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Optimizing Basic Competition Selection Book Distribution Costs Using the North West Corner and Modified Distribution Methods

Alfian Putra Ardana[1], Dimas Anggrawan Hadinata[1], Nuzla Af'idatur Robbaniyyah[1*]

[1] *Department of Mathematics, Universitas Mataram, Indonesia*
[*] *Corresponding author: nuzla@unram.ac.id*

A B S T R A C T

High distribution costs represent a major challenge in delivering Basic Competency Selection (BCS) books across various regions in Indonesia, primarily due to inefficient allocation of shipments. This study aims to optimize distribution costs by applying transportation methods through a combination of the North West Corner (NWC) and Modified Distribution (MODI) methods. The data used are quantitative, obtained through direct interviews with distributors, including transportation costs, supply capacities from each source, and demand at each destination. The NWC method is employed to generate an initial feasible solution, which is then improved using the MODI method to achieve an optimal solution. The results indicate that the initial distribution cost of Rp4,533,000 can be reduced to Rp3,651,000 after optimization, reflecting a cost efficiency of 19.46%. Therefore, the combination of NWC and MODI methods is proven to be effective in minimizing distribution costs and can serve as a practical decision-support tool in logistics planning, particularly in educational material distribution.

Keywords: Optimizing distribution costs , Transportation method , North West Corner (NWC) , Modified Distribution (MODI) , BCS books.

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1. Introduction

The Basic Competency Selection (BCS) book plays a crucial role for students aiming to enter government-run universities and civil servant candidates who will face selection tests [1]. The high market demand for these books has forced manufacturers to distribute them quickly and efficiently throughout Indonesia. However, the main obstacle that often arises is the inflated logistics costs. Therefore, a distribution strategy is needed that can reduce costs without sacrificing market reach.

One practical solution to optimize these expenses is to implement transportation methods [2]. This technique focuses on how to allocate shipments of goods from various sources to their destinations with the goal of achieving the lowest total cost [3]. In the process, this optimization begins with

determining a feasible initial solution [4]. One of the most popular techniques for obtaining these initial numbers is the Northwest Corner (NWC) method [5–7]. As the name suggests, NWC works simply by filling in the allocation starting from the upper left corner (northwest) of the distribution table, then continuing systematically until all requirements are met [6].

Although NWC is effective in providing an initial overview, the results obtained are usually not yet at the most economical point [8]. This is why further evaluation and refinement are necessary. One instrument that has proven effective is the Modified Distribution (MODI) method [9]. Through MODI, each distribution route is reviewed to identify potential savings by calculating its opportunity cost index [10–12]. Using MODI, the rough solution from NWC can be refined to produce truly minimal distribution costs [13].

A number of previous studies have proven the effectiveness of combining NWC and MODI in reducing operational costs. For example, this strategy has been successfully implemented in the delivery of bread products [14] and LPG gas distribution [15]. Despite the success of NWC and MODI in various sectors, a significant research gap remains in the logistics of educational materials. Currently, there is a lack of evidence regarding the integration of these methods specifically for BCS book distribution, leaving a critical void in cost-effective strategies for educational publishers. Based on this gap, this study aims to apply NWC as an initial step, which is then refined by MODI. It is hoped that this study will produce a more efficient distribution pattern and make a real contribution to the literature on logistics management, especially for educational books.

2. Research Methods (Optional)

This research is a quantitative descriptive study with an experimental approach, which aims to analyze and optimize distribution costs at the BCS Bookstore using the transportation method. The data used in this study is quantitative, including variables such as transportation costs, supply capacity (source), and destination demand (destination) to conduct calculation simulations using the North West Corner (NWC) method. While other methods such as the Least Cost Method and Vogel's Approximation Method (VAM) are also available to find initial solutions, this study specifically utilizes NWC due to its simplicity and computational efficiency, particularly when dealing with large-scale distribution data where a straightforward initial allocation is required before refinement. Previous comparative studies have indicated that although VAM often provides a closer initial result to the optimum, the combination of NWC and MODI remains highly robust and easier to implement in practical logistical software environments. Therefore, this study prioritizes the NWC-MODI synergy to establish a clear, step-by-step optimization framework for educational book distribution. The results of the initial solution calculation are then evaluated using the Modified Distribution (MODI) optimality method.

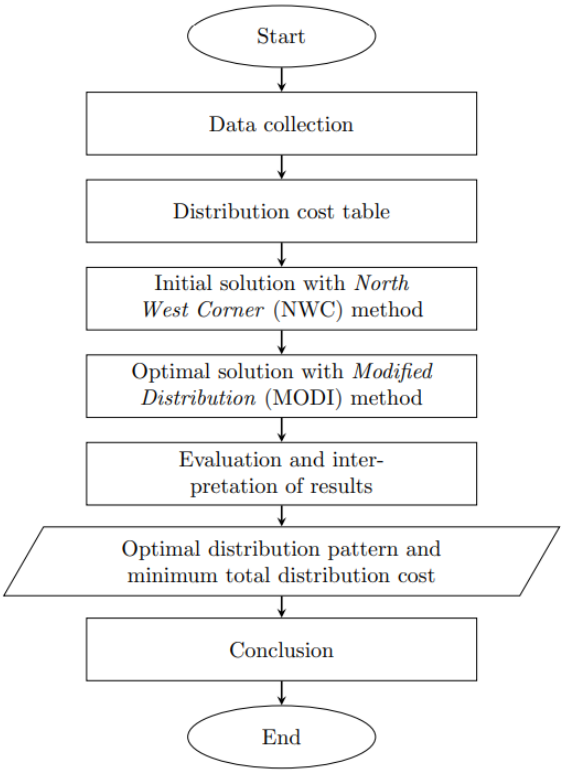

Figure 1. Research flowchart

- Data collection was conducted at the BCS Bookstore, including shipping costs from each source to destination, supply quantities, and demand quantities.
- The collected data was then compiled into a transportation table. This table displays the relationship between sources and destinations, along with shipping costs, capacity, and required requirements.
- The process with the North West Corner (NWC) method at this stage involves initial calculations to determine a feasible solution by filling in the cost table starting from the top left corner (north-west) sequentially according to the rules of the NWC method. The goal is to obtain a basis for initial calculations. The steps of the North West Corner (NWC) method are:

  1. Begin from the upper-left (north-west) cell of the transportation table, which is the first row and first column.
  2. Allocate the maximum possible amount to that cell:

$$x_{11} = \min(\text{Supply}_1, \text{Demand}_1)$$

  3. Update the supply and demand. If the supply is exhausted, move to the next row. If the demand is exhausted, move to the next column.
  4. Continue the allocation process to the next cell according to the movement rules (right or downward), then allocate:

$$x_{ij} = \min(\text{remaining supply},\ \text{remaining demand})$$

  5. Repeat the process until all supply and demand are satisfied, resulting in an initial feasible solution.

- Process using the Modified Distribution (MODI) method. This method is used to evaluate and improve the initial solution in order to obtain the minimum (optimal) total transportation costs. The steps in the Modified Distribution (MODI) method are:
  1. Identify an initial feasible solution. The initial solution is obtained using the Northwest Corner (NWC).
  2. Determine row and column potentials. Compute the row potentials (u_i) and column potentials (v_j) for each row and column based on:

     $$u_i + v_j = c_{ij}$$

     These potentials are calculated only for the occupied (basic) cells. One potential value, typically u_1, is set to zero to start the calculations.
  3. Compute the opportunity cost. For each empty (non-basic) cell, calculate:

     $$k_{ij} = c_{ij} - (u_i + v_j)$$

  4. Test for optimality. If all $k_{ij} \geq 0$, the current solution is optimal. If any $k_{ij} < 0$, select the cell with the most negative value as the candidate for improvement.
  5. A loop is constructed using the stepping-stone method. In forming the loop, movement is restricted to horizontal and vertical directions between basic cells and must result in a closed path that returns to the starting cell. The (+) and (−) signs are assigned alternately at each node. The loop is formed only through allocated cells (basic cells), except for the starting cell, which is to be included in the basis. This rule ensures that the constructed loop is valid during the MODI optimization process.
  6. Determine the step size (θ). Identify the minimum allocation among the cells with a minus sign:

     $$\theta = \min(x_{ij}^{(-)})$$

  7. Update the allocations. The cell whose allocation becomes zero is removed from the basis, and the candidate cell is added as a new basic cell.
  8. Repeat the process. Recalculate u_i, v_j, and k_{ij}, and repeat steps 4–7 until all $k_{ij} \geq 0$ and the optimal solution is obtained.

- The calculation results are compared between the initial solution (NWC) and the optimal solution (MODI). This stage aims to assess distribution efficiency and determine whether the obtained solution is optimal
- Summarize the research results based on calculations and analysis, including the minimum cost values obtained and recommendations for increasing distribution efficiency.

3. Result and Discussion

This section presents the results of research and discussion related to the optimization of BCS book distribution. The analysis was conducted based on data on source capacity, destination demand, and transportation costs that form the transportation problem model. The data was then processed using the North West Corner (NWC) method as the initial solution and the Modified Distribution (MODI) method to obtain the optimal distribution solution. The data was obtained through direct interviews with Tika and Hakim, who are BCS book distributors. The following is the book capacity data from each source.

3.1. Research Data

3.1.1. Source of Book Capacity

The following are the sources that provide BCS books along with their respective supply capacities, which are used as distribution origins in this study and are presented in detail in Table 1.

Table 1. BCS Book Sources and Capacity

BCS book business	book capacity
Tika	50
Hakim	60

Source : interview results

Table 1 presents the sources of BCS book suppliers and their supply capacity. The distribution sources in this study consist of two BCS book businesses, namely Tika and Hakim, which act as BCS book distributors. The supply capacity of each source is 50 units and 60 units of BCS books. This data was obtained directly through interviews with the owners or managers of the relevant BCS book businesses, thus reflecting the actual conditions of production and distribution capabilities.

3.1.2. Distribution destinations and demand for BCS books

The following are the distribution destinations and demand for BCS books from the two sources. There are five distribution destinations for BCS books, namely Central Java, East Java, East Nusa Tenggara, Bali, and North Sumatra, as shown in Table 2.

Table 2. Destination areas with demand

Destination Areas	Demand
Central Java	36
East Java	28
East Nusa Tenggara	13
Bali	21
North Sumatera	12

Source : interview results

The Table 2 shows the demand for BCS books in each distribution destination area, namely Central Java, East Java, East Nusa Tenggara, Bali, and North Sumatra. The demand data in this table is used as a parameter for modeling transportation issues. This information is used as a basis for determining the optimal allocation of BCS books from the source to the destination area so that the needs of each area can be met with minimum distribution costs.

3.1.3. Distribution Cost

The following are the distribution costs for BCS obtained in a single shipment along with the total number of BCS books sent to each destination area as shown in Table 3.

Table 3. Distribution Costs and Demand Volume in Each Region

Source	Purpose	Cost(Rp)	Total Number of Books
TIKA	Central Java	53,000	15
	East Java	63,000	10
	East Nusa Tenggara	48,000	8
	North Sumatra	53,000	7
	Bali	48,000	5
HAKIM	Central Java	48,000	21
	East Java	10,000	18
	East Nusa Tenggara	13,000	5

Source	Purpose	Cost(Rp)	Total Number of Books
	North Sumatra	58,000	14
	Bali	18,000	7
Source : interview results			

The Table 3 shows the distribution costs and number of BCS book requests sent from two distribution sources, namely TIKA and HAKIM, to five destination areas. Each source has different distribution costs and demand quantities for each region. The data is used as a basis for modeling transportation problems using the North West Corner (NWC) method as the initial solution and the Modified Distribution (MODI) method to obtain the optimal solution with minimum distribution costs.

3.2. Transportation Table Modeling

The collected data was then arranged in a transportation table, which was subsequently used to apply the NWC method to obtain an initial solution. This resulted in the following table:

Table 4. Transportation Table Model

Source	Destination					Supply
	Central Java	East Java	NTT	North Sumatra	Bali	
Tika	53	63	48	53	48	50
Hakim	48	10	13	58	18	60
Demand	36	28	13	21	12	110

Table 4 will be used to find the initial solution and optimal solution for BCS distribution costs through the application of the North West Corner and Modified Distribution methods.

3.3. Searching for Initial Solutions Using the North West Corner Method

In this section, the initial solution for the distribution cost of BCS books to five destination areas will be calculated using the North West Corner method. The calculation using the North West Corner method can be seen in Table 5.

Table 5. Transportation Table Model

Source	Destination					Supply
	Central Java	East Java	NTT	North Sumatra	Bali	
Tika	53(36)	63(14)	-	-	-	50
Hakim	-	10(14)	13(13)	58(21)	18(12)	60
Demand	36	28	13	21	12	110

Based on the results of the North West Corner method calculation, the initial solution for the distribution cost of BCS books is

- Delivery of 36 units from the Tika Warehouse to the Central Java region.
- Delivery of 14 units from the Tika Warehouse to the East Java region.
- Delivery of 14 units from the Hakim Warehouse to the East Java region.
- Delivery 13 units from the Hakim Warehouse to the NTT region.
- Delivery of 21 units from the Hakim Warehouse to North Sumatra.
- Delivery of 12 units from Hakim Warehouse to the Bali region.

$$\begin{aligned} Z &= c_{11} \cdot 36 + c_{12} \cdot 14 + c_{22} \cdot 14 + c_{23} \cdot 13 + c_{24} \cdot 21 + c_{25} \cdot 12 \\ &= (53 \cdot 36) + (63 \cdot 14) + (10 \cdot 14) + (13 \cdot 13) + (58 \cdot 21) + (18 \cdot 12) \\ &= 4.533 \text{ (Ribu Rupiah)} \end{aligned}$$

The initial solution for BCS book distribution was obtained using the North West Corner (NWC) method, which produced delivery allocations based on the initial position of the transportation table without considering the distribution costs. This allocation was able to meet all demand in the five destination areas in accordance with the capacity of each source, thus producing a feasible solution. The total distribution cost in the initial solution was Rp4,533,000, calculated from the product of the number of books shipped on each route and the distribution cost per unit. Although it meets all constraints, this initial solution does not consider the cost structure optimally, so the resulting distribution cost is still relatively high. Therefore, the initial NWC solution is used as the basis for applying the Modified Distribution (MODI) method to test optimality and improve distribution allocation, with the aim of reducing the total cost to obtain a more efficient final solution.

3.4. Searching for an Optimal Solution Using the Modified Distribution Method

In this section, we will find the optimal value of BCS book distribution costs using the Modified Distribution method as described in the following steps.

Table 6. Cost Distribution and Allocation Using the NWC Method

	Central Java	**East Java**	**NTT**	**North Sumatera**	**Bali**	**Supply**
Tika	53 (36)	63 (14)	48 (0)	53 (0)	48 (0)	50
Hakim	48 (0)	10 (14)	13 (13)	58 (21)	18 (12)	60
Demand	36	28	13	21	12	110

Based on the initial solution table using the NWC method, the optimal table was obtained in the sixth iteration. The next step is to determine the optimal solution for BCS book distribution costs using the MODI method.

Step 1: Determine the potential of rows and columns

The first iteration is performed to evaluate each base cell (cell allocated > 0) in the table using the following formula.

$$u_i + v_j = c_{ij}.$$

Our first step is to assume $u_1 = 0$, then calculate the values of c_{ij} for each row and column as follows:

$$\begin{aligned}
c_{11} &= u_1 + v_1 \rightarrow 53 = 0 + v_1 \rightarrow v_1 = 53,\\
c_{12} &= u_1 + v_2 \rightarrow 63 = 0 + v_2 \rightarrow v_2 = 63,\\
c_{22} &= u_2 + v_2 \rightarrow 10 = u_2 + 63 \rightarrow u_2 = -53,\\
c_{23} &= u_2 + v_3 \rightarrow 13 = -53 + v_3 \rightarrow v_3 = 66,\\
c_{24} &= u_2 + v_4 \rightarrow 58 = -53 + v_4 \rightarrow v_4 = 111,\\
c_{25} &= u_2 + v_5 \rightarrow 18 = -53 + v_5 \rightarrow v_5 = 71.
\end{aligned}$$

Step 2: Calculate the opportunity cost k_{ij}

After obtaining the values u_i and v_j, calculate the value for each empty cell (non-basis) using the formula:

$$k_{ij} = c_{ij} - (u_i + v_j).$$

Some important calculations:

$$k_{13} = c_{13} - (u_1 + v_3) \rightarrow k_{13} = 48 - (0 + 66) = -18,$$

$$k_{14} = c_{14} - (u_1 + v_4) \rightarrow k_{14} = 53 - (0 + 111) = -58,$$
$$k_{15} = c_{15} - (u_1 + v_5) \rightarrow k_{15} = 48 - (0 + 71) = -23,$$
$$k_{21} = c_{21} - (u_2 + v_1) \rightarrow k_{21} = 48 - (-53 + 53) = 48.$$

Since there is $k_{ij} < 0$ ($k_{14} = -58$ is the most negative), the solution is not yet optimal. Select the cell with the most negative k as the basis entry cell: that is cell (14) (Tika – North Sumatra).

Step 3: Form a closed loop and determine θ

Enter cell $(1, 4)$ into the basis (initial value 0) then form a closed loop connecting the input cell with the basis cells. One valid loop:

$$(1,4) \rightarrow (1,2) \rightarrow (2,2) \rightarrow (2,4) \rightarrow (1,4).$$

Mark alternating positions with + in the input cell, and − in the next cell, so that:

$$+ (1,4), - (1,2), + (2,2), - (2,4).$$

Take,

$$\theta = \min\{\text{ alocation in the with the mark } - \} = \min\{x_{1,2}, x_{2,4}\} = \min\{14, 21\} = 14.$$

Make allocation adjustments: add θ to cells marked + and subtract θ from cells marked −:

$$x_{1,4} \leftarrow 0 + 14 = 14,$$
$$x_{1,2} \leftarrow 14 - 14 = 0 \quad \text{(leave the base)},$$
$$x_{2,2} \leftarrow 14 + 14 = 28,$$
$$x_{2,4} \leftarrow 21 - 14 = 7.$$

Table 7. Cost Distribution and Allocation Table Results of the First Iteration

	Central Java	**East Java**	**NTT**	**North Sumatera**	**Bali**	**Supply**
Tika	53 (36)	63 (0)	48 (0)	53 (14)	48 (0)	50
Hakim	48 (0)	10 (28)	13 (13)	58 (7)	18 (12)	60
Demand	36	28	13	21	12	110

Step 4: Recalculate the potential (u, v)

Based on the table of the first iteration results, a new basis $c_{11}, c_{14}, c_{22}, c_{23}, c_{24}, c_{25}$ is obtained, then calculate and determine the value of c_{ij} Assume $u_1 = 0$:

$$c_{11} = u_1 + v_1 \rightarrow 53 = 0 + v_1 \rightarrow v_1 = 53,$$
$$c_{14} = u_1 + v_4 \rightarrow 53 = 0 + v_4 \rightarrow v_4 = 53,$$
$$c_{22} = u_2 + v_2 \rightarrow 10 = 5 + v_2 \rightarrow v_2 = 5,$$
$$c_{23} = u_2 + v_3 \rightarrow 13 = 5 + v_3 \rightarrow v_3 = 8,$$
$$c_{24} = u_2 + v_4 \rightarrow 58 = u_2 + 53 \rightarrow u_2 = 5,$$
$$c_{25} = u_2 + v_5 \rightarrow 18 = 5 + v_5 \rightarrow v_5 = 13.$$

Step 5: Recalculate k_{ij}

Calculate $k_{ij} = c_{ij} - (u_i + v_j)$ for non-basis cells:

$$k_{12} = c_{12} - (u_1 + v_2) \rightarrow k_{12} = 63 - (0 + 5) = 58,$$
$$k_{13} = c_{13} - (u_1 + v_3) \rightarrow k_{13} = 48 - (0 + 8) = 40,$$
$$k_{15} = c_{15} - (u_1 + v_5) \rightarrow k_{15} = 48 - (0 + 13) = 35,$$
$$k_{21} = c_{21} - (u_2 + v_1) \rightarrow k_{21} = 48 - (5 + 53) = -10.$$

There is still $k_{2,1} = -10 < 0$, so cell $(2, 1)$ becomes a candidate for inclusion in the basis.

Step 6: Cycle for cell $(2, 1)$ and adjustment

A closed cycle connecting $(2, 1)$ with the existing basis, for example:

$$(2, 1) \rightarrow (1, 1) \rightarrow (1, 4) \rightarrow (2, 4) \rightarrow (2, 1).$$

Alternating signs:

$$+ (2, 1), - (1, 1), + (1, 4), - (2, 4).$$

Transferable value:

$$\theta = \min\{x_{1,1}, x_{2,4}\} = \min\{36, 7\} = 7.$$

Update allocation:

$$x_{2,1} \leftarrow 0 + 7 = 7,$$
$$x_{1,1} \leftarrow 36 - 7 = 29,$$
$$x_{1,4} \leftarrow 14 + 7 = 21,$$
$$x_{2,4} \leftarrow 7 - 7 = 0 \quad \text{(leave the base)}.$$

Step 7: Allocation table after the second adjustment

Table 8. Cost Distribution and Revenue Allocation in the Second Iteration

	Central Java	**East Java**	**NTT**	**North Sumatera**	**Bali**	**Supply**
Tika	53 (29)	63 (0)	48 (0)	53 (21)	48 (0)	50
Hakim	48 (7)	10 (28)	13 (13)	58 (0)	18 (12)	60
Demand	36	28	13	21	12	110

Based on the table of the second iteration results, new bases $c_{11}, c_{14}, c_{21}, c_{22}, c_{23}, c_{25}$ are obtained, then calculate and determine the value of c_{ij}. Assume $u_1 = 0$:

$$c_{11} = u_1 + v_1 \rightarrow 53 = 0 + v_1 \rightarrow v_1 = 53,$$
$$c_{14} = u_1 + v_4 \rightarrow 53 = 0 + v_4 \rightarrow v_4 = 53,$$
$$c_{21} = u_2 + v_1 \rightarrow 48 = u_2 + 53 \rightarrow u_2 = -5,$$
$$c_{22} = u_2 + v_2 \rightarrow 10 = -5 + v_2 \rightarrow v_2 = 15,$$
$$c_{23} = u_2 + v_3 \rightarrow 13 = -5 + v_3 \rightarrow v_3 = 18,$$
$$c_{25} = u_2 + v_5 \rightarrow 18 = -5 + v_5 \rightarrow v_5 = 23.$$

Calculate $k_{ij} = c_{ij} - (u_i + v_j)$ for non-basis cells:

$$k_{12} = c_{12} - (u_1 + v_2) \rightarrow k_{12} = 63 - (0 + 15) = 48,$$

$$k_{13} = c_{13} - (u_1 + v_3) \rightarrow k_{13} = 48 - (0 + 18) = 30,$$
$$k_{15} = c_{15} - (u_1 + v_5) \rightarrow k_{15} = 48 - (0 + 23) = 25,$$
$$k_{21} = c_{24} - (u_2 + v_4) \rightarrow k_{24} = 58 - (-5 + 53) = 10.$$

All $k_{ij} > 0$, so the solution is now **optimal**.

Step 8: Total transportation costs (optimal solution)

Calculate the total cost:

$$\begin{aligned} Z &= c_{11} \cdot 29 + c_{14} \cdot 21 + c_{21} \cdot 7 + c_{22} \cdot 28 + c_{23} \cdot 13 + c_{25} \cdot 12 \\ &= (53 \cdot 29) + (53 \cdot 21) + (48 \cdot 7) + (10 \cdot 28) + (13 \cdot 13) + (18 \cdot 12) \\ &= 3.651 \text{ (Ribu Rupiah)} \end{aligned}$$

Based on the results of calculations using the North West Corner (NWC) method as the initial solution, which was then tested using the Modified Distribution (MODI) method, an optimal distribution solution was obtained with a total cost of Rp3,651,000, which is the minimum cost for distributing BCS books to all destination areas. These results show that the resulting distribution allocation is able to meet all demand in each destination area without exceeding the available source capacity. Therefore, the application of a quantitative approach-based transportation optimization method can be used as an effective decision-making support tool in distribution planning, particularly to reduce transportation costs and improve inter-regional distribution efficiency.

4. Conclusions

This study demonstrates that the application of the North West Corner (NWC) and Modified Distribution (MODI) methods significantly improves the efficiency of BCS book distribution through optimal allocation. The optimization results indicate a reduction in total distribution costs from Rp4,533,000 to Rp3,651,000, corresponding to an efficiency gain of approximately 19.46% , while ensuring that all demand at destination points is fully satisfied in accordance with the available supply capacities.For future research, it is recommended to explicitly define the scope and limitations of the study, including the distribution coverage area, capacity assumptions, and the number of distribution points analyzed. Furthermore, the integration of alternative methods such as the Least Cost Method, Vogel's Approximation Method (VAM), and the Stepping Stone method—could provide a more diverse range of results and enrich the analysis, thereby improving the quality of distribution planning.

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