Application Of Stepping Stone And Simplex Methods For Planting Optimization With Topsis As A Determining Criteria

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Abstract

Wonorejo Surabaya Nursery plays a strategic role in supporting urban green open spaces, which requires effective plant selection, resource allocation, and distribution planning. This study aims to develop an integrated decision-support model combining the TOPSIS method for multi-criteria plant selection, the Simplex method for resource allocation optimization, and the Stepping Stone method for distribution cost minimization. The data used in this study consist of four plant alternatives and five evaluation criteria obtained from field observations, operational records, and expert judgment at the Wonorejo Nursery. The results of the study show four priority plants, namely Bromeliad (0.47487), Gandasuli (0.46952), Spiderlili (0.45214), and Adam Hawa (0.59221). These results are subsequently used as the objective function in the Simplex model under constraints related to land, water, labor, working hours, and compost availability. The Z max value is 23.668 with the Adam Hawa decision variable value of 40. The findings demonstrate that the integrated model improves decision consistency, resource efficiency, and distribution cost effectiveness. the Stepping Stone method, resulting in an efficiency of 0.88%. This approach can serve as a practical framework for urban nursery management and sustainable green infrastructure planning.

Keywords: *Planting Optimization, Simplex, Stepping Stone, TOPSIS, Wonorejo Seed Garden*

1. Introduction

Urban green spaces are essential for sustainable city ecosystems, offering ecological, aesthetic, and health benefits[1], [2]. Kebun Bibit Wonorejo Surabaya plays a key role in supporting these efforts through the cultivation and distribution of plants for reforestation and urban greening[3], [4]. However, the nursery faces challenges in selecting the right plant species, allocating limited resources, and optimizing distribution to various city districts[5], [6], [7].

This study proposes an integrated optimization model combining the TOPSIS method for plant selection, the Simplex method for optimal resource allocation, and the Stepping Stone method for efficient distribution[8], [9], [10]. TOPSIS ranks plant alternatives based on multiple criteria such as growth rate, resilience, and ecological value[11]. Simplex is applied to determine the best allocation of land, water, labor, and compost[12], while Stepping Stone is used to minimize distribution costs[13].

In practical nursery management, decision-making does not occur in isolated stages. The selection of plant species based on multiple criteria directly affects resource utilization and distribution efficiency. A plant prioritized through multi-criteria decision-making may require specific land areas, water volumes, labor intensity, and logistics capacity. Therefore, separating plant selection from resource allocation and distribution optimization can lead to suboptimal or infeasible implementation. Integrating multi-criteria selection (TOPSIS), resource optimization (Simplex), and distribution optimization (Stepping Stone) ensures that strategic decisions at the selection stage are consistent with operational constraints and logistical realities. This integrated approach allows decision-makers to simultaneously consider ecological priorities, resource limitations, and transportation efficiency within a single coherent decision-support framework. Unlike previous studies that address these issues separately, this research integrates all three methods into a unified framework, offering a comprehensive decision support tool[14]. The approach is tested on Kebun Bibit Wonorejo and aims to improve operational efficiency, reduce costs, and enhance decision-making[15].

The integration of MCDM and optimization methods in a real-world nursery context contributes to both theory and practice, particularly in managing green infrastructure in urban environments[16].

2. Methods

(1). TOPSIS for Plant Prioritization

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is used to prioritize plants based on five main criteria: growth rate, water use efficiency, resistance to extreme weather, aesthetic value, and ecological function. Plant alternatives are assessed based on these criteria and then formed into an initial decision matrix. The weighting of each criterion is determined based on input from experts and the garden management[17].

The TOPSIS process consists of five main steps: normalizing the decision matrix, weighting the values, determining the positive and negative ideal solutions, calculating the Euclidean distance to these two solutions, and calculating the closeness coefficient of each alternative to the ideal solution. The higher the CCi value, the more likely the plant is to be prioritized for planting[18].

In the context of nurseries and green spaces, this method is relevant because it can evaluate plant species based on a combination of criteria such as environmental resilience, water efficiency, and aesthetic value. TOPSIS has been widely applied in data-driven decision-support systems for multi-criteria evaluation problems (Afzal et al., 2024), extending its flexibility in handling uncertainty and qualitative preferences. These studies demonstrate that TOPSIS is a robust, flexible, and efficient method for supporting complex, multi-criteria-based alternative selection processes, as applied in this study to determine the best plant priorities at the Wonorejo Nursery Garden.

(2). Simplex for Resource Allocation

The Simplex method is a cornerstone of linear programming, widely used in industrial and agricultural applications where multiple constraints interact with a single optimization objective. Originally developed by Dantzig (1947), it allows decision-makers to identify optimal solutions through systematic iteration over feasible solutions. In agriculture, it is often used to determine the best mix of crops or livestock given land, labor, and input constraints[19].

In nursery management, the Simplex method offers a powerful tool to model planting plans by translating real constraints (e.g., available land, water usage, manpower) into linear inequalities. The objective function—whether maximizing profit, yield, or plant priority—guides the algorithm toward the best combination of plants that can be cultivated within available resources. Tools like QM for Windows and Excel Solver are commonly used to apply Simplex in real-world problems due to their ability to handle multiple variables simultaneously [20].

Recent studies, such as those by Lozano Medina et al. (2024), highlight the importance of applying Simplex in multi-resource environments, especially where cost-effectiveness and sustainability intersect. In the context of this study, Simplex is used not to maximize financial profit but to prioritize planting based on ecological value and strategic needs, aligning with the broader environmental goals of urban forestry programs [15].

(3). Stepping Stone Method in Transportation Optimization

The Stepping Stone method is traditionally used to refine transportation plans in logistics and distribution networks. It works by evaluating empty cells in a transportation table to detect potential reductions in total cost. The method forms closed loops from unallocated routes and tests them for improvement by shifting allocations along the loop path[21].

In nursery operations, especially those distributing to multiple city districts like Kebun Bibit Wonorejo, transportation cost becomes a significant part of operational efficiency. Each plant species needs to be delivered to its designated planting area with minimal logistics expenditure. The Stepping Stone method ensures that all planting zones receive their required allocations without incurring excess distribution costs[22]. This method has proven efficient for application in structured distribution systems with fixed demand patterns but limited supply sources. Therefore, Stepping Stone becomes a strategic tool in supporting logistical efficiency and the smooth implementation of urban greening programs in a systematic and measurable manner.

Several studies—Biomej et al. (2024), Annisa & Mardiningsih (2021)—have successfully applied this method to real-world supply chain problems. These applications highlight the method's strength in iteratively improving upon basic feasible solutions, such as those generated by the Northwest Corner method, and identifying more cost-efficient alternatives. In this study, Stepping Stone ensures that the post-optimization planting plan is not only resource-efficient but also logistically viable[23].

3. Results and Discussion

Data Sources and Computational Tools

The data used in this study were obtained from operational records, direct field observations, and expert judgment at the Wonorejo Nursery Garden, Surabaya. The dataset includes four plant alternatives (Bromeliad, Gandasuli, Spiderlily, and Adam and Eve plants) and five evaluation criteria related to plant characteristics and operational requirements. Resource constraint data, such as land availability, water usage, labor capacity, working hours, and compost availability, were collected from daily operational reports of the nursery.

The TOPSIS calculations were performed manually to ensure transparency and traceability of each computational step. The Simplex optimization model was solved using QM for Windows version 5 software to validate manual calculations and obtain the optimal solution efficiently. The transportation optimization using the Stepping Stone method was carried out through iterative tabulation based on standard transportation problem procedures.

(1). Analisis TOPSIS

In this study, the calculation stages using the TOPSIS method are as follows:

1. Problem Identification
2. Decision Matrix Construction
3. Decision Matrix Normalization (Rij)
4. Determining the Positive Ideal Solution (A^+) and the Negative Ideal Solution (A^-)
5. Calculating the Distance to the Positive and Negative Ideal Solutions
6. Determining the Preference Value (V_i)

In a structured manner it will be discussed as below:

(a). Problem Identification

The plants to be evaluated are Bromeliads, Gandasuli, Spiderlilies, and Adam and Eve. The decision-making process considers five main criteria:

Table 1. Criteria Weight

Unit	Criteria	Code
C1	Plant Age	Month
C2	Water Consumption Requirements	Liters/Week
C3	Economic Value	Rp/ Bag Plants
C4	Ease of Maintenance	1-5
C5	Weather Adaptability	1-5

So the weight conversion value is as follows:

Table 2. Conversion of Criteria Weight Values

Alternative	C1	C2	C3	C4	C5
Bromelia	6	20	15.000	3	4
Gandasuli	4	30	12.000	4	5

Spiderlili	12	20	8.000	5	5
Adam Hawa	8	35	13.000	3	3

For each of the other alternatives, the normalized decision matrix can be calculated. The overall squared value is shown in the following table.

Table 3. Square Values

Alternative	C1	C2	C3	C4	C5
Bromelia	36	400	225	9	16
Gandasuli	16	900	144	16	25
Spiderlili	144	400	64	25	25
Adam Hawa	64	1225	169	9	9

(b). Summing the squares of each criterion
The resulting squares will then be added together, so that C1= 36+16+144+64 = 260
The square root for each criterion is: C1 = √260 = 16.12
The complete results of the square root for each criterion are as follows:

Table 4. Sum of Squares and Square Roots

	C1	C2	C3	C4	C5
Sum Squared	260	2925	602	59	75
Square root	16.12	54.08	24.54	7.68	8.66

(c). Decision Matrix Normalization ( ) Decision Matrix Normalization Table
The normalization matrix (Rij) is obtained by dividing each value in the decision matrix by the square root of the sum of all the values in its column, then multiplying it by the weight of each criterion.
R11 = X11 / square root (C1)
= 6 / 16.12 = 0.372104
R21 = X21 / square root (C1)
= 4 / 16.12 = 0.248069
The complete table will be presented as follows:

Table 5. Decision Matrix Normalization Table

0.372104	0.3698	0.611354	0.390567	0.46188
0.248069	0.5547	0.489083	0.520756	0.57735
0.744208	0.3698	0.326056	0.650945	0.57735
0.496139	0.64715	0.52984	0.390567	0.34641

(d). Weighted Normalized Decision Matrix

The Weighted Normalized Decision Matrix is a matrix derived from the weights of each criterion multiplied by the normalized decision matrix.

With the formula Vi = Wij * Rij

The weights for each criterion are as follows:

C1	C2	C3	C4	C5
0.15	0.25	0.3	0.15	0.15

So that

V11 = W1 * C11 = 0.372104 * 0.15 = 0.055816
V12 = W2 * C11 = 0.36980 * 0.25 = 0.09245
V13 = W3 * C11 = 0.611354 * 0.30 = 0.183406
V14 = W4 * C11 = 0.390567 * 0.15 = 0.058585
V15 = W5 * C11 = 0.46188 * 0.15 = 0.069282

The following is the complete Decision Normalization Matrix (Vij) as follows:

Table 6. Nilai Weighted Normalized Decision Matrix

Alternative	C1	C2	C3	C4	C5
Bromelia	0.05581 6	0.09245	0.18340 6	0.05858 5	0.06928 2
Gandasuli	0.03721	0.13867 5	0.14672 5	0.07811 3	0.08660 3
Spiderlili	0.11163 1	0.09245	0.09781 7	0.09764 2	0.08660 3
Adam Hawa	0.07442 1	0.16178 8	0.15895 2	0.05858 5	0.05196 2

(e). Determine the positive ideal solution and the negative ideal solution.

The positive ideal solution is the value closest to 1 and is considered the best condition, while the negative ideal solution is the value closest to 0 and reflects the worst condition.

A_1^+ = max {0.055816; 0.03721; 0.111631; 0.074421} = 0.111631 and so on up to A_5^+.

A_1^- = min {0.055816; 0.03721; 0.111631; 0.074421} = 0.03721 and so on up to A_5^-.

The following table presents the positive and negative ideal solution values for each criterion.

Table 7. Positive and Negative Ideal Solutions

	Maks Vj+	Maks Vj-
A 1	0.111631	0.03721
A 2	0.161788	0.09245
A 3	0.183406	0.09781 7
A 4	0.097642	0.05858 5
A 5	0.086603	0.05196 2

(f). Calculating Separation

Separation is the distance of an alternative from the ideal solution, either positive or negative, calculated using the Euclidean method. This method measures the distance between two points: the alternative value and the positive ideal solution (D^+) and the negative ideal solution (D^-).

$$S^+_{A1} = \sqrt{(0.055816 - 0.111631)^2 + (0.09245 - 0.161788)^2 +}$$
$$\sqrt{(0.183406 - 0.183406)^2 + (0.058585 - 0.097642)^2 +}$$
$$\sqrt{(0.069282 - 0.086603)^2}$$
$$= 0.098734496$$

$S^+_{A2} = 0.088314894$

$S^+_{A3} = 0.11015114$

$S^+_{A4} = 0.068615201$

The distance to the negative-ideal solution is defined as follows:

$$S^-_{A1} = \sqrt{(0.055816 - 0.03721)^2 + (0.09245 - 0.09245)^2 +}$$
$$\sqrt{(0.183406 - 0.097817)^2 + (0.058585 - 0.058585)^2 +}$$
$$\sqrt{(0.069282 - 0.051962)^2}$$
$$= 0.089284574$$

$S^-_{A2} = 0.07816735$

$S^-_{A3} = 0.090905914$

$S^-_{A4} = 0.099648629$

(g). Calculate the relative closeness to the ideal solution

The relative closeness to the ideal solution is the result of dividing the negative ideal solution by the sum of the positive and negative ideal solutions.

$$C^+_1 = \frac{0.089284574}{0.098734496 + 0.089284574} = 0.47486978$$

$$C^+_2 = \frac{0.07816735}{0.088314894 + 0.07816735} = 0.469523646$$

$$C^+_3 = \frac{0.090905914}{0.11015114 + 0.090905914} = 0.452139889$$

$$C^+_4 = \frac{0.099648629}{0.068615201 + 0.099648629} = 0.592216575$$

(h). Ranking

Order preferences from highest to lowest, or take the alternative with the highest score closest to 1. The resulting ranking of the best plant criteria is described in the table.

Table 8. Plant Criteria Ranking

Alternative	Results	Ranking
Bromelia (A1)	0.47486978	2
Gandasuli (A2)	0.469523646	3
Spiderlili (A3)	0.452139889	4
Adam Hawa (A4)	0.592216575	1

(i). Results

Based on the ranking of values, the A4 (Adam Hawa) plant, with the highest value 0.592216575, is the best alternative.

Sensitivity Analysis

A sensitivity analysis was conducted conceptually to observe the robustness of the TOPSIS ranking with respect to changes in criteria weights. Several hypothetical scenarios were considered by increasing and decreasing the weights of key criteria such as water consumption (C2) and ecological value (C5). The analysis indicates that Adam and Eve (A4) consistently remains the top-ranked alternative under moderate weight variations, particularly due to its balanced performance across multiple criteria. Minor changes in ranking among Bromeliad, Gandasuli, and Spiderlily may occur when aesthetic value or maintenance ease weights are significantly increased. This suggests that the proposed model is relatively robust and reliable, while still flexible enough to accommodate policy-driven priority adjustments.

(2). Calculation with the Simplex Method

Based on the theoretical foundation and the problems explained, a conceptual framework can be developed to achieve an optimal solution. A conceptual framework is a systematic pattern of thinking used as the basis for providing temporary answers to research problems. This study includes four variables:

X_1 : Bromelia Plants
X_2 : Gandasuli Plant
X_3 : Spiderlily Plant
X_4 : Adam and Hawa Plant

(a). Decision Variables

The decision variables in this study can be explained as follows: X_1: Bromeliad plants, X_2: Gandasuli plants, X_3: Spiderlili plants and X_4: Adam and Hawa plants.

(b). Constraint Function

The constraint function shows the limitations that a company has. The limitations in this study are:

1) Availability of soil mixture (S1)
2) Availability of water (S2)
3) Number of workers (S3)
4) Personnel working hours (S4)
5) Availability of compost mixture (S5)

(c). Objective Function

In this study, the goal of the nursery is the total weight of the preferred quality of the planting allocation as calculated using the TOPSIS method, namely: X_1: Bromeliad Plants, X_2: Gandasuli Plants, X_3: Spiderlilies and X_4: Adam and Eve Plants. The maximum number is expressed in the number of plants (Bag).

The following details the limitations and material requirements for the plant nursery process.

(1). Garden land available is a maximum of 500 m² with each individual's needs Bromelia 0.03 M²/ Bag, Gandasuli 0.07 M²/ Bag, Spiderlili 0.07 M²/ Bag, Adam Hawa 0.03 M²/ Bag

(2). Maximum water requirement 5,000 liters/day with each individual's needs Bromelia 15 liter/ Bag, Gandasuli 20 liter/ Bag, Spiderlili 18 liter/ Bag, Adam Hawa 12 liter/ Bag

(3). The maximum number of Task Force personnel is 15 with each individual's needs Bromelia 0.08 Person/ Bag, Gandasuli 0.10 Person/ Bag, Spiderlili 0.07 Person/ Bag, Adam Hawa 0.09 Person/ Bag

(4). Maximum working hours of the Task Force are 8 hours/day with each individual's needs Bromelia 0.25 hours/ Bag, Gandasuli 0.5 hours/ Bag, Spiderlili 0.3 hours/ Bag, Adam Hawa 0.2 hours/ Bag

(5). Compost is available for a maximum of 1,000 m² with each individual's needs Bromelia 0.06 hours/ Bag, Gandasuli 0.14 hours/ Bag, Spiderlili 0.14 hours/ Bag, Adam Hawa 0.10 hours/ Bag

The solution using the simplex method uses the following steps:

a. Determine the constraints of the problem.

Garden Land	$0{,}03\, X_1 + 0{,}07\, X_2 + 0{,}07\, X_3 + 0{,}03\, X_4 \leq 500$
Water	$15\, X_1 + 20\, X_2 + 18\, X_3 + 12\, X_4 \leq 5.000$
Labor	$0{,}08\, X_1 + 0{,}10\, X_2 + 0{,}07\, X_3 + 0{,}09\, X_4 \leq 15$

Working hours $0{,}25\ X_1 + 0{,}5\ X_2 + 0{,}3\ X_3 + 0{,}2\ X_4 \leq 8$

Compost mix $0{,}06\ X_1 + 0{,}14\ X_2 + 0{,}14\ X_3 + 0{,}10\ X_4 \leq 1.000$

b. Determine the objective function of the problem.

Max $Z = 0.47486978X_1 + 0.469523646X_2 + 0.452139889X_3 + 0.592216575\ X_4$

c. Change the inequality (≤) to (=) by adding a slack variable and a dummy variable for the inequality (≥) to the left side of the constraint.

$0{,}03\ X_1 + 0{,}07\ X_2 + 0{,}07\ X_3 + 0{,}03\ X_4 + S_1 = 500$

$15\ X_1 + 20\ X_2 + 18\ X_3 + 12\ X_4 + S_2 = 5.000$

$0{,}08\ X_1 + 0{,}10\ X_2 + 0{,}07\ X_3 + 0{,}09\ X_4 + S_3 = 15$

$0{,}25\ X_1 + 0{,}5\ X_2 + 0{,}3\ X_3 + 0{,}4\ X_4 + S_4 = 8$

$0{,}06\ X_1 + 0{,}14\ X_2 + 0{,}14\ X_3 + 0{,}10\ X_4 + S_5 = 1.000$

$Z = 0.47486978X_1 + 0.469523646X_2 + 0.452139889X_3 + 0.592216575\ X_4 + S_1 + S_2 + S_3 + S_4 + S_5$

$Z - 0.47486978X_1 - 0.469523646X_2 - 0.452139889X_3 - 0.592216575\ X_4 - S_1 - S_2 - S_3 - S_4 - S_5 = 0$

d. Create a simplex table by entering all the coefficients of the decision variables and the slack variables.

Table 9. Initial Simplex Table

VD	Z	X_1	X_2	X_3	X_4	S_1	S_2	S_3	S_4	S_5	NK
Z	1	-0.4749	-0.4695	-0.4521	-0.5922	0	0	0	0	0	0
S_1	0	0,03	0,07	0,07	0,03	1	0	0	0	0	500
S_2	0	15	20	18	12	0	1	0	0	0	5.000
S_3	0	0,08	0,10	0,07	0,09	0	0	1	0	0	15
S_4	0	0,25	0,5	0,3	0,4	0	0	0	1	0	8
S_5	0	0,06	0,14	0,14	0,10	0	0	0	0	1	1.000

e. Next, iterate to find the maximum Z value. The results of the iteration calculation will produce a new table.

Table 10. Basic Row Operations

VD	Z	X1	X2	X3	X4	S1	S2	S3	S4	S5	RHS	Ratio
Z	1	-0,4749	-0,4695	-0,4521	-0,5922	0	0	0	0	0	0	
S1	0	0,03	0,07	0,07	0,03	1	0	0	0	0	500	16.667
S2	0	15	20	18	12	0	1	0	0	0	5.000	416,67
S3	0	0,08	0,10	0,07	0,09	0	0	1	0	0	15	166,67
S4	0	0,25	0,5	0,3	0,2	0	0	0	1	0	8	40,00
S5	0	0,06	0,14	0,14	0,10	0	0	0	0	1	1.000	10.000

Table 11. Simplex Model Iteration 1

	VD	Z	X1	X2	X3	X4	S1	S2	S3	S4	S5	RHS
-0.5922	Z	1	0.26535	1.011	0.4362	0	0	0	0	2.961	0	23.688
0.03	S1	0	-0.0075	-0.005	0.025	0	1	0	0	-0.015	0	499.88
12	S2	0	0	-10	0	0	0	1	0	-60	0	4520
0.09	S3	0	-0.0325	-0.125	-0.065	0	0	0	1	-0.45	0	11.4

0.2	X4	0	1.25	2.5	1.5	1	0	0	0	5	0	40
0.10	S5	0	-0.065	-0.11	-0.01	0	0	0	0	-0.5	1	995.76

The results above show that the results are feasible, marked with a positive Z value, all with just 1 iteration. allows for larger planting quantities and meets all constraints without violating them with the resulting yield: Z =23.688 ; $X_1 = 0$; $X_2 = 0$; $X_3 = 0$; $X_4 = 40$, validation as follows:

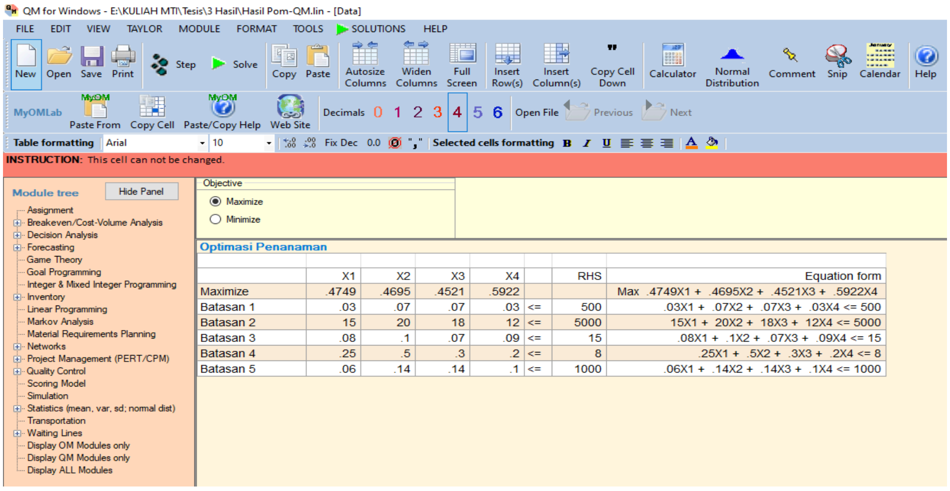
Max Z = $0.47486978X_1 + 0.469523646X_2 + 0.452139889X_3 + 0.592216575\,X_4$

$0.47486978\,(0) + 0.469523646\,(0) + 0.452139889\,(0) + 0.592216575\,(40)$

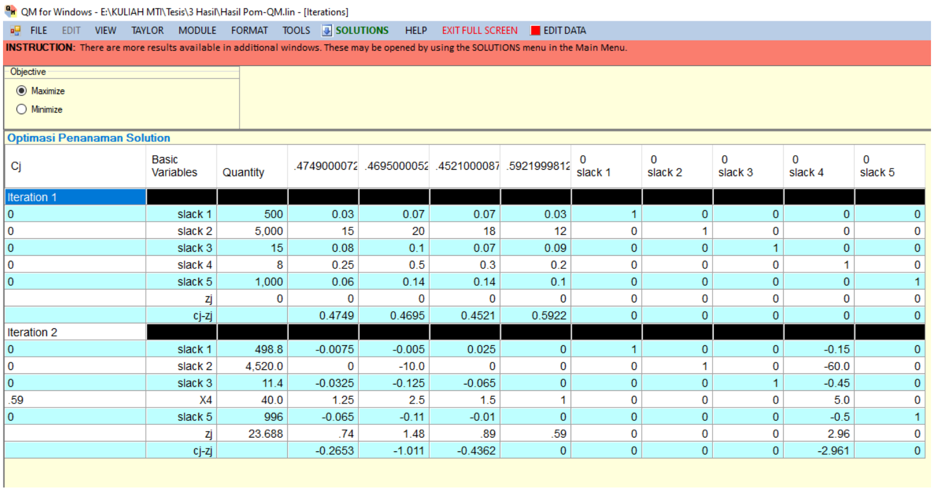
= **23.668**

Simplex Calculations Using QM for Windows V5 Software

The following shows the linear programming menu of the QM for Windows V5 software, starting from the initial data input to obtaining optimal results.



Picture 1. Initial Data Input Display (source)



Cj	Basic Variables	Quantity	.4749000072	.4695000052	.4521000087	.5921999812	0 slack 1	0 slack 2	0 slack 3	0 slack 4	0 slack 5
Iteration 1											
0	slack 1	500	0.03	0.07	0.07	0.03	1	0	0	0	0
0	slack 2	5,000	15	20	18	12	0	1	0	0	0
0	slack 3	15	0.08	0.1	0.07	0.09	0	0	1	0	0
0	slack 4	8	0.25	0.5	0.3	0.2	0	0	0	1	0
0	slack 5	1,000	0.06	0.14	0.14	0.1	0	0	0	0	1
	zj	0	0	0	0	0	0	0	0	0	0
	cj-zj		0.4749	0.4695	0.4521	0.5922	0	0	0	0	0
Iteration 2											
0	slack 1	498.8	-0.0075	-0.005	0.025	0	1	0	0	-0.15	0
0	slack 2	4,520.0	0	-10.0	0	0	0	1	0	-60.0	0
0	slack 3	11.4	-0.0325	-0.125	-0.065	0	0	0	1	-0.45	0
.59	X4	40.0	1.25	2.5	1.5	1	0	0	0	5.0	0
0	slack 5	996	-0.065	-0.11	-0.01	0	0	0	0	-0.5	1
	zj	23.688	.74	1.48	.89	.59	0	0	0	2.96	0
	cj-zj		-0.2653	-1.011	-0.4362	0	0	0	0	-2.961	0

Picture 2. QM for Windows V5 iteration and optimal solution

(3). Transportation with the Stepping Stone Method

The distribution of 1,200 units of Adam Hawa plant seedlings per month using the simplex method requires an efficient delivery system to seven service areas. To support this activity, the Surabaya City

Environmental Agency (DLH) operates three distribution fleets, each with a capacity of 500 bags, 300 bags, and 400 bags. Each district has varying planting needs, ranging from 190 to 200 bags of shrubs. The Stepping Stone method is applied to determine the most efficient distribution route by calculating shipping costs from each fleet to each district.

(a). Organize the data into a transportation table

Table 12. Distribution Costs and Demand per Location

To/From	(P)	(T1)	(T2)	(S)	(U)	(B1)	(B1)	Capacity
A1	280	150	210	380	550	650	750	500
A2	230	120	170	330	520	620	680	300
A3	250	130	190	350	530	610	720	400
Demand	280	120	140	210	160	200	90	1.200

(b). The initial solution uses the Northwest Corner Method (NWC).

Table 13. Initial Loading

To/From	(P)	(T1)	(T2)	(S)	(U)	(B1)	(B1)	Capacity
A1	280 280	150 120	210 100	38	55	65	75	500
A2	23	12	170 40	330 210	540 50	62	68	300
A3	25	13	19	35	530 110	610 200	720 90	400
Demand	280	120	140	210	160	200	90	1,200

Z = 280 (280) + 120 (150) +100 (210) + 40 (170) + 210 (330) +
50 (540) + 110 (530) + 200 (610) + 90 (720)
= 465,600

Next is a further evaluation using the Stepping Stone method which shows that there is no negative opportunity cost value in the empty cells, which indicates that the NWC solution is optimal.

Table 14. Initial Solution Results for Northwest Corner (NWC)

To/From	(P)	(T1)	(T2)	(S)	(U)	(B1)	(B1)	Capacity
A1	280 280	150 120	210 100	380	550	650	750	500
A2	230	120	170 40	330 210	540 50	620	680	300
A3	250	130	190	350	530 110	610 200	720 90	400
Demand	280	120	140	210	160	200	90	1,200

The following are non-basic variables that will determine the trajectory according to table

A1-S : C14-C13+C23-C24 = 10
A1-U : C15-C13+C23-C25 = -30
A1-B1 : C16-C13+C23-C25+C35-C36 = 150
A1-B2 : C17-C13+C23-C25+C35-C37 = -20
A2-P : C21-C11+C13-C23 = -10
A2-T1 : C22-C23+C13-C12 = 10

A2-B1 : C26-C25+C35-C36 = 0
A2-B2 : C27-C25+C35-C37 = -50 (Biggest Negative)
A3-P : C31-C11+C13-C23+C25-C35 = 20
A3-T1 : C32-C12+C13-C23+C25-C35 = 30
A3-T2 : C33-C23+C25-C35 = 30
A3-S : C34-C24+C25-C35 = 30

Because the optimization test using the Stepping Stone method by determining the Stepping Stone path and cost changes for each non-basic variable still has negative values (the largest cost reduction), and the one with the largest negative value is selected, it is continued with the 2nd iteration.

Table 15. Iteration 2

To/From	(P)	(T1)	(T2)	(S)	(U)	(B1)	(B2)	Capacity
A1	280 280	150 120	210 100	380	550	650	750	500
A2	230	120	170 40	330 210	540	620	680 50	300
A3	250	130	190	350	530 160	610 200	720 40	400
Demand	280	120	140	210	160	200	90	1,200

The same as the previous step will be repeated by calculating the value of each empty cell.
A1-S : C14-C13+C23-C24 = 10
A1-U : C15-C13+C23-C27+C37-C35 = 20
A1-B1 : C16-C13+C23-C27+C37-C36 = 40
A1-B2 : C17-C13+C23-C27 = 30
A2-P : C21-C11+C13-C23 = -10
A2-T1 : C22-C12+C13-C22 = 10
A2-B1 : C26-C27+C37-C36 = 50
A2-U : C25-C35+C37-C27 = 50
A3-P : C31-C11+C13-C23+C27-C37 = -30 (Biggest Negative)
A3-T1 : C32-C12+C13-C23+C27-C37 = -20
A3-T2 : C33-C23+C27-C37 =-20
A3-S : C34-C24+C27-C37 = -20

Table 16. Iteration 3

To/From	(P)	(T1)	(T2)	(S)	(U)	(B1)	(B2)	Capacity
A1	280 240	150 120	210 140	380	550	650	750	500
A2	230	120	170	330 210	540	620	680 90	300
A3	250 40	130	190	350	530 160	610 200	720	400
Demand	280	120	140	210	160	200	90	1,200

A1-S : C14 = 380
A1-U : C15-C35+C31-C11 = -10 (Biggest Negative)
A1-B1 : C16-C11+C31-C36 = 10
A1-B2 : C17 = 750
A2-P : C21 = 230
A2-T1 : C22 = 120
A2-T2 : C23 = 170
A2-U : C25 = 540
A2-B1 : C26 = 620
A3-T1 : C32-C31+C11-C12 = 10

A3-T2 : C33-C31+C11-C13 = 10
A3-S : C37 = 720

Table 17. Iteration 4

To/From	(P)	(T1)	(T2)	(S)	(U)	(B1)	(B2)	Capacity
A1	280 200	150 120	210 140	380	550 40	650	750	500
A2	230	120	170	330 210	540	620	680 90	300
A3	250 80	130	190	350	530 120	610 200	720	400
Demand	280	120	140	210	160	200	90	1,200

Next calculate the value of empty cells:
A1-S : C14 = 380
A1-B1 : C16-C15+C35-C36 = 20
A1-B2 : C17 = 750
A2-P : C21 = 230
A2-T1 : C22 = 120
A2-T2 : C23 = 170
A2-U : C25-C15+C11-C31+C35 = 550
A2-B1 : C26 = 620
A3-T1 : C32-C31+C11-C12 = 10
A3-T2 : C33-C31+C11-C13 = 10
A3-S : C34 = 350
A3-B2 : C37 = 720

The optimization test on the fourth iteration using the Stepping Stone method by determining the Stepping Stone path and cost changes for each non-basic variable turns out to have no negative values (the largest cost reduction), so the solution on the fourth iteration solution is optimal with distribution costs. Z = 200 (280) + 120 (150) +140 (210) + 40 (550) + 210 (330) +90 (680) + 80 (250) + 120 (530) + 200 (610) = 461,500

Evaluation and optimization were conducted using the Stepping Stone method. Through four iterations, empty cells in the distribution table were tested to determine whether there was a stepping stone path that could reduce total distribution costs. After these iterations, a more efficient allocation combination was identified, reducing total distribution costs to Rp 461,500.-

(4) Comparison with Previous Studies

Previous studies on urban greening and nursery optimization generally focus on a single aspect of decision-making. Multi-criteria decision-making methods such as TOPSIS have been widely used to rank alternatives based on ecological or technical criteria [5], [11], [18]. Separately, linear programming techniques such as the Simplex method have been applied to optimize resource allocation under multiple constraints [12], [20]. Likewise, transportation optimization using the Stepping Stone method has been implemented to reduce distribution costs in logistics systems [6], [22], [23]. However, these approaches are typically applied independently.

This study differs from previous research by integrating TOPSIS, Simplex, and Stepping Stone methods into a single, sequential decision-support model. The TOPSIS results directly inform the objective function of the Simplex model, ensuring that resource allocation aligns with plant priority rankings. Furthermore, the optimized planting plan becomes the input for transportation optimization using the Stepping Stone method. To the authors' knowledge, such an end-to-end integrated model for nursery management and urban planting optimization has not been comprehensively addressed in prior studies. This integration provides a more realistic and implementable solution for urban green infrastructure planning.

4. Conclusion

This study demonstrates that the integration of TOPSIS, Simplex, and Stepping Stone methods provides a coherent and practical decision-support model for nursery management and urban planting optimization. Rather than treating plant selection, resource allocation, and distribution as separate problems, the proposed framework ensures consistency between strategic priorities and operational feasibility.

The integrated model developed in this study can be extended to other municipal nurseries or adapted for broader urban forestry planning contexts, where decision-makers face similar challenges related to multi-criteria evaluation, limited resources, and complex distribution networks. Future research may expand the model by incorporating dynamic demand, uncertainty analysis, or environmental impact indicators to further enhance its applicability.

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