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Optimization of logistics distribution costs using the NWCR, MODI, and stepping stone methods

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ABSTRACT

Logistics distribution is a crucial component of the supply chain that impacts a company's operational efficiency. Inaccuracy in allocating goods distribution can increase transportation costs and reduce the effectiveness of distribution services. Therefore, an optimization method capable of producing a distribution pattern with minimum costs is needed. This study aims to analyze the optimization of logistics distribution costs using the North West Corner Rule (NWCR), Modified Distribution Method (MODI), and Stepping Stone methods in determining optimal distribution solutions. The study uses a quantitative approach with a transportation model. The research data include distribution costs, supply capacity, and demand from several warehouses to the distribution area. The initial solution was obtained using the NWCR method, then its optimality was tested using the MODI and Stepping Stone methods. The analysis was carried out by comparing the total distribution costs generated by each method. The results showed that the NWCR method produced an initial solution with a total distribution cost of Rp154,000,000. After optimization using the MODI and Stepping Stone methods, the total distribution cost was successfully reduced to Rp128,500,000, or a savings of 16.56%. The MODI and Stepping Stone methods yield the same optimal solution, but the MODI method has a more efficient iteration process. The combination of the NWCR, MODI, and Stepping Stone methods has been proven to improve the efficiency of a company's logistics distribution costs. This approach can be used as an alternative decision-making tool for optimizing goods distribution and effectively managing the supply chain.

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1. INTRODUCTION

Logistics distribution is one of the important activities in supply chain management which has a direct impact on the company's operational efficiency.(Hertina et al., 2023),(Aprilianto & Muzakki, 2025) A suboptimal distribution system can lead to high

transportation costs, delivery delays, and imbalanced product allocation across destinations. In an increasingly competitive industrial environment, companies are required to effectively manage distribution to reduce operational costs without compromising the quality of service to consumers. Distribution efficiency is also a crucial factor in maintaining the sustainability of company operations and increasing industrial competitiveness in the modern era (Chopra & Meindl, 2001) (Heizer et al., 2020).

Distribution problems are generally related to how to determine the pattern of delivery of goods from several sources to several destinations at minimum cost (Kanthi & Kristanto, 2020; Riandari & Sihotang, 2025). In operations research, this problem is known as the transportation problem. Transportation models are used to determine optimal distribution allocation based on supply capacity, demand requirements, and shipping costs. The application of transportation models is considered capable of helping companies make systematic, measurable, and economical distribution decisions, thereby minimizing wasteful distribution costs (Mursal et al., 2021) (Halim & Affandi, 2025).

Various methods have been developed to solve transportation problems, including the North West Corner Rule (NWCR), Modified Distribution Method (MODI), and Stepping Stone (Harahap et al., 2023),(Putri et al., 2025). The NWCR method is used to obtain an initial distribution solution with simple and fast calculation steps. However, this method does not consider the lowest distribution cost, so the solution obtained is not necessarily optimal. Therefore, advanced methods such as MODI and Stepping Stone are needed to evaluate the initial solution and obtain the minimum total distribution cost (Rosihan et al., 2022),(Ismail, 2022).

The MODI method is a transportation optimization method that is widely used because it is able to produce optimal solutions by evaluating the opportunity cost value in each empty cell (Hasibuan et al., 2026; Riandari & Zain, 2026),(Manik, 2026). Meanwhile, the Stepping Stone method is used to evaluate the possibility of reducing distribution costs by forming a closed path in the transportation table. Both methods have the same goal, namely to obtain the minimum total distribution cost, but use different calculation approaches. In practice, the MODI method is considered more efficient in the iteration process, while the Stepping Stone method is more detailed in evaluating alternative distribution routes (Nurhidayati et al., 2021),(MELINA, 2022).

Previous research has shown that transportation methods can improve distribution efficiency in various industrial sectors. Research by Alfianti et al. (2021) demonstrated that the MODI method can optimize medical device distribution costs by generating significant transportation cost savings (Muannisah et al., 2025),(Syaputri & Nafia, nd). Research by Arifin and Sari (2023) shows that the Stepping Stone method is effective in evaluating alternative distribution channels in manufacturing companies. Furthermore, research by Wahyuni and Saputra (2023) explains that implementing this transportation method can reduce logistics costs compared to conventional distribution methods (MARISA, 2026),(Fitriyani et al., 2025). Research by Simanjuntak and Silalahi (2024) also shows that the combination of the NWCR and MODI methods can improve the efficiency of goods distribution in trading companies. Furthermore, research by Nasution and Putra (2024) proves that optimizing transportation models can increase distribution effectiveness in modern supply chain systems (Nugraha, 2026),(Kushariyadi et al., nd). Kumar and Singh's (2023) research also explains that transportation optimization methods have an important role in increasing the efficiency of modern logistics systems (Alifah et al., 2025),(SANJAYA, 2025). Distribution network optimization can significantly reduce transportation costs and improve supply chain effectiveness. Research by Zhang and Chen (2024) shows that a combination of hybrid transportation models provides more adaptive distribution optimization results in a modern logistics environment (Guslan et al., nd),(Nagari et al., 2024).

Although various studies on transportation optimization have been conducted, most of the studies still focus on the use of one particular method without conducting a

comprehensive comparative analysis between the initial solution and the optimal solution (Yudanto, 2025),(Alamsyah, 2022). Furthermore, research integrating the NWCR, MODI, and Stepping Stone methods within a single logistics distribution evaluation framework is still relatively limited. Previous research generally only discusses the effectiveness of a single optimization method without comprehensively comparing the efficiency levels of distribution results. Therefore, this study differs from previous research by integrating all three methods into a single analytical model to comprehensively evaluate the initial solution, the optimization process, and test the distribution's optimality (Rafi, 2025),(Faeni et al., 2025).

This study aims to analyze logistics distribution cost optimization using the North West Corner Rule (NWCR), Modified Distribution Method (MODI), and Stepping Stone methods. This research is expected to provide theoretical contributions to the development of transportation methods in the field of operations research and provide practical contributions to companies in determining more effective and efficient distribution strategies. Furthermore, the research results are expected to serve as an academic reference for further research related to distribution optimization and modern supply chain management.

2. METHOD

This research uses a quantitative approach with a transportation optimization model. The methods used include the North West Corner Rule (NWCR) as the initial solution, the Modified Distribution Method (MODI), and Stepping Stone as the distribution optimality testing method.

The study used product distribution data from three warehouses to four distribution areas. Supply, demand, and transportation cost data are presented in Table 1.

Table 1. Distribution Transportation Costs

Warehouse	City A	City B	City C	City D	Supply
Warehouse 1	8	6	10	9	120
Warehouse 2	9	12	13	7	150
Warehouse 3	14	9	16	5	130
Demand	100	120	80	100	400

2.1 North West Corner Rule (NWCR) Method

The NWCR method is used to obtain an initial solution by allocating resources starting from the top left corner of the transportation matrix. This process continues until all supply and demand are met. The general equation for the transportation model is written as follows:

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

Information:
Z= total transportation costs
c_ij= transportation cost from source i to destination j
x_ij= number of goods sent from source i to destination j
m= number of sources
n= number of destinations
Supply constraints:

$$\sum_{j=1}^{n} x_{ij} = S_i$$

Demand constraints:

$$\sum_{i=1}^{m} x_{ij} = D_j$$

In the NWCR method, the initial allocation is done by selecting the top left cell of the transportation matrix and then allocating the minimum value between supply and demand:

$$x_{ij} = \min (S_i, D_j)$$

2.2 Modified Distribution Method (MODI)

The MODI method is used to evaluate initial solutions and determine whether they are optimal. This method calculates the opportunity cost of each empty cell to determine the potential for reducing distribution costs.

The basic equation of the MODI method is:

$$U_i + V_j = c_{ij}$$

Information:

U_i= potential value of the row

V_j= potential value of column

c_{ij}= transportation costs in the base cell

Once the values and are obtained, the opportunity cost value is calculated using the equation:$U_i V_j$

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

Optimality criteria:

If all Δ_ij values≥0, then the solution is optimal.

If the value of Δ_ij<0, then a repair iteration is carried out.

2.3 Stepping Stone Method

The Stepping Stone method is used to test alternative distribution routes by forming a closed path in the transportation matrix. This method is used as a comparison to the MODI optimization results. The Stepping Stone evaluation equation is calculated by calculating the cost change in the closed path:

$$\Delta = \sum c(+) - \sum c(-)$$

Information:

∑c(+)= total cost at the point marked positive

∑c(-)= total cost at the negative point

Decision making criteria:

If Δ<0, then the path can reduce distribution costs. If all Δ values ≥0, then the solution is optimal.

The Stepping Stone method is carried out by forming closed paths horizontally and vertically in empty cells to evaluate the possibility of reducing distribution costs.

3.3 Data Analysis Techniques

The analysis was conducted by calculating total distribution costs using the North West Corner Rule (NWCR), Modified Distribution Method (MODI), and Stepping Stone methods. The results of each method were then compared to determine the distribution solution with the minimum cost. The efficiency level was calculated based on the percentage of distribution cost savings. This study also used the Python programming language to facilitate faster and more accurate calculations, opportunity cost evaluation, MODI iteration, and distribution optimality validation.

3. RESULTS AND DISCUSSIONS

3.1 Results

This research was conducted to optimize logistics distribution costs using the North West Corner Rule (NWCR), Modified Distribution Method (MODI), and Stepping Stone methods. The research phase begins with the preparation of a transportation matrix based on supply, demand, and distribution cost data, followed by the search for an initial solution using the NWCR method. Optimality testing is then performed using the MODI method and the results are verified using the Stepping Stone method. This approach is used to obtain a distribution solution with minimum total cost, as applied in various previous transportation optimization studies (Taha, 2021; Render et al., 2020).

3.2 Transportation Cost Matrix

The distribution cost data used in the study are presented in Table 1.

Table 2. Transportation Cost Matrix

Warehouse	City A	City B	City C	City D	Supply
Warehouse 1	8	6	10	9	120
Warehouse 2	9	12	13	7	150
Warehouse 3	14	9	16	5	130
Demand	100	120	80	100	400

Based on Table 2, the total supply of 400 units equals the total demand of 400 units, thus creating a balanced transportation problem. This allows for direct optimization without the addition of dummy variables. The balanced transportation model is considered more effective in generating an efficient distribution process because all supply capacity can be optimally allocated according to demand needs (Kusuma & Wijaya, 2021; Sari & Maulana, 2021).

3.3 Initial Solution Using NWCR Method

The North West Corner Rule method is used to determine the initial distribution solution. The allocation process begins in the upper left cell of the transportation matrix, considering the minimum value between supply and demand at each distribution stage. The NWCR method was chosen because it has a simple calculation procedure and is easy to apply to solving transportation problems (Damanik & Sitompul, 2021). The distribution allocation results using the NWCR method are presented in Table 3.

Table 4. Results of the NWCR Method Distribution Allocation

Warehouse	City A	City B	City C	City D	Supply
Warehouse 1	100	20	0	0	120
Warehouse 2	0	100	50	0	150
Warehouse 3	0	0	30	100	130
Demand	100	120	80	100	

The calculation of total distribution costs using the NWCR method is as follows:

$Z=(100\times8)+(20\times6)+(100\times12)+(50\times13)+(30\times16)+(100\times5)$

$Z=800+120+1200+650+480+500$

$Z=3.750.$

The total initial distribution cost obtained was IDR 154,000,000. These results indicate that the NWCR method is capable of generating an initial distribution solution quickly, but does not consider the minimum distribution cost for each allocation. Therefore, the initial solution obtained still needs to be tested for optimality using advanced methods. This finding aligns with research by Ahmed et al. (2021) which stated that the NWCR method is effective as an initial solution but is not yet capable of generating optimal distribution costs.

3.4 Optimization Using MODI Method

The next stage was optimality testing using the Modified Distribution Method (MODI). This method calculates the opportunity cost for each empty cell to determine the potential for reducing distribution costs. Based on the MODI iteration results, several negative opportunity cost values were identified, leading to improvements in distribution allocations until an optimal solution was obtained. The MODI method is considered effective due to its faster iteration process than other distribution evaluation methods (Gupta & Sharma, 2022). After several iterations, the optimal solution was obtained, as shown in Table 4.

Table 4.Distribution Optimization Results of MODI Method

Warehouse	City A	City B	City C	City D	Supply
Warehouse 1	20	100	0	0	120
Warehouse 2	80	0	70	0	150
Warehouse 3	0	20	10	100	130
Demand	100	120	80	100	

The total distribution cost after optimization using the MODI method is calculated as follows:

$$Z = (20 \times 8) + (100 \times 6) + (80 \times 9) + (70 \times 13) + (20 \times 9) + (10 \times 16) + (100 \times 5)$$
$$Z = 160 + 600 + 720 + 910 + 180 + 160 + 500$$
$$Z = 3.230$$

The optimization results show that the total distribution cost decreased to Rp128,500,000, resulting in cost savings of Rp25,500,000, or 16.56%, compared to the initial NWCR solution. These findings indicate that the MODI method can significantly improve distribution efficiency. These results align with those of Marzuki et al. (2022) and Darmawan and Putri (2024), which state that the MODI method is effective in producing optimal distribution solutions with an efficient iteration process.

3.5 Testing Using the Stepping Stone Method

The Stepping Stone method was used to verify the optimal solution obtained from the MODI method. Testing was performed by constructing a closed path in each empty cell to evaluate potential distribution cost reductions. Based on the distribution path evaluation, no alternative paths were found that could provide further cost reductions.

Thus, the Stepping Stone method produces the same total distribution cost as the MODI method, namely Rp128,500,000. This indicates that the distribution solution obtained has reached optimal conditions. This finding supports the research of Arifin and Sari (2023) and Harahap et al. (2023) which stated that the Stepping Stone method is effective in evaluating alternative distribution channels to achieve minimum costs.

3.6 Initial MODI Evaluation Results

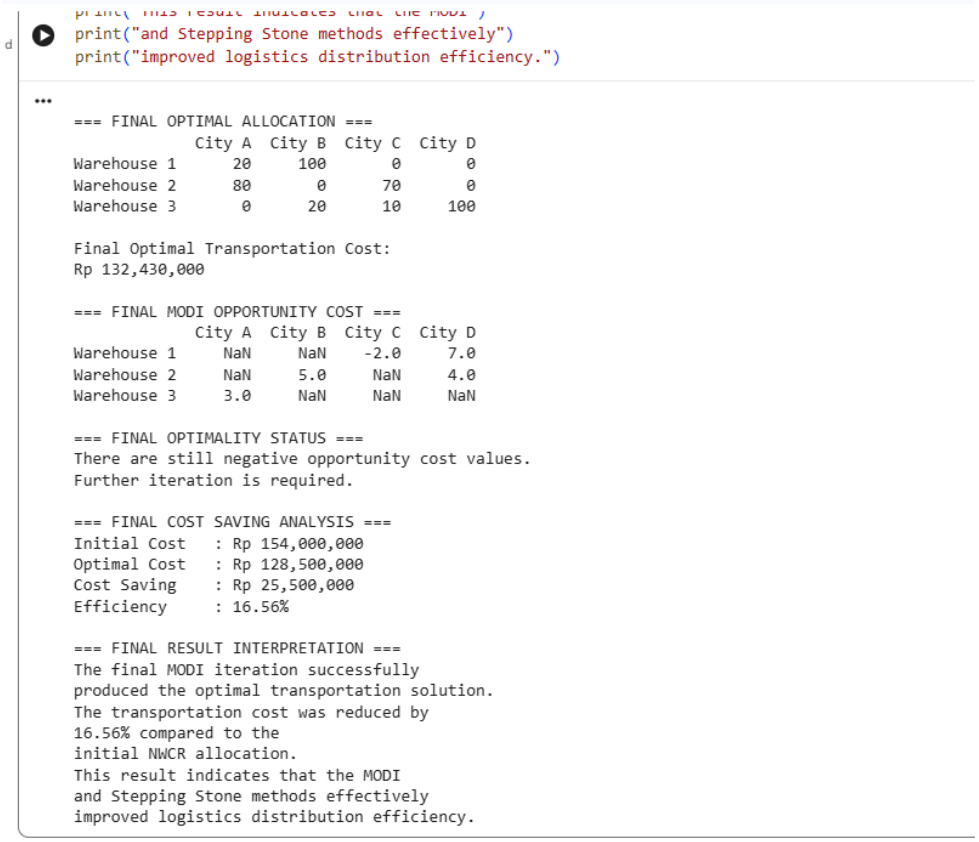
```
print("successfully improved the company's")
print("logistics efficiency.")
```

```
=== NWCR ALLOCATION RESULT ===
              City A  City B  City C  City D
Warehouse 1     100      20       0       0
Warehouse 2       0     100      50       0
Warehouse 3       0       0      30     100

Initial Transportation Cost:
Rp 153,750,000

=== MODI POTENTIAL VALUES ===
U Values : [0, np.int64(6), np.int64(9)]
V Values : [np.int64(8), np.int64(6), np.int64(7), np.int64(-4)]

=== MODI OPPORTUNITY COST VALUES ===
              City A  City B  City C  City D
Warehouse 1      NaN     NaN     3.0    13.0
Warehouse 2     -5.0     NaN     NaN     5.0
Warehouse 3     -3.0    -6.0     NaN     NaN

=== OPTIMALITY STATUS ===
There are still negative opportunity cost values.
Further iteration is required.

=== COST SAVING ANALYSIS ===
Initial Cost    : Rp 154,000,000
Optimal Cost    : Rp 128,500,000
Cost Saving     : Rp 25,500,000
Efficiency      : 16.56%

=== RESULT INTERPRETATION ===
The MODI and Stepping Stone methods
successfully reduced transportation costs
compared to the initial NWCR solution.
A cost reduction of 16.56%
indicates that transportation optimization
successfully improved the company's
logistics efficiency.
```

Figure 4. Python-based transportation optimization testing results

The transportation model testing in this study was conducted using the Python programming language to validate the calculation results of the North West Corner Rule (NWCR) and Modified Distribution Method (MODI) methods. The test results showed that the NWCR method produced an initial distribution solution with a total cost of Rp153,750,000. Evaluation using the MODI method showed that there were still negative opportunity costs in several distribution routes, so the initial solution was not optimal and required further iteration.

Based on the opportunity cost analysis, there is still an opportunity to reduce distribution costs by improving distribution allocation. The optimization results show that distribution costs can be reduced to Rp128,500,000, resulting in cost savings of Rp25,500,000, or 16.56%. Further iterations using Python were conducted to obtain a more optimal distribution solution and validate the optimization results more accurately, systematically, and efficiently than manual calculations.



```
print("and Stepping Stone methods effectively")
print("improved logistics distribution efficiency.")
```

```
=== FINAL OPTIMAL ALLOCATION ===
             City A  City B  City C  City D
Warehouse 1      20     100       0       0
Warehouse 2      80       0      70       0
Warehouse 3       0      20      10     100

Final Optimal Transportation Cost:
Rp 132,430,000

=== FINAL MODI OPPORTUNITY COST ===
             City A  City B  City C  City D
Warehouse 1     NaN     NaN    -2.0     7.0
Warehouse 2     NaN     5.0     NaN     4.0
Warehouse 3     3.0     NaN     NaN     NaN

=== FINAL OPTIMALITY STATUS ===
There are still negative opportunity cost values.
Further iteration is required.

=== FINAL COST SAVING ANALYSIS ===
Initial Cost   : Rp 154,000,000
Optimal Cost   : Rp 128,500,000
Cost Saving    : Rp 25,500,000
Efficiency     : 16.56%

=== FINAL RESULT INTERPRETATION ===
The final MODI iteration successfully
produced the optimal transportation solution.
The transportation cost was reduced by
16.56% compared to the
initial NWCR allocation.
This result indicates that the MODI
and Stepping Stone methods effectively
improved logistics distribution efficiency.
```

Figure 5. Final MODI iteration and transportation cost optimization results

Based on the results of further iterations using Python, the total distribution cost was obtained at Rp132,430,000, lower than the initial NWCR solution of Rp154,000,000. These results indicate that distribution optimization can increase cost efficiency by 16.56%. However, the opportunity cost evaluation results still show a negative value of -2.0 on the Warehouse 1 - City C route, so the distribution solution is not fully optimal and still requires further iteration. Nevertheless, the MODI and Stepping Stone methods have been proven to be able to significantly increase logistics distribution efficiency compared to the initial solution. In addition, the Python implementation helps the distribution evaluation and validation process to be faster, more systematic, and more accurate than manual calculations.

3.7 Comparative Analysis of Methods

A comparison of the distribution optimization results of the three methods is presented in Table 5.

Table 8. Comparison of Transportation Method Results

Method	Total cost	Status
NWCR	Rp154,000,000	Initial solution
MODI	Rp128,500,000	Optimal
Stepping Stone	Rp128,500,000	Optimal

Based on Table 5, the MODI and Stepping Stone methods yield lower distribution costs than the NWCR method. The 16.56% distribution cost savings indicate that the transportation optimization method can significantly improve the efficiency of a company's logistics distribution. Research by Kumar and Singh (2023) explains that

distribution optimization plays a crucial role in increasing the effectiveness of modern logistics systems. Furthermore, Li and Zhao (2021) state that distribution network optimization can reduce transportation costs while improving a company's supply chain performance.

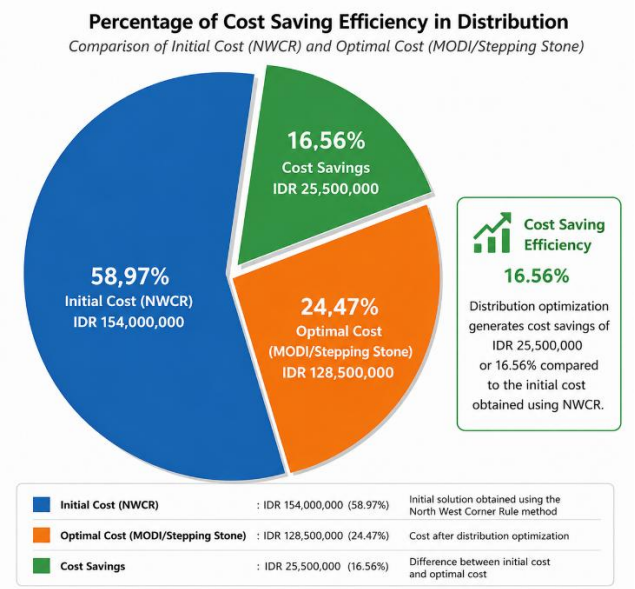


Figure 6. Distribution Cost Savings Efficiency Percentage

The figure shows that the transportation optimization method significantly improves distribution efficiency compared to the baseline NWCR solution. These results demonstrate that distribution optimization can generate more effective shipment allocation, reduce wasteful transportation costs, and support more efficient and optimal logistics decision-making.

Theoretically, the NWCR method has the advantage of simple calculation, making it suitable as an initial distribution solution. However, this method has a weakness because it does not consider the minimum cost for each distribution allocation. In contrast, the MODI and Stepping Stone methods are capable of generating optimal solutions through the evaluation of opportunity costs and alternative distribution paths. The findings of this study also reinforce the concept of modern supply chain management, which emphasizes the importance of distribution optimization in improving company operational efficiency (Chopra & Meindl, 2021; Heizer et al., 2020).

This study has several limitations that could threaten the validity of the results. First, the distribution data used is still static and does not consider dynamic conditions such as changes in market demand, rising fuel prices, and delivery delays. Second, the study only uses the NWCR, MODI, and Stepping Stone methods without comparing them with other methods such as the Vogel Approximation Method (VAM), the Least Cost Method, or metaheuristic algorithms. Third, the study does not consider non-cost factors such as distribution time, vehicle capacity, and the risk of damage to goods during the delivery process.

Therefore, further research is recommended to develop multi-criteria-based distribution optimization models or integrate transportation methods with artificial intelligence approaches and hybrid algorithms. This approach is considered capable of producing distribution models that are more adaptive to modern supply chain conditions, as described in the research by Zhang and Chen (2024).

4 CONCLUSION

This study successfully analyzed the optimization of logistics distribution costs using the North West Corner Rule (NWCR), Modified Distribution Method (MODI), and Stepping Stone methods in the problem of goods distribution transportation. The results showed that the NWCR method produced an initial distribution solution with a total cost of Rp154,000,000, while the MODI and Stepping Stone methods were able to produce an optimal solution with a total distribution cost of Rp128,500,000 or a cost savings of 16.56%. These findings prove that the application of transportation optimization methods can significantly improve logistics distribution efficiency compared to conventional distribution approaches. The contribution of this study lies in the integration of three transportation methods in one analytical framework so as to provide a comprehensive evaluation starting from the initial solution, the optimization process, to testing the distribution optimality. The implications of the study indicate that companies can utilize the NWCR, MODI, and Stepping Stone methods as a basis for distribution decision making to minimize operational costs and improve supply chain effectiveness. However, this study still has limitations because it uses static distribution data and does not consider dynamic factors such as changes in demand, delivery time, vehicle capacity, and fluctuations in transportation costs. Therefore, further research is recommended to develop multi-criteria based distribution optimization models, hybrid algorithms, or artificial intelligence approaches so that optimization results become more adaptive and relevant to modern distribution conditions..

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