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OPTIMIZATION OF RED CHILI DELIVERY ROUTES FROM PRODUCTION CENTERS TO MARKET TO MINIMIZE DISTANCES WITH THE MODIFIED DISTRIBUTION (MODI) METHOD

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Abstract. The distribution of red chili from the production center to the market faces the problem of determining efficient routes due to differences in distance, supply capacity, and market needs. This study aims to form a transportation model and determine a delivery pattern of red chili that can meet all market demand while minimizing the total distribution distance as the objective function. The research data came from Tanjung Kubah, Sukaramai, and Aras villages as well as four destination markets, namely Indrapura, Air Putih, Simpang Dolok, and Pagurawan. The approach used was a transportation model with the North West Corner (NWC) method to obtain an initial solution and the Modified Distribution Method (MODI) to test and improve optimality. The total supply and total demand was 20,000 kg each so that the model was in a balanced condition. The calculation results in the thesis show that the initial NWC solution has a value of 222,000, while the results of the first iteration of MODI are stated to be 214,000, with a saving of 8,000. All opportunity cost values in the final result are declared positive or equal to zero, so the solution is considered optimal. The optimal allocation pattern reported is Tanjung Kubah to Indrapura 6,000 kg, Tanjung Kubah to Air Putih 2,000 kg, Sukaramai to Air Putih 3,000 kg, Sukaramai to Simpang Dolok 4,000 kg, and Aras to Pagurawan 5,000 kg. These findings show that MODI can be used as a data-driven approach to help with red chili distribution planning.

Keywords: **Transportation Model; North West Corner; Modified Distribution (MODI); Distribution Optimization; Red Chili**

A. Introduction

Red chili peppers are a horticultural commodity that has a supply chain and distribution pattern that involves various actors, ranging from producers to consumers. Long distribution structures can increase costs and cause inefficiencies if delivery allocations are not systematically planned (Wigati et al., 2020; Ningsih et al., 2020). Research on the red chili supply chain in Indonesia also shows that distribution efficiency is related to coordination between sectors, supply availability, and distribution mechanisms. However, most of these studies emphasize general supply-chain coordination and cost efficiency, and have not specifically addressed the optimization of shipment allocation from several production centers to several markets using a transportation model that combines the North West Corner (NWC) and Modified Distribution (MODI) methods with distribution distance as the objective function. This gap is what the present study seeks to address (Hayuningtyas et al., 2020; Ningsih et al., 2020).

Poorly planned distribution can lead to longer transportation distances and inefficient use of distribution resources and waste of resources. In the context of distribution optimization, transportation models can be used to determine the allocation of goods from multiple sources to multiple destinations by considering supply capacity and destination needs (Syam et al., 2021; Arofah & Gesthantiara, 2021; Kartika et al., 2020). A number of studies have shown that transportation approaches can result in more efficient distribution patterns than initial patterns (Ranti et al., 2022; Syahruddin et al., 2023; Sofiati, 2020).

The transportation model is one of the approaches in operations research to determine the allocation of shipments from a number of sources to a number of destinations. The North West Corner (NWC) method produces an initial feasible solution, while the Modified Distribution (MODI) method evaluates the optimality of that solution and improves it until the optimal allocation is obtained. and this combined NWC-MODI procedure (Syam et al., 2021; Arofah & Gesthantiara, 2021; Syahruddin et al., 2023; Harahap et al., 2023). The application of NWC and MODI has also been used in the distribution of water, medical device products, LPG, and other commodities (Syam et al., 2021; Ranti et al., 2022; Syahruddin et al., 2023; Kartika et al., 2020).

The aim of the study was to establish a distribution model of red chili and determine the optimal delivery pattern from the production center to the destination market by considering the distribution distance. This approach is expected to provide a more structured alternative to data-driven distribution planning. The use of transportation models to support distribution decisions can also be strengthened with the support of information systems and digital mapping in the logistics environment (Hao & Dai, 2021; Hao & Dai, 2021).

B. Research Method

The research uses quantitative data sourced from observations and documentation in the area of Batu Bara Regency, Air Putih District, Indrapura City, Tanjung Kubah Village, Mawar Hamlet. The research time starts from the submission of the title on June 16, 2025 until the research is completed. The data analyzed includes delivery distance, transportation costs, market demand, and supply capacity. These variables are the main components in the formulation of the transportation model, namely the sum
ber, destination, supply capacity, destination needs, and shipping parameters (Syam et al., 2021; Arofah & Gesthantiara, 2021; Kartika et al., 2020).

1. Initial Methods

The *NorthWest Corner* (NWC) method is one of the easiest transportation methods to do, but the results are not necessarily optimal. In this NWC method, the source and destination location are sorted from left to right and from top to bottom in a matrix data map. The method of calculating transportation costs using the NWC method as the name implies, starts from the top left side, then moves to the left or down according to the production capacity of the source (*supply*) and or the destination demand (*demand*). The rules that apply to this NWC method are as follows:

a. Allocating the initial value of the cell is set to the cell at the top left of the table. The value of the initial cell depends on the supply and demand constraints for the cell. The steps in determining the initial solution of this method are as follows: Allocate as many values as possible to cell x_{11} by taking into account the supply and demand constraints.
example: x_{11} = mind {S1, d1}
b. Allocate as many values as possible to the cells adjacent to cell X11. example: if S1 > d1 then x11 + x12 = S1, x12 =... S1 > d1 then x11 + x21 – d1, x21 – ...
3. Repeat step 2 until all constraints are met.

The transportation method is a method of development of a simple method that is specialized in calculating the problems of shipping an item from one place to another. The transportation method is centered on the selection of a route in the distribution network of a product between the industrial center and the distribution of the warehouse or between the distribution of the warehouse and the local distribution. In the use of the transportation method, management determines the route with the level of expenditure control to be more optimal in order to minimize distribution costs so as to obtain greater revenue or minimize the time used.

Thus, the formulation or general formula to solve the transportation problem is as follows:

$$Min: C = \sum_{j=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$$

Subject to:

$$\sum_{i=1}^{n} X_{ij} = a_i \ (i = 1,2,3, \dots, m) \ a_i \geq 0$$

$$\sum_{j=1}^{m} X_{ij} = b_j (j = 1,2,3, \dots, n) b_j \geq 0$$

$$X\_\{ij\} \ \geq 0, \ \forall i, j\}$$

2. Resources and Procedures

Procedurally, the research was carried out through the stages of problem identification, data collection, preparation of transportation models, determination of initial solutions using the North West Corner Rule (NWC), and testing and optimization of solutions using the Modified Distribution Method (MODI). These stages are in accordance with the characteristics of transportation problems which aim to determine the allocation of a number of sources to a number of destinations by considering the supply capacity and needs of the destination (Syam et al., 2021; Arofah & Gesthantiara, 2021; Syahruddin et al., 2023). Data were obtained through observation and documentation of the distribution process of red chili from the production center to the destination market. The distribution source consists of three production centers, namely Tanjung Kubah, Sukaramai, and Aras, while the distribution destination consists of four markets, namely Indrapura, Air Putih, Simpang Dolok, and Pagurawan.

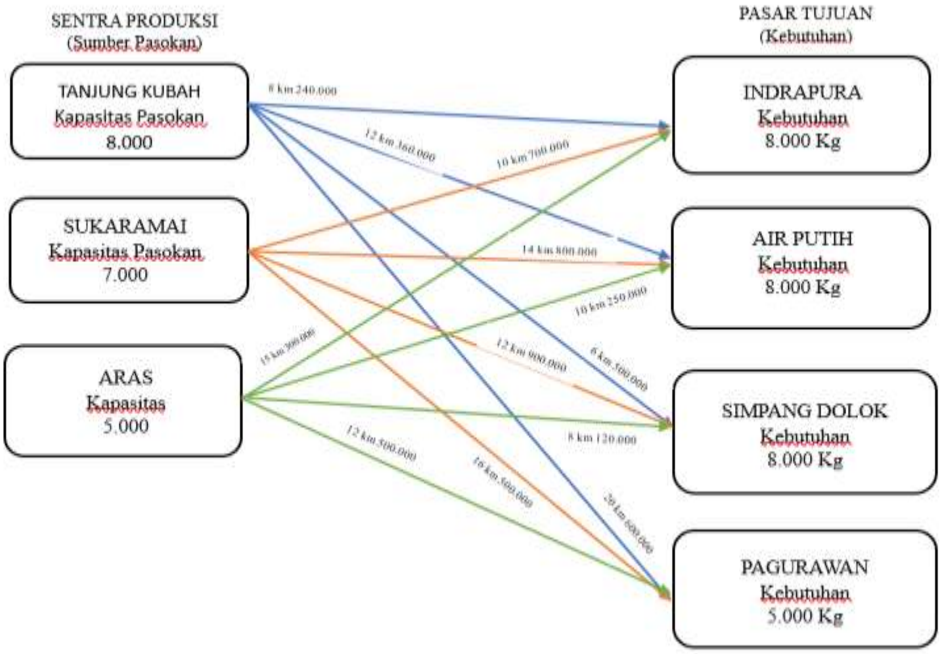

Figure 1. Red Chili Delivery Distribution Map

3. Data Processing

The data that has been collected is processed in the form of a transportation matrix that connects three sources of supply to four market destinations. The data on distance, shipping costs, demand, and supply capacity are compiled so that each matrix cell represents an alternative delivery from one production center to one destination market. The total supply capacity and total demand are 20,000 kg each so that the transportation model is in a balanced condition. Decision variable x_{ij} Declares the amount of red chili peppers sent from source I to destination J. The formulation follows the general structure of the transport model used in distribution optimization research (Syam et al., 2021; Arofah & Gesthantiara, 2021; Wang, 2021).

$$\min Z = \sum_i \sum_j c_{ij} x_{ij}$$

Subject to

$$\sum_j x_{ij} = s_i, \qquad \forall i$$

$$\sum_i x_{ij} = d_j, \qquad \forall j$$

$$x_{ij} \geq 0, \qquad \forall i, j$$

with supply capacity constraints and the fulfillment of destination demand. Settlement is carried out with NWC to obtain a feasible initial solution. Furthermore, MODI is used by calculating the potential value of the U-line$_i$ and column V_j Through the C relationship $ij = U_i + V_j$ on the base cell, then calculate the opportunity cost on the empty cell. If the whole value *opportunity cost* meeting the optimality criteria, the solution is declared optimal.

4. Interpretation

The interpretation of the results is carried out by connecting the optimal allocation pattern with the supply and demand conditions in the distribution network being studied. The solution is considered to meet the research objectives if all market demand can be met, all supply capacity can be allocated, and the MODI test results show optimal conditions. This approach is in line with the use of the transportation model in operational research, which is to obtain a feasible and optimal distribution pattern for the minimum size.

Based on the results of the thesis, the MODI solution produced a total distance of 214,000 km-units compared to the initial NWC solution of 222,000 km-units, resulting in savings of 8,000 km-units. The optimal allocation pattern reported was Tanjung Kubah–Indrapura of 6,000 kg, Tanjung Kubah–Air Putih of 2,000 kg, Sukaramai–Air Putih of 3,000 kg, Sukaramai–Simpang Dolok of 4,000 kg, and Aras–Pagurawan of 5,000 kg (Syam et al., 2021).

C. Result and Analysis

1. Descriptive Analysis

Descriptive analysis aims to provide an overview of the distribution of values from each variable used.

Table 1. All Data X1, X2, X3, and X4

No.	Production Centers	Destination Markets	*X1* Distance (km)	*X2* Shipping Cost (Rp)	*X3* Market Demand (kg)	*X4* Supply Capacity (kg)
1	Tanjung Kubah	Indrapura	8	240.000	6.000	8.000
		Air Putih	12	360.000	5.000	8.000
		Simpang Dolok	6	500.000	4.000	8.000
		Pagurawan	20	600.000	5.000	8.000
2	Sukaramai	Indrapura	10	700.000	6.000	7.000
		Air Putih	14	800.000	5.000	7.000
		Simpang Dolok	12	900.000	4.000	7.000
		Pagurawan	16	500.000	5.000	7.000
3	Aras	Indrapura	15	300.000	6.000	5.000
		Air Putih	10	250.000	5.000	5.000
		Simpang Dolok	8	120.000	4.000	5.000
		Pagurawan	12	500.000	5.000	5.000

Source: Tanjung Kubah Village, Sukaramai, Aras

Based on Table 1, the research data consisted of data on delivery distance, shipping costs, supply capacity, and market demand which were used as the basis for the preparation of the transportation model. The data was then used to determine the optimal solution for the distribution of red chilies. Distance was used as the main parameter of optimization, while transportation costs became supporting information. Demand and supply capacity became obstacles in the model.

Table 2. Distance Data, Demand, and Supply Capacity

Yes	Sentra	Indrapura	Air Putih	Simpang Dolok	Pagurawan	Supply (kg)
1	Tanjung Kubah	8	12	6	20	8.000
2	Sukaramai	10	14	12	16	7.000
3	Aras	15	10	8	12	5.000
4	Demand (kg)	6.000	5.000	4.000	5.000	20.000

Table 2 shows that the total supply capacity of 20,000 kg is equal to the total market demand of 20,000 kg. The distance between centers and markets varies, so the allocation of shipments needs to be determined systematically. The data is in accordance with the table of distance, demand, and supply capacity in the thesis.

Supply capacity data is the amount of red chili production available at each production center and ready to be distributed to the destination market. This variable functions as a supply constraint in the transportation model so that the number of shipments from each production center should not exceed the available capacity. The balance between total supply capacity and total market demand is an important requirement in the formation of the transportation model used in this study.

The data obtained from Table 2 will be made a mathematical model with the objective functions and constraint functions of linear program formulation as follows:

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}\, x_{ij}$$

$$Z = \sum_{i=1}^{3} \sum_{j=1}^{4} c_{ij} \, x_{ij}$$

$$Z = c_{11}x_{11} + c_{12}x_{12} + c_{13}x_{13} + c_{14}x_{14} + c_{21}x_{21} + c_{22}x_{22} + c_{23}x_{23} + c_{24}x_{24} + c_{31}x_{31} + c_{32}x_{32} + c_{33}x_{33} + c_{34}x_{34}$$

$$Z = 240.000x_{11} + 360.000x_{12} + 500.000x_{13} + 600.000x_{14} + 700.000x_{21} + 800.000x_{22} + 900.000x_{23} + 500.000x_{24} + 300.000x_{31} + 250.000x_{32} + 120.000x_{33} + 500.000x_{34}$$

Supply Constraints

$$\sum_{j=1}^{4} x_{ij} \leq s_i; i = 1,2,3$$

$$x_{11} + x_{12} + x_{13} + x_{14} \leq 8.000$$
$$x_{21} + x_{22} + x_{23} + x_{24} \leq 7.000$$
$$x_{31} + x_{32} + x_{33} + x_{34} \leq 5.000$$

Demand Constraints

$$\sum_{i=1}^{3} x_{ij} \geq d_i; \; j \; = \; 1,2,3,4$$

$$x_{11} + x_{21} + x_{31} \geq 6.000$$
$$x_{12} + x_{22} + x_{32} \geq 4.000$$
$$x_{13} + x_{23} + x_{33} \geq 5.000$$
$$x_{14} + x_{24} + x_{34} \geq 5.000$$
$$x_{ij} \geq 0, \forall i, j$$

z = Total distribution cost
c_{ij} = Cost of transportation of the unity of goods from source i to destination j
x_{ij} = Quantity of goods distributed from source i to destination j
s_i = Quantity of goods supplied from source i
DJ = the number of items requested by the purpose j

Table 3. Transportation Costs Used as Supporting Information

No.	Sentra	Indrapura	Air Putih	Simpang Dolok	Pagurawan
1	Tanjung Kubah	240.000	360.000	500.000	600.000
2	Sukaramai	700.000	800.000	900.000	500.000
3	Aras	300.000	250.000	120.000	500.000

The transportation costs in Table 3 are used as supporting information regarding the actual distribution conditions. Although the research focuses on minimizing distance, transportation costs remain relevant as an indicator of distribution operational conditions. Previous studies have shown that transportation models can be used to evaluate and minimize distribution costs from multiple sources to multiple destinations (Arofah & Gesthantiara, 2021; Kartika et al., 2020; Sofiati, 2020).

The initial solution of NWC was obtained by allocating shipments starting from the upper left cell of the transportation table and moving according to the rest of supply and demand. The NWC procedure is one of the simple ways to obtain a feasible initial solution to transportation problems before optimality testing is carried out (Syam et al., 2021; Arofah & Gesthantiara, 2021; Ranti et al., 2022). The results of the initial allocation are 6,000 kg from Tanjung Kubah to Indrapura, 2,000 kg from Tanjung Kubah to Air Putih, 3,000 kg from Sukaramai to Air Putih, 4,000 kg from Sukaramai to Simpang Dolok, and 5,000 kg from Aras to Pagurawan.

Table 4. Initial Solutions With All Ui and Vj

From \ to	Indrapura (A)		Air Putih (B)		Simpang Dolok (C)		Pagurawan(D)		Supply (Supply)
Tanjung Kubah (1)	6.000	240.000	2.000	360.000		500.000		600.000	8.000
Sukaramai (2)		700.000	3.000	800.000	4.000	900.000		500.000	7.000
Aras (3)		300.000		250.000		120.000	5.000	500.000	5.000
Demand (Request)		6.000		5.000		4.000		5.000	20.000

Source: Data Processing Results 2025

Based on Table 4, the potential values of rows (Ui) and columns (Vj) are determined as the first step in the implementation of the MODI method. These values are used to calculate the value of the improvement index (*opportunity cost*) on each empty cell so that it can be known whether the initial solution is optimal or still needs improvement. The total total initial distribution distance is:

$$Z = \sum c_{ij} x_{ij}$$

$$Z = (6.000 \times 8) + (2.000 \times 12) + (3.000 \times 14) + (4.000 \times 12) + (5.000 \times 12)$$
$$= 48.000 + 24.000 + 42.000 + 48.000 + 60.000$$
$$= 222.000\ km - unit$$

Table 5. Results of Iteration 1 NWC Calculation

Sentra	Indrapura	Air Putih	Simpang Dolok	Pagurawan	Supply
Tanjung Kubah	6.000	-	2.000	-	8.000
Sukaramai	-	5.000	2.000	-	7.000
Aras	-	-	-	5.000	5.000

Source: Data Processing Results 2025

$$Z = \sum c_{ij} x_{ij}$$

$$Z = (6.000 \times 8) + (2.000 \times 6) + (5.000 \times 14) + (2.000 \times 12) + (5.000 \times 12)$$
$$= 48.000 + 12.000 + 70.000 + 24.000 + 60.000$$
$$= 214.000\ km - unit$$

Next, the following formula is used to evaluate empty cells to determine the opportunity cost of a nonbasic variable. $Iij = ui + vj - cij$ where Iij equals the cost increase or cost decrease that might occur by allocating to the cell, for all empty cells in Table 6, the formula returns the following values. With the following formula:

$$\Delta_{ij} = C_{ij} - (U_i + V_j)$$

Description:
C_{ij} = Original cost/distance on the transport table
U_i = potential value of the line
V_j = potential value of the column
By Calculation:
$\Delta 13$ = Row 1 = Tanjung Kubah
Column 3 = Simpang Dolok

$$C13 = 18$$
$$U1 = 0$$
$$V3 = 10$$
$$\begin{aligned} \Delta 13 &= 6 - (0+10) \\ &= 6 - 10 \\ &= -4 \\ \Delta 14 &= 20 - (0+14) \\ &= 20 - 14 \\ &= 6 \end{aligned}$$

And so on until the 14th

Table 6. MODI optimality test results

No.	Empty cells	Calculation	Δ_{ij}
1	X13	$6-(0+10)$	4
2	X14	$20-(0+14)$	6
3	X21	$10-(2+8)$	0
4	X24	$16-(2+14)$	0
5	X31	$15-(-2+8)$	9
6	X32	$10-(-2+12)$	0

All values of Δij are positive or equal to zero. Based on the optimality criteria of the MODI method, if the total opportunity cost value (Δ_{ij}) is ≥ 0, the solution obtained is optimal and does not require further allocation improvement. Thus, the optimal distribution pattern of red chili peppers is:

1) Tanjung Kubah → Indrapura of 6,000 kg.
2) Tanjung Kubah → Air Putih of 2,000 kg.
3) Sukaramai → Air Putih of 3,000 kg.
4) Sukaramai → Simpang Dolok of 4,000 kg.
5) Aras → Pagurawan of 5,000 kg.

The optimal distribution pattern reported in the thesis consists of five routes, namely Tanjung Kubah to Indrapura of 6,000 kg, Tanjung Kubah to Air Putih of 2,000 kg, Sukaramai to Air Putih of 3,000 kg, Sukaramai to Simpang Dolok of 4,000 kg, and Aras to Pagurawan of 5,000 kg. This pattern meets all market demand and all supply capacity. This result is consistent with previous research which shows that transportation methods can produce allocation patterns that meet the needs of destinations while improving distribution efficiency (Arofah & Gesthantiara, 2021; Syahruddin et al., 2023; Kartika et al., 2020).

Table 7. Comparison of NWC and MODI Solutions

No.	Method	Z Value	Savings
1	NWC	222.000	–
2	Iteration MODE 1	214.000	8.000

Based on Table 7, the thesis reported the value of the initial solution of NWC of 222,000 and the value of the first iteration of MODI of 214,000, so the reported savings were 8,000. Thus, the results of the study showed an improvement in the objective value after the optimization process. These findings are in line with the distribution study applying NWC/MODI, which showed that the initial solution can be improved through MODI optimality testing (Syam et al., 2021; Syahruddin et al., 2023; Harahap et al., 2023).

2. Discussion

Before optimization, red chili was distributed from three production centers, namely Tanjung Kubah, Sukaramai, and Aras, to four destination markets, namely Indrapura, Air Putih, Simpang Dolok, and Pagurawan. The total available supply was 20,000 kg and the total market demand was also 20,000 kg, so the transportation model was in a balanced condition. In the initial shipping pattern obtained from the North West Corner method, allocation was carried out sequentially starting from the upper-left cell of the transportation table without considering the shortest distance, so that several markets were supplied by production centers that were relatively far away. This condition produced a total distribution distance of 222,000 distance-units, which became the initial reference before the optimization process.

The improvement in the allocation pattern was carried out through the MODI method by evaluating the opportunity cost of each empty cell. When an empty cell had a negative opportunity cost, the allocation was redirected to that cell because it could lower the total distribution distance. For example, part of the shipment that was initially allocated to a market with a longer distance was reduced and reassigned to a market that produced a lower total distance, while still respecting the supply capacity and demand constraints. Through this iteration, the total distribution distance decreased from 222,000 distance-units in the initial NWC solution to 214,000 distance-units, a saving of 8,000 distance-units.

The optimal distribution pattern consists of five shipping routes. Tanjung Kubah supplies Indrapura with 6,000 kg and Air Putih with 2,000 kg; Sukaramai supplies Air Putih with 3,000 kg and Simpang Dolok with 4,000 kg; and Aras supplies Pagurawan with 5,000 kg. With this allocation, the demand of every destination market is fully met and the entire supply capacity of the three production centers is used up, confirming that the balanced transportation model has been solved optimally. All opportunity-cost values in the final iteration are positive or equal to zero, which meets the optimality criterion of the MODI method, so no further iteration is required.

These results are consistent with previous studies that applied the transportation model to distribution problems. Studies on water distribution (Syam et al., 2021) and on the distribution of goods and fresh produce (Arofah & Gesthantiara, 2021; Ranti et al., 2022) also reported that the NWC solution can still be improved through MODI optimality testing. Compared with those studies, the present research is focused on red chili distribution and uses distribution distance rather than only cost as the objective function, so the results are more directly relevant to shortening delivery routes among production centers and markets.

The contribution of this study lies in providing a data-driven and structured alternative for planning red chili distribution from several production centers to several markets. By explicitly formulating the minimization of total distribution distance as the objective function and solving it with the combined NWC-MODI procedure, this study offers a distribution pattern that can be used as a practical reference by farmers, collectors, and local logistics managers to allocate shipments more efficiently.

This study has several limitations. The model uses static supply, demand, and distance data at one point in time and assumes a balanced transportation problem, so it does not yet capture fluctuations in harvest, price, and road conditions. Future research is recommended to use larger and time-varying data, to compare the NWC-MODI method with other approaches such as the Vogel Approximation Method and Stepping Stone, and to integrate the model with geographic information systems so that route optimization can be applied dynamically in real distribution conditions.

D. Conclusion

This study shows that the Modified Distribution (MODI) method can be used to evaluate and optimize the distribution pattern of red chili from the production center to the market. Based on the results of the thesis, the reported solution met the optimal criteria because the total opportunity cost (Δij) was greater than or equal to zero. The application of MODI resulted in a total minimum distribution distance of 214,000 km-units, compared to the initial NWC solution of 222,000 km-units, resulting in savings of 8,000 km-units. These results support the findings of previous research on the effectiveness of transportation models and MODI in distribution optimization.

The results of this study can be used as a reference in determining a more efficient distribution pattern so that costs and delivery time can be minimized. For the next researcher, it involves more production centers and destination markets, as well as considering other variables such as actual transportation costs, travel time, road conditions, vehicle capacity, and the degree of product damage during delivery. In addition, further research can compare the MODI method with other optimization methods, such as Vogel's Approximation Method (VAM), Least Cost Method (LCM), Stepping Stone, or software-based optimization approaches so that more comprehensive results can be obtained and provide more effective distribution solutions alternatives.

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