS Sultan Mansyur Street, and so on until p_{27} as TWDS Anwar Arsad Street in front of Indomaret. The variables of villages were defined as q_i, where $i = 1,2, \dots ,6$ that can be seen in Table 3.

In compliance with the Minister of Public Works of the Republic of Indonesia (Number 03/PRT/M/2013) regarding the implementation of waste infrastructure and facilities for the disposal of household waste and waste similar to that produced by households, Article 32 stipulates that the distance separating two TWDS shall be no greater than 500 metres.

Table 3. Variable definition of villages in the IB-I sub-district

Variable	Definition of Variable
q_1	Bukit Lama Village
q_2	Bukit Baru Village
q_3	26 Ilir D. I Village
q_4	Lorok Pakjo Village
q_5	Demang Lebar Daun Village
q_6	Siring Agung Village

Data on the distance between TWDS in this study was obtained from DLHK Palembang City with the help of Google Maps. Furthermore, distance data that is less than or equal to 500 m is used for the SCLP model formulation.

3.1 Formulation of SCLP Model

The SCLP model is as belows.

Minimize $Z_{SCLP} = p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8 + p_9 + p_{10} + p_{11} + p_{12} + p_{13} + p_{14} + p_{15} + p_{16} + p_{17} + p_{18} + p_{19} + p_{20} + p_{21} + p_{22} + p_{23} + p_{24} + p_{25} + p_{26} + p_{27}$ (1)

Subject to

$$p_1 + p_2 \geq 1 \quad (2)$$
$$p_3 \geq 1 \quad (3)$$
$$p_4 \geq 1 \quad (4)$$
$$p_5 \geq 1 \quad (5)$$
$$p_6 + p_7 \geq 1 \quad (6)$$
$$p_8 + p_9 \geq 1 \quad (7)$$
$$p_{10} + p_{11} \geq 1 \quad (8)$$
$$p_{10} + p_{11} + p_{12} \geq 1 \quad (9)$$
$$p_{11} + p_{12} \geq 1 \quad (10)$$
$$p_{13} + p_{14} \geq 1 \quad (11)$$
$$p_{13} + p_{14} + p_{15} \geq 1 \quad (12)$$
$$p_{14} + p_{15} \geq 1 \quad (13)$$
$$p_{16} + p_{17} + p_{18} \geq 1 \quad (14)$$
$$p_{16} + p_{17} + p_{18} + p_{19} \geq 1 \quad (15)$$
$$p_{17} + p_{18} + p_{19} + p_{20} \geq 1 \quad (16)$$
$$p_{19} + p_{20} + p_{21} \geq 1 \quad (17)$$
$$p_{20} + p_{21} \geq 1 \quad (18)$$
$$p_{22} \geq 1 \quad (19)$$
$$p_{23} \geq 1 \quad (20)$$
$$p_{24} \geq 1 \quad (21)$$
$$p_{25} + p_{26} \geq 1 \quad (22)$$
$$p_{27} \geq 1 \quad (23)$$
$$p_1, p_2, \dots, p_{27} \in \{0,1\} \quad (24)$$

The SCLP model, as represented by Equation (1) and Inequalities (2)-(24), demonstrates that the objective function (1) is designed to minimize the number of potential TWDS in the IB-I sub-district. Furthermore, Constraint (2)-(23) outlines the demand point constraint models, while Constraint (24) indicates that all variables are binary. The SCLP model in the IB-I sub-district was solved using LINGO 18.0. The optimal solution is presented in Table 4.

Table 4 indicates that the solver status box displays the model class as PILP (Pure Integer Linear Programming), identifying the model being solved as an integer linear programming problem. All decision variables produced are integer values of either 1 or 0. The state indicates that the solution obtained is globally optimal, with an objective function value of 15. This outcome was achieved with zero iterations and an infeasibility of zero, indicating that the SCLP model produces a feasible solution. As indicated in the supplementary solver status box, the solver employed the branch-and-bound method. The optimal outcome of this SCLP model is for 15 TWDS to be located within the IB-I sub-district. The objective bound yields a value of 15. The number of steps and active memory is 0. The memory allocation is 26K, as the Generated Memory Used (GMU) value indicates. Concurrently, the Elapsed Runtime (ER) suggests that the total time required to complete the model was 0 seconds.

Table 4. The optimal solution of the SCLP model

Solver Status	
Model Class	*PILP*
State	*Global Optimal*
Objective	15
Infeasibility	0
Iterations	0
Extended Solver Status	
Solver Type	*Branch and Bound*
Best Objective	15
Objective Bound	15
Steps	0
Active	0
Update Interval	2
GMU (K)	26
ER (sec)	0

The optimal solutions for the TWDS are $p_2 = p_3 = p_4 = p_5 = p_7 = p_9 = p_{11} = p_{14} = p_{18} = p_{20} = p_{22} = p_{23} = p_{24} = p_{26} = p_{27} = 1$. Upon completion of the SCLP model in the IB-I sub-district, the optimal TWDS is 15, as indicated in Table 5.

Table 5. The optimal TWDS based on the SCLP model

Name of Village	**Name of TWDS**
Bukit Lama	• TWDS Sultan Mansyur Street • TWDS Polygon Housing • TWDS Siguntang • TWDS Srijaya Negara Street Padang Selasa Market
Bukit Baru	• TWDS Demang Lebar Daun Street in front of City Trading Office Bus Stop
Lorok Pakjo	• TWDS Bintan Street beside Mandiri Bank • TWDS Puncak Sekuning Street • TWDS opposite Palembang Square

	• TWDS Demang Lebar Daun Street in front of Capil Office
Demang Lebar Daun	• TWDS Angkatan 45 Street opposite Kejora Lane (Harapan Lane) • TWDS Demang Lebar Daun Street Brimob Retention Point
Siring Agung	• TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge • TWDS Inspektur Marzuki Street Intersection Pakjo Lane • TWDS Pakjo Prison Complex • TWDS Anwar Arsad Street in front of Indomaret

Table 5 displays the ideal TWDS utilizing the SCLP model, founded on villages in the IB-I sub-district of Palembang City. The Bukit Lama village comprises four optimal TWDS, the Bukit Baru village includes one optimal TWDS, the Lorok Pakjo village includes four optimal TWDS, the Demang Lebar Daun village has two optimal TWDS, the Siring Agung village also includes four optimal TWDS. In contrast, the 26 Ilir D.I village has no optimal TWDS.

3.2 Formulation of MCLP Model

The objective of MCLP is to identify the optimal location of p facilities in order to maximize the coverage of demand within a specified distance. The variables and demand points in the IB-I sub-district are presented in Table 6.

Table 6. The variable definition of demand points in the IB-I sub-district

Variable	Demand Point
r_1	TWDS PDAM Street Bukit Lama Village
r_2	TWDS Sultan Mansyur Street
r_3	TWDS Polygon Housing
r_4	TWDS Siguntang
r_5	TWDS Demang Lebar Daun Street in front of City Trading Office Bus Stop
r_6	TWDS Srijaya Negara Street beside Jaya Sempurna Street
r_7	TWDS Srijaya Negara Street Padang Selasa Market
r_8	TWDS Natuna Street beside BPN
r_9	TWDS Bintan Street beside Mandiri Bank
r_{10}	TWDS Illegal beside Five Intersection of DPRD Province in front of Pindang Kuyung Restaurant
r_{11}	TWDS Puncak Sekuning Street
r_{12}	TWDS Aerobik Street in front of DPD GOLKAR Office
r_{13}	TWDS Intersection Kaca Piring Street
r_{14}	TWDS opposite Palembang Square
r_{15}	TWDS Kapten A. Rivai Street Karya Lane
r_{16}	TWDS Angkatan 45 Street in front of Sang Merah Putih Street
r_{17}	TWDS Angkatan 45 Street in front of Persatuan Lane
r_{18}	TWDS Angkatan 45 Street opposite Kejora Lane (Harapan Lane)
r_{19}	TWDS Angkatan 45 Street Intersection Harisan Lane
r_{20}	TWDS Demang Lebar Daun Street Brimob Retention Point
r_{21}	TWDS beside Financial Office
r_{22}	TWDS Demang Lebar Daun Street in front of Capil Office
r_{23}	TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge
r_{24}	TWDS Inspektur Marzuki Street Intersection Pakjo Lane
r_{25}	TWDS Pakjo Children’s Prison
r_{26}	TWDS Pakjo Prison Complex
r_{27}	TWDS Anwar Arsad Street in front of Indomaret

Based on Table 6, r_1 is a variable that states the demand point at TWDS PDAM Street Bukit Lama Village, r_2 is a variable that displays the demand point at TWDS Sultan Mansyur Street, and so on until r_{27}. Furthermore, the optimal solution of the SCLP model yields the MCLP model, as illustrated in Model (25)-(55).

Maximize

$$Z_{MCLP} = r_1 + r_2 + r_3 + r_4 + r_5 + r_6 + r_7 + r_8 + r_9 + r_{10} + r_{11} + r_{12} + r_{13} + r_{14} + r_{15} + r_{16} + r_{17} + r_{18} + r_{19} + r_{20} + r_{21} + r_{22} + r_{23} + r_{24} + r_{25} + r_{26} + r_{27} \quad (25)$$

Subject to

$$p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8 + p_9 + p_{10} + p_{11} + p_{12} + p_{13} + p_{14} + p_{15} + p_{16} + p_{17} + p_{18} + p_{19} + p_{20} + p_{21} + p_{22} + p_{23} + p_{24} + p_{25} + p_{26} + p_{27} = 15 \quad (26)$$

$$p_1 + p_2 \geq r_1 \quad (27)$$

$$p_1 + p_2 \geq r_2 \quad (28)$$

$$p_3 \geq r_3 \quad (29)$$

$$p_4 \geq r_4 \quad (30)$$

$$p_5 \geq r_5 \quad (31)$$

$$p_6 + p_7 \geq r_6 \quad (32)$$

$$p_6 + p_7 \geq r_7 \quad (33)$$

$$p_8 + p_9 \geq r_8 \quad (34)$$

$$p_8 + p_9 \geq r_9 \quad (35)$$

$$p_{10} + p_{11} \geq r_{10} \quad (36)$$

$$p_{10} + p_{11} + p_{12} \geq r_{11} \quad (37)$$

$$p_{11} + p_{12} \geq r_{12} \quad (38)$$

$$p_{13} + p_{14} \geq r_{13} \quad (39)$$

$$p_{13} + p_{14} + p_{15} \geq r_{14} \quad (40)$$

$$p_{14} + p_{15} \geq r_{15} \quad (41)$$

$$p_{16} + p_{17} + p_{18} \geq r_{16} \quad (42)$$

$$p_{16} + p_{17} + p_{18} + p_{19} \geq r_{17} \quad (43)$$

$$p_{16} + p_{17} + p_{18} + p_{19} \geq r_{18} \quad (44)$$

$$p_{17} + p_{18} + p_{19} + p_{20} \geq r_{19} \quad (45)$$

$$p_{19} + p_{20} + p_{21} \geq r_{20} \quad (46)$$

$$p_{20} + p_{21} \geq r_{21} \quad (47)$$

$$p_{22} \geq r_{22} \quad (48)$$

$$p_{23} \geq r_{23} \quad (49)$$

$$p_{24} \geq r_{24} \quad (50)$$

$$p_{25} + p_{26} \geq r_{25} \quad (51)$$

$$p_{25} + p_{26} \geq r_{26} \quad (52)$$

$$p_{27} \geq r_{27} \quad (53)$$

$$r_1, r_2, \ldots, r_{27} \in \{0,1\} \quad (54)$$

$$p_1, p_2, \ldots, p_{27} \in \{0,1\} \quad (55)$$

The objective function (25) aims to maximize the total demand covered. Constraint (26) states that 15 facilities will be deployed. Constraints (27)-(53) state that the opened TWDS only covered the demand point. Constraints (54)-(55) ensure that all solutions are binary. Furthermore, the model is solved with the assistance of the LINGO 18.0 program, the results of which can be found in Table 7.

Table 7. The optimum solution of the MCLP model

Solver Status	
Model Class	PILP
State	*Global Optimal*
Objective	27
Infeasibility	0
Iterations	0
Extended Solver Status	
Solver Type	*Branch and Bound*
Best Objective	27
Objective Bound	27
Steps	0
Active	0
Update Interval	2
GMU (K)	34
ER (sec)	0

The optimum variables of the MCLP model are $r_1 = r_2 = r_3 = r_4 = r_5 = r_6 = r_7 = r_8 = r_9 = r_{10} = r_{11} = r_{12} = r_{13} = r_{14} = r_{15} = r_{16} = r_{17} = r_{18} = r_{19} = r_{20} = r_{21} = r_{22} = r_{23} = r_{24} = r_{25} = r_{26} = r_{27} = 1$ and the value $p_2 = p_3 = p_4 = p_5 = p_7 = p_9 = p_{11} = p_{14} = p_{17} = p_{20} = p_{22} = p_{23} = p_{24} = p_{26} = p_{27} = 1$ which mean all demand points are covered. the optimal TWDS based on the MCLP model can be seen in Table 8.

Table 8. The optimal TWDS based on the MCLP model

Name of Village	**Name of TWDS**
Bukit Lama	• TWDS Sultan Mansyur Street • TWDS Polygon Housing • TWDS Siguntang • TWDS Srijaya Negara Street Padang Selasa Market
Bukit Baru	• TWDS Demang Lebar Daun Street in front of City Trading Office
Lorok Pakjo	• TWDS Bintan Street beside Mandiri Bank • TWDS Puncak Sekuning Street • TWDS opposite Palembang Square • TWDS Demang Lebar Daun Street in front of Capil Office
Demang Lebar Daun	• TWDS Angkatan 45 Street in front of Persatuan Lane • TWDS Demang Lebar Daun Street Brimob Retention Point
Siring Agung	• TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge • TWDS Inspektur Marzuki Street Intersection Pakjo Lane • TWDS Pakjo Prison Complex • TWDS Anwar Arsad Street in front of Indomaret

Table 8 presents the optimal TWDS with the MCLP model based on villages in the IB-I sub-district. Bukit Lama village, Lorok Pakjo village, and Siring Agung village comprise four optimal TWDS each. Bukit Baru village has one optimal TWDS, while Demang Lebar Daun village has two optimal TWDS. In contrast, 26 Ilir D.I village needs an optimal TWDS.

3.3 Formulation of the bi-objective benders decomposition model

The bi-objective benders decomposition model is formulated using location data from TWDS derived from solving the SCLP model. The objective is to reduce the number of TWDS and enhance the coverage of unfulfilled TWDS in the IB-I sub-district. Table 9 displays the variables and capacity of each TWDS in the IB-I sub-district.

Table 9. Variables and waste volume capacity in each village of IB-I sub-district

Variable	Definition of Variable	Waste Volume Capacity
W_1	Bukit Lama Village	12 m^3
W_2	Bukit Baru Village	1 m^3
W_3	26 Ilir D.I Village	2 m^3
W_4	Lorok Pakjo Village	20 m^3
W_5	Demang Lebar Daun Village	4 m^3
W_6	Siring Agung Village	20 m^3

The formulation of bi-objective benders decomposition model is as follow.

$$\text{Minimize } f_1 = \sum_{j\in J} p_j \text{ , } j = 1,2,\dots,27 \quad (56)$$

$$\text{Minimize } f_2 = \sum_{j\in J} u_j \text{ , } j = 1,2,\dots,27 \quad (57)$$

Subject to

$$u_j \leq \sum_{i\in I}\sum_{j\in J} y_{i,j} \text{ , } i = 1,2,\dots,6 \text{ and } j = 1,2,\dots,27 \quad (58)$$

$$p_j \geq u_j, \ j = 1,2,\dots,27 \quad (59)$$

$$W_i p_j \geq y_{i,j}, \ i = 1,2,\dots,6 \text{ and } j = 1,2,\dots,27 \quad (60)$$

$$\sum_{i\in I}\sum_{j\in J} y_{i,j} \leq W_i, \ \ i = 1,2,\dots,6 \text{ and } j = 1,2,\dots,27 \quad (61)$$

$$p_j \in \{0,1\}, j = 1,2,\dots,27 \quad (62)$$

$$y_{i,j} \geq 0, i = 1,2,\dots,6 \text{ and } j = 1,2,\dots,27 \quad (63)$$

$$u_j \geq 0, j = 1,2,\dots,27 \quad (64)$$

The objective function (56) is designed to reduce the number of TWDS deployed in the IB-I sub-district. The objective function (57) also seeks to minimize the minimum number of TWDS required to cover all demands. Constraint (58) prohibits demand locations covered by TWDS in the IB-I sub-district from exceeding the assigned village. Constraint (59) guarantees that TWDS in the IB-I sub-district stay within their capacity. Constraint (60) ensures that demand points are only assigned to open TWDS in the IB-I sub-district. Constraint (61) guarantees the coverage of every demand point in a village in the IB-I sub-district. Constraint (62) specifies that the decision variable is binary. Constraints (63) and (64) stipulate that the TWDS in the IB-I sub-district must cover a minimum amount of demand.

The bi-objective benders decomposition model was solved using LINGO 18.0. The results of this analysis are presented in Table 10, which indicates an optimal solution.

Table 10. The optimum solution of the bi-objective benders decomposition model

Solver Status	
Model Class	*MILP*
State	*Global Optimal*
Objective	12
Infeasibility	0
Iterations	476
Extended Solver Status	
Solver Type	*Branch and Bound*
Best Objective	12
Objective Bound	12
Steps	0
Active	0
Update Interval	2
GMU (K)	101
ER (sec)	0

The optimal TWDS based on the bi-objective benders decomposition model can be seen in Table 11.

Table 11. The optimal TWDS based on the bi-objective benders decomposition model

Name of Village	Name of TWDS
Bukit Lama	• TWDS Siguntang • TWDS Demang Lebar Daun Street in front of City Trading Office • TWDS Srijaya Negara Street beside Jaya Sempurna Street • TWDS Angkatan 45 Street opposite Kejora Lane (Harapan Lane) • TWDS Angkatan 45 Street Intersection Harisan Lane • TWDS beside Financial Office • TWDS Demang Lebar Daun Street in front of Capil Office
Bukit Baru	• TWDS Demang Lebar Daun Street Brimob Retention Point
26 Ilir D. I	• TWDS Sultan Mansyur Street • TWDS Angkatan 45 Street in front of Sang Merah Putih Street
Lorok Pakjo	• TWDS Intersection Kaca Piring Street • TWDS Inspektur Marzuki Street Intersection Pakjo Lane • TWDS Pakjo Prison Complex • TWDS Anwar Arsad Street in front of Indomaret
Demang Lebar Daun	• TWDS Bintan Street beside Mandiri Bank • TWDS Aerobik Street in front of DPD GOLKAR Office • TWDS Kapten A. Rivai Street Karya Lane • TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge
Siring Agung	• TWDS PDAM Street Bukit Lama Village • TWDS Polygon Housing • TWDS Srijaya Negara Street Padang Selasa Market • TWDS Natuna Street beside BPN • TWDS Illegal beside Five Intersection DPRD Province in front of Pindang Kuyung Restaurant • TWDS Puncak Sekuning Street • TWDS opposite Palembang Square • TWDS Pakjo Children’s Prison

The study proposes the bi-objective benders decomposition model as the optimal solution to meet all demands within the IB-I sub-district of Palembang City. Figure 1 illustrates the optimal solution derived from the bi-objective benders decomposition model.

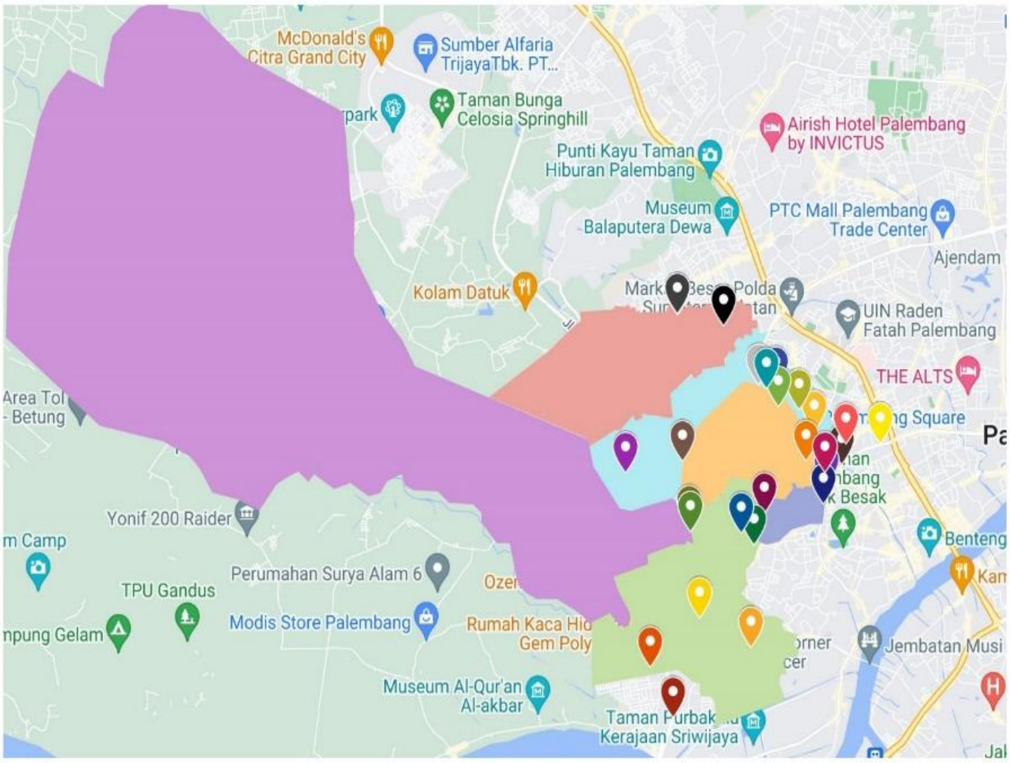

Fig. 1. Map of TWDS in the IB-I sub-district

Color description:

- TWDS Siguntang
- TWDS Demang Lebar Daun Street in front of City Trading Office
- TWDS Srijaya Negara Street beside Jaya Sempurna Street
- TWDS Angkatan 45 Street opposite Kejora Lane (Harapan Lane)
- TWDS Angkatan 45 Street Intersection Harisan Lane
- TWDS beside Financial Office
- TWDS Demang Lebar Daun Street in front of Capil Office
- TWDS Demang Lebar Daun Street Brimob Retention Office
- TWDS Sultan Mansyur Street
- TWDS Angkatan 45 Street in front of Sang Merah Putih Street
- TWDS Intersection Kaca Piring Street
- TWDS Inspektur Marzuki Street Intersection Pakjo Lane
- TWDS Pakjo Prison Complex
- TWDS Anwar Arsad Street in front of Indomaret

TWDS Bintan Street beside Mandiri Bank
TWDS Aerobik Street in front of DPD GOLKAR Office
TWDS Kapten A. Rivai Street Karya Lane
TWDS Soekarno Hatta Street Intersection Kancil Putih Bridge
TWDS PDAM Street Bukit Lama Village
TWDS Polygon Housing
TWDS Srijaya Negara Street Padang Selasa Market
TWDS Natuna Street beside BPN
TWDS Illegal Five Intersection DPRD Province in front of Pindang Kuyung Restaurant
TWDS opposite Palembang Square
TWDS Pakjo Children’s Prison
TWDS Angkatan 45 Street in front of Persatuan Lane
TWDS Puncak Sekuning Street

4 Conclusion

Based on the comparison of the results of the SCP model and the bi-objective benders decomposition model, there are differences in the optimal TWDS, where the bi-objective benders decomposition model can fulfil all demand points in the IB-I sub-district of Palembang City. Therefore, this study recommends the solution of the bi-objective benders decomposition model as a solution for the placement of optimal TWDS in the IB-I sub-district Palembang City. The bi-objective benders decomposition model resulted in 27 optimal TWDS can be seen in Table 11 and Figure 1.

References

[1] Alfian R, Phelia A.: Evaluasi efektifitas sistem pengangkutan dan pengelolaan sampah di TPA Sarimukti Kota Bandung. Vol. 02, No.01, pp. 16-23. Journal of Infrastructural in Civil Engineering, (2021)

[2] Puspita FM, Octarina S, Pane H.: Pengoptimalan lokasi tempat pembuangan sementara (TPS) menggunakan greedy reduction algorithm (GRA) di Kecamatan Kemuning. In: Prosiding Annual Research Seminar. pp. 267-274 (2018)

[3] Angresti DN, Djunaidy A, Mukhlason A.: Penerapan hiperheuristik berbasis metode simulated annealing untuk penyelesaian permasalahan optimasi lintas domain. Vol. 05, No. 01, pp. 33-40. Jurnal Nasional Teknologi dan Sistem Informasi, (2019)

[4] Bangun PBJ, Octarina S, Aniza R, Hanum L, Puspita FM, Supadi SS.: Set covering model using greedy heuristic algorithm to determine the temporary waste disposal sites in Palembang. Vol. 7, No. 1, pp. 98-105. Science and Technology Indonesia, (2022)

[5] Ahmadi-Javid A., Seyedi P., Syam S.S.: A survey of healthcare facility location. Vol. 79, pp. 223-263. Computers and Operations Research, (2017)

[6] Vaezihir A., Safari F., Tabarmayeh M, Khalafi AA.: Application of MCLP and LINGO methods to optimal design of groundwater monitoring network in an oil refinery site. Vol. 23, No. 4, pp. 812-830. Journal of Hydroinformatics, (2021)

[7] Cordeau JF, Furini F, Ljubić I.: Benders decomposition for very large scale partial set covering and maximal covering location problems. Vol. 275, No. 3, pp. 882-896. European Journal of Operational Research, (2019)
[8] Gomes MJ, De Oliveira EJ, De Castro MA, De Oliveira LW, Dias BH.: Two stage dual decomposition to solve long-term hydrothermal operation planning. Vol. 1. IEEE Manchester PowerTech, Powertech 2017, (2017)
[9] Lefever W, Touzout FA, Hadj-Hamou K, Aghezzaf EH.: Benders' decomposition for robust travel time-constrained inventory routing problem. Vol. 0, pp. 1-25. International Journal of Production Research, (2019)
[10] Hooshmand F, Mirarabrazi F, MirHassani SA.: Efficient Benders decomposition for distance-based critical node detection problem. Vol. 93. Omega (United Kingdom), (2020)
[11] Mardan E, Govindan K, Mina H, Gholami-Zanjani SM.: An accelerated benders decomposition algorithm for a bi-objective green closed loop supply chain network design problem. Vol. 235, pp. 1499-1514. Journal of Cleaner Production, (2019)
[12] Daskin MS, Maass KL.: Location analysis and network design. Lecture Notes in Logistics. Springer International Publishing. pp. 379-398 (2019)
[13] Kwon YS, Lee BK, Sohn SY.: Optimal location-allocation model for the installation of rooftop sports facilities in metropolitan areas. Vol. 20, No. 2, pp. 189-204. European Sport Management Quarterly, (2020)
[14] Firmansyah, Aprilia R.: Algoritma model penentuan lokasi fasilitas tunggal dengan program dinamik. Vol. 02, No. 1, pp. 31-39. Algoritm Jurnal Ilmu Komputer dan Informatika, (2018)
[15] Octarina S, Puspita FM, Supadi SS, Eliza NA.: Greedy reduction algorithm as the heuristic approach in determining the temporary waste disposal sites in Sukarami Sub-District, Palembang, Indonesia. Vol. 7, No. 4, pp. 469-480. Science and Technology Indonesia, (2022)
[16] Sundar S, Singh A.: A hybrid heuristic for the set covering problem. Vol. 12, No.3, pp. 345-365. Operational Research, (2012)
[17] Wolf GW.: Location covering models: history, applications and advancements (Advances in Spatial Science). Vol. 33, No. 11, pp. 2334-2335. International Journal of Geographical Information Science, (2019)
[18] Bergantiños G, Gómez-Rúa M, Llorca N, Pulido M, Sánchez-Soriano J.: Allocating costs in set covering problems. Vol. 284, No. 3, pp. 1074-1087. Europeran Journal of Operational Research, (2020)
[19] Octarina S, Puspita FM, Supadi SS.: Models and heuristic algorithms for solving discrete location problems of temporary disposal places in Palembang City. Vol. 52, No. 2, pp. 1-11. IAENG International Journal of Applied Mathematics, (2022)
[20] Octarina S, Puspita FM, Supadi SS, Afrilia R, Yuliza E.: Set covering location problem and p-median problem model in determining the optimal temporary waste disposal sites location in Seberang Ulu I sub-district Palembang. In: AIP Conference Proceedings. pp. 1–10 (2022)