Optimization of soybean distribution costs with the transportation method: a case in SME's

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ABSTRACT

The distribution of soybean raw materials is not only related to aspects of quality and smooth production of tofu making but can also influence cost efficiency to increase competitiveness. In this situation, the number of soybeans shipped, transportation costs per unit, and the choice of transportation service used are transportation model issues. This research aims to determine the cheapest cost of sending soybean raw materials from four agent locations to three tofu factory locations with a choice of two transportation services that can be adopted. The case studied is a case of unbalanced transportation with supply greater than demand. The method used is the application of a transportation model, with the Northwest Corner method to determine the initial base solution and the Modified Distribution method to optimize distribution costs for soybean raw materials in the context of tofu production supply. Based on data processing, the results showed that the first and second transportation services offered services with a total shipping cost of IDR 691,750 and IDR 605,250. Observation of these differences leads to the conclusion that the second transportation service offers the most optimal value for money. The research results provide additional knowledge for tofu makers in optimizing costs and delivery routes for soybean raw materials, supporting production continuity, and increasing competitiveness in an ever-changing market.

1. Introduction

Micro, Small, and Medium-Sized Enterprises (MSMEs) are vital to the local and national economy in this age of globalization and intensifying economic competitiveness. MSMEs must prioritize operational efficiency, with a particular emphasis on the seamless raw material distribution process, in order to preserve their competitiveness (Yuliana et al., 2022). The primary factor that not only decides whether production will continue but also has a major influence on production costs is the delivery or distribution of raw materials, which comes first in the sequence of incidents (Putra et al., 2020). In order to save costs and ensure smooth production activities, deciding on shipping alternatives and the appropriate mode of transportation might be crucial in overcoming this difficulty (Almahdi et al., 2023).
One of the primary ingredients used to make the high-protein tofu is soybeans. The distribution of soybean raw materials is essential to the entire process of making tofu. In addition to ensuring the smooth operation of tofu producers, the availability and effective distribution of these raw materials also directly influences the cost and quality of production (Hartawan & Marwan, 2017). The distribution of soybean raw materials is crucial for smooth production and quality, but it can also have an impact on cost effectiveness. Competitive tofu manufacturing prices can be maintained in large part by

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optimizing distribution and transportation expenses. The transportation model in this case is influenced by the quantity of soybeans delivered, the cost of transportation per unit, and the method of transportation service used.

The existence of multiple sources and destinations, the quantity of goods distributed from each source and required by each destination, the sending of goods from a source to a destination in proportion to the level of demand, and the cost of sending goods from a source to a destination are some of the specific characteristics of transportation problems (Amaliah et al., 2022; Moslem et al., 2023). Cost minimization and profit maximization are two categories into which the problem can be subdivided based on the function of the aim (Ahmed et al., 2021). Meanwhile, it can be classified as balanced or imbalanced depending on the quantity of supply and demand. Generally speaking, the primary objective of the transport model is to determine the most economical way to move commodities from many sources to multiple destinations. This model incorporates known factors into a system of equations and inequalities that explain the mathematical structure of the distribution problem (Mitlif et al., 2020). These variables include the number of units that may be supplied, the cost of shipping, and the number of requests to the destination. This model uses a linear program method, where the purpose is to discover solutions that optimize objective functions—in this case, the overall cost of delivery—while meeting resource allocation limitations (Evtyukov et al., 2021). The process of identifying the ideal solution must begin with the original base solution. Before the optimization process starts, initial base solutions give a summary of how the choice variables are allocated. These allocations are made using techniques like Vogel's Approximation, Northwest Corner, and Least Cost. The initial base solution is then optimized into one that minimizes overall distribution costs, or, to put it another way, becomes the optimal solution, through a series of iterations and adjustments to the allocation of items on the transport table cells. In addition to being useful for addressing distribution and logistics issues, transport models are also crucial for strategic decision-making across a range of commercial and industrial domains (M. L. Aliyu et al., 2019).

It is evident how transportation model issues are applied in manufacturing, communication networks, and logistics (Prifti et al., 2020). Prior research has investigated the efficacy of transportation models in the areas of distribution network design and optimization, supply chain efficiency enhancement, and logistical challenge resolution (Shaikh et al., 2018). Transportation models are used in production to manage product distribution, improve raw material allocation, and reduce transportation costs (Pečený et al., 2020; Sang et al., 2021). Additionally, for the most economical distribution of commodities, Batubara (2020) uses three different types of transhipment services in conjunction with transportation techniques. The study found the best alternate distribution routes and optimal cost solutions using four transportation models using the ideas of linear programming (Batubara & Widyasari, 2023). New algorithms are utilized not just to minimize overall distribution costs but also to address the issue of allocating goods from many manufacturers to multiple machines with the aim of maximizing profits (Bhadane et al., 2021; Kader & Alam, 2019). Other techniques, such evolutionary algorithms, are also used to identify the best solutions for transport models (Kusumawardani, 2017). The most economical way to move gasoline goods from warehouses to filling stations inside Iraq's borders is to compare genetic algorithms with conventional methods (linear programming) (Ashour et al., 2022). These investigations have given future research to enhance operational efficiency and resource management a solid theoretical basis.

Reviewing the distribution conditions of tofu raw materials in the company is important to identify inefficiencies and possible risks. Risks that may be associated with the distribution of tofu raw materials in companies include delays in delivery, damage or contamination of raw materials during transportation, uncertainty in supply from suppliers, increased operational costs, risks of compliance with food regulations, as well as supply chain disruptions due to external events such as natural disasters. or transportation disruptions. Lack of efficiency in distribution can also result in reduced product quality and loss of customer trust. By making improvements in the distribution process, companies can reduce these risks and increase operational efficiency. According to the justification given above, the purpose of this study is to thoroughly examine and comprehend the comparison between the shipping prices of soybean raw materials and the available delivery options for MSMEs. This research aims to maintain production continuity, boost competitiveness in a changing market, and optimize the cost and delivery channels of soybean raw materials for MSMEs that make tofu by highlighting the significance of low costs.

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2. Methods

The research taken place in the Bekasi, Karawang, and Cikampek Regencies, which are significant locations containing lots of tofu makers and supplies of soybean raw materials. The research project happened through a one-month period in 2023, beginning in October and ending in November. The research locations were chosen based on the diversity of tofu manufacturing operations and the distribution of soybean raw materials in the two areas, which enabled the collection of representative and relevant data. The selected research time frame was used to investigate distribution patterns and supply chain dynamics in depth, spanning periods that represent seasonal fluctuations or other factors that may impact distribution costs. As a result, the location and timing of the research were carefully chosen to ensure the relevance and validity of the research findings to the situation being researched. This study uses both quantitative and qualitative data. Quantitative data includes the amount of soybean results, distribution costs, and distance between production locations, while qualitative data includes consumer preferences, product quality features, and operational supply chain hurdles. Secondary data sources include literature, industry reports, and government statistics, as well as primary data from interviews with stakeholders such as tofu makers, distributors, and soybean farmers. Direct observation at manufacturing or distribution locations is frequently utilized to acquire a visual picture of operations and critical supply chain factors. The basis for determining distribution distances and routes includes geographic data, such as maps and coordinates of production and distribution locations, as well as daily or monthly operating data from the supply chain.

This study uses an experimental research technique to improve distribution costs for soybean raw materials in the context of the tofu production supply chain by using transportation models, namely the Northwest Corner (NWC) and Modified Distribution (MODI) approaches. There are two important elements to the research stage: formulation or issue formulation and problem solution, which contains seven processes that must be implemented (Fig. 1). The following is a quick description of the seven stages of this research.

The first part of this research, in the transportation issue formulation section, begins with selecting the transportation services that will be employed and collecting data on the distribution of soybean raw materials from various sources to various tofu manufacturing locations. At this first step, factors that are decision variables to decide the solution to the soybean raw material transportation model problem are also determined. The objective function and constraint function are created in the second step, which is followed by the third stage, which is the construction of a transportation model table. The transportation model problem may be stated numerically as follows:

$$Minimation\ Z = \sum_{i=1}^{m} X_{ij}\, B_{ij} \quad (1)$$

$$\sum_{j=1}^{n} X_{ij} \le a_{ij}, i = 1, 2, \ldots, m\ (function\ of\ demand\ constraint) \quad (2)$$

$$\sum_{i=1}^{m} X_{ij} \ge b_{ij}, j = 1, 2, \ldots, n\ (inventory\ constraint\ function) \quad (3)$$

$$X_{ij} \ge 0 \quad (4)$$

Where:

m denotes of the number of agents or sources
n denotes the number of destinations
a_i denotes the capacity of the agent i
b_j denotes the request at the destination j
B_{ij} denotes shipping cost per-unit from agent i to destination j
X_{ij} denotes the quantity of units of commodities transferred from agent i to destination j

An unbalanced transportation model situation is one in which the entire amount required does not equal the total quantity provided. There are two possibilities: the entire demand is larger than or less than the supply. This uneven situation can be represented as follows:

$$\sum_{i=1}^{m} a_i \ge \sum_{i=1}^{n} b_j \quad (5)$$

$$\sum_{i=1}^{m} a_i \le \sum_{i=1}^{n} b_j \quad (6)$$

The fourth and fifth stages of the study in the transportation model solution segment involve the use of transportation models, particularly the NWC and MODI approaches, as optimization tools to identify optimal allocation from source to destination while reducing distribution costs. The NWC approach is used to identify the first base solution, followed by the MODI method to get the ideal

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solution. The overall cost of delivering soybeans between the two transportation services will then be compared. Finally, in addition to determining the cheapest transportation option, distribution routes for soybean raw materials and transportation services will be developed.

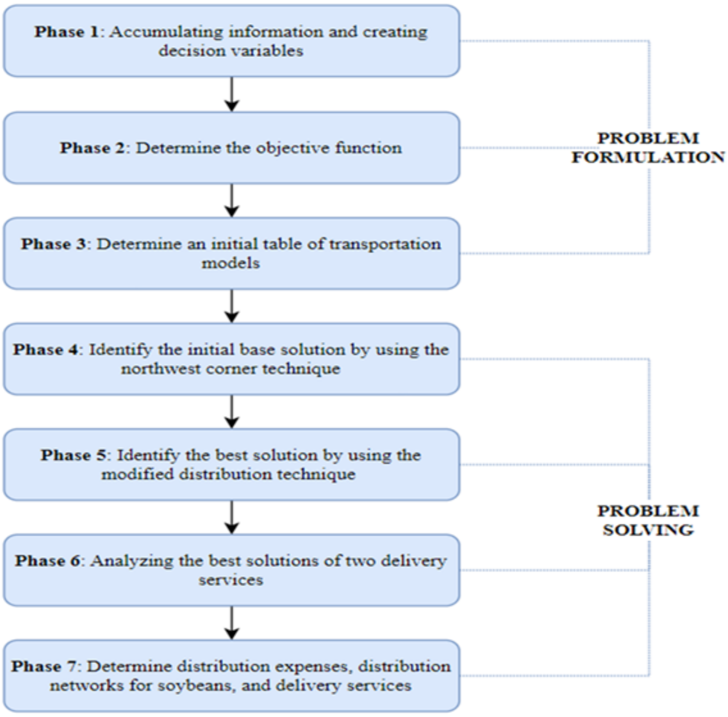

Fig. 1 Research flow.

3. Results and Discussion

The purpose of this study is to compare the prices of two distinct transportation providers. This comparison was made between the first and second transportation services in the hopes of obtaining the best value in raw material supply. The focus of this transportation analysis is on the distribution of raw materials from warehouses in Bekasi, Cikampek, Karawang, and Cibitung to the same city where the raw materials originated. In this study, two different forms of transportation services were used and classified. Table 1 contains information on distribution expenses to each city, the number of inquiries, and the number of offers.

Table 1 Total warehouse capacity and total factory demand

Agent		Factory	
Location	**Capacity (Kg)**	**Location**	**request (Kg)**
Bekasi	2000	Bekasi	1750
Cikampek	2000	Cikampek	1250
Karawang	2000	Karawang	1500
Cibitung	2000		

Table 2 then displays information on transportation costs, demand, and unit costs. Table 3 shows the transportation method table for the first transportation service based on the transportation data presented above.

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Table 2 Shipping costs, the number of requests, and the number of offers for the first transportation service

Route	Number of requests (Kg)	Cost (Rp)	
		Shipping costs	Cost / kilogram
Bekasi to Bekasi	1750	187.000	107
Bekasi to Karawang	1500	367.000	245
Cikampek to Cikampek	1250	226.000	213
Cikampek to Karawang	1500	298.000	198
Karawang to Cikampek	1250	298.000	239
Karawang to Karawang	1500	226.000	151
Cibitung to Bekasi	1750	235.750	135
Cibitung to karawang	1500	333.250	223

Table 3 Shipping costs, number of requests, number of offers for the first transportation service

Agent	Factory			Capacity
	Bekasi	Cikampek	Karawang	
Bekasi	107	-	245	2000 kg
Cikampek	-	213	198	2000 kg
Karawang	-	239	151	2000 kg
Cibitung	135	-	223	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	∑ 8000
				∑ 4500

Table 4 shows transportation data for the second transportation service, and Table 5 shows the transportation mode table.

Table 4 Shipping costs, number of requests and offers for the second transportation service

Route	Number of requests (Kg)	Cost (Rp)	
		Shipping costs	Cost / kilogram
Bekasi to Bekasi	1750	208.488	120
Bekasi to Karawang	1500	349.115	233
Cikampek to Cikampek	1250	198.224	159
Cikampek to Karawang	1500	259.895	174
Karawang to Cikampek	1250	256.420	205
Karawang to Karawang	1500	196.224	131
Cibitung to Bekasi	1750	205.831	117
Cibitung to karawang	1500	285.547	191

Table 5 Shipping costs, number of requests and offers for the second transportation service

Agent	Factory			Capacity
	Bekasi	Cikampek	Karawang	
Bekasi	120	-	233	2000 kg
Cikampek	-	159	174	2000 kg
Karawang	-	205	131	2000 kg
Cibitung	117	-	191	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	∑ 8000
				∑ 4500

The amount of raw materials shipped from the warehouses in Bekasi (T1), Cikampek (T2), Karawang (T3), and Cibitung (T4) to the same city is coded S1, S2, S3 correspondingly. The purpose is to save transportation expenses by adhering to raw material availability constraints at the agency. There are eight research variables, which are represented by letter symbols in Table 6.

From Table 6, the decision variables in this research are:
B_{11} = The number of soybeans transported from the Bekasi agent to the Bekasi factory

B_{12} = The number of soybeans transported from the Bekasi agent to the Karawang factory
B_{21} = The number of soybeans transported from the Cikampek agent to the Cikampek factory
B_{22} = The number of soybeans transported from the Cikampek agent to the Karawang factory
B_{31}= The number of soybeans transported from the Karawang agent to the Cikampek factory
B_{32} = The number of soybeans transported from the Karawang agent to the Karawang factory
B_{41} = The number of soybeans transported from the Cibitung agent to the Bekasi factory
B_{42} = The number of soybeans transported from the Cibitung agent to the Karawang factory

Table 6 Research variables

Agent	Factory		
	Bekasi (S1)	**Cikampek(S2)**	**Karawang(S3)**
Bekasi (T1)	B_{11}	-	B_{12}
Cikampek (T2)	-	B_{21}	B_{22}
Karawang (T3)	-	B_{31}	B_{32}
Cibitung (T4)	B_{41}	-	B_{42}

The goal function equation and limits of modeling this transportation problem can be discussed using the data in Tables 3 and 5.
The goal function

Minimization of first transportation services $Z_1 = 107\ B_{11} + 245\ B_{12} + 213\ B_{21} + 198\ B_{22} + 239\ B_{31} + 151\ B_{32} + 135\ B_{41} + 223\ B_{42}$

Minimization of secondary transportation services $Z_2 = 120\ B_{11} + 233\ B_{12} + 159\ B_{21} + 174\ B_{22} + 205\ B_{31} + 131\ B_{32} + 117\ B_{41} + 191\ B_{42}$

Limitation function

$B_{11} + B_{12} \leq 2000$

$B_{21} + B_{22} \leq 2000$

$B_{31} + B_{32} \leq 2000$

$B_{41} + B_{41} \leq 2000$

$B_{11} + B_{41} = 1750$

$B_{21} + B_{31} = 1250$

$B_{12} + B_{22} + B_{32} + B_{42} = 1200$

$B_{11}, B_{12}, B_{21}, B_{22}, B_{31}, B_{32}, B_{41}, B_{42} \geq 0$

Given that shipping costs vary based on the shipping route chosen, the purpose of solving this problem is to determine the optimal number of units of commodities to transport from each source to each destination. The primary goal is to meet demand from each destination while minimizing total transport costs. The NWC approach was used in this research, and the testing process was carried out utilizing MODI. It is vital to note that raw material distribution imbalances add a level of complication; thus, dummy tables are employed as a strategic tool to develop ideal delivery routes. Dummy tables are an important step in addressing distribution problems and developing cost-effective solutions.The following are the processes for resolving this case using the NWC and MODI methodologies for the first transportation service.

3.1 Results on the First Transportation Services

Calculating the costs incurred from the Table 7, Z = IDR 738,750. The total expenditures incurred to procure raw material suppliers reached IDR. 738,750 by using the first transportation service. Transportation charges, services, and other potential factors associated with the process of supplying these raw materials are all included in these prices. Companies or connected parties can do comprehensive financial analysis to understand the impact on their operational budgets, as well as analyze the effectiveness and sustainability of using first-line transportation services to meet their raw material supply demands, if they are aware of these expenses.

Table 7 The results using the NWC method for the first transportation service

Agent	Factory				Capacity
	Bekasi	Cikampek	Karawang	Dummy	
Bekasi	107 1750		245 250	0	2000 kg
Cikampek		213 1250	198 750	0	2000 kg
Karawang		239	151 500	0 1500	2000 kg
Cibitung	135		223	0 2000	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	3500	∑8000

MODI is one approach used in this testing process. This method is critical in evaluating and verifying that the finished solution reaches the intended degree of efficiency and performance. Tables 8 to 10 show the methods for addressing this case utilizing the MODI approach for the first transportation service.

Table 8 Iteration 1 of the MODI approach for the initial transportation service

Agent	Factory				Capacity
	Bekasi	Cikampek	Karawang	Dummy	
Bekasi	107 1750		245 250	0	2000 kg
Cikampek		213 1250	198 750	0	2000 kg
Karawang		239	151 500	0 1500	2000 kg
Cibitung	135		223	0 2000	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	3500	∑8000

Table 9 Iteration 2 of the MODI approach for the initial transportation service

Agent	Factory				Capacity
	Bekasi	Cikampek	Karawang	Dummy	
Bekasi	107 1750		245 250	0	2000 kg
Cikampek		213 1250	198 -	0 750 +	2000 kg
Karawang		239	151 1250 +	0 750 -	2000 kg
Cibitung	135		223	0 2000	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	3500	∑8000

When analyzing the computation results in Table 10, it is clear that no negative values were found, indicating a positive result. As a result, this condition allows the test calculations to continue using the Modified Distribution technique.

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Table 10 Iteration 3 of the MODI approach for the initial transportation service

Agent	Factory				Capacity
	Bekasi	Cikampek	Karawang	Dummy	
Bekasi	107 1750		245 -	0 250 +	2000 kg
Cikampek		213 1250	198 250 +	0 500 -	2000 kg
Karawang		239	151 1250	0 750	2000 kg
Cibitung	135		223	0 2000	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	3500	∑8000

Using Modified Distribution in this context can provide further insight into the optimal resource distribution in transportation models. In the absence of negative numbers, the next calculating procedure is intended to produce a solution that is consistent with and in compliance with the main goal, namely achieving resource distribution at a cost of Z = IDR 691,750

3.2 Results on the Second Transport Service

The results of estimating shipping costs for the second transportation service using the NWC and MODI methods are shown in Table 11. In accordance with Table 11, the transportation costs include Z = IDR 663,000.

Table 11 The results of the NWC method for the second transportation service

Agent	Factory				Capacity
	Bekasi	Cikampek	Karawang	Dummy	
Bekasi	120 1750		233 250	0	2000 kg
Cikampek		159 1250	174 750	0	2000 kg
Karawang		205	131 500	0 1500	2000 kg
Cibitung	117		191	0 2000	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	3500	∑8000

As result, the costs associated with obtaining raw material supplies by utilizing the second transportation service amount IDR 663,000. This statistic covers numerous cost aspects associated with raw material procurement, such as transportation charges and services from the transportation provider in question. Companies or individuals can perform a full review of the financial factors involved in ensuring the supply of raw materials for their operations by estimating this amount.

Next, the case resolution process using the MODI technique for the second transportation service produces answers as in Tables 12 to 14.

Table 12 Iteration 1 of the MODI approach for the second transportation service

Agent	Factory				Capacity
	Bekasi	Cikampek	Karawang	Dummy	
Bekasi	120 1750		233 250	0	2000 kg
Cikampek		159 1250	174 750	0	2000 kg
Karawang		205	131 500	0 1500	2000 kg
Cibitung	117		191	0 2000	2000 kg
Request	1750 Kg	1250 kg	1500 Kg	3500	∑8000

Table 13 Iteration 2 of the MODI approach for the second transportation service

Agent	Factory								Capacity
	Bekasi		Cikampek		Karawang		Dummy		
Bekasi	120	1750			233	-	0	250 +	2000 kg
Cikampek			159	1250	174	750	0		2000 kg
Karawang			205		131	750 +	0	1250 -	2000 kg
Cibitung	117				191		0	2000	2000 kg
Request	1750 Kg		1250 kg		1500 Kg		3500		∑8000

Table 14 Iteration 3 of the MODI approach for the second transportation service

Agent	Factory								Capacity
	Bekasi		Cikampek		Karawang		Dummy		
Bekasi	120	1750			233		0	250	2000 kg
Cikampek			159	1250	174	-	0	750 +	2000 kg
Karawang			205		131	1500 +	0	500 -	2000 kg
Cibitung	117				191		0	2000	2000 kg
Request	1750 Kg		1250 kg		1500 Kg		3500		∑8000

When no negative values were detected in the calculation results in table 14, the test results can be calculated using the Modified Distribution, namely Z = IDR 605,250.

3.3 Cost Comparison of Transportation Services

In this section, we compare the costs of transportation services between two different methods that differ in price and the type of transportation we have used to transfer soybean raw materials. The last step is to establish the ideal solution for the two transportation services utilized to transfer soybean raw materials; transportation cost solutions generated from earlier data processing are compared in Table 15.

Table 15 The comparison of optimal transportation solutions

Transportation Services	*Nort West Corner* (NWC)	*Modified Distribution* (MODI)
First	IDR 738,750	IDR 663,000
Second	IDR 691,750	IDR 605,250

There are significant discrepancies in the findings of cost calculations for transportation services utilizing the Northwest Corner (NWC) and Modified Distribution (MODI) techniques. NWC charges IDR 738,750 for the initial transportation service, while MODI charges IDR 663,000. The NWC charges IDR 691,750 for the second transportation service, whereas MODI charges IDR 605,250. As a result, the comparative results demonstrate that the second transportation service has the lowest expenses. In the previous condition, the allocation of raw materials for tofu production utilized a transportation method that restricted shipment capacity, thus limiting the possibility of large-scale deliveries. Consequently, transportation costs escalated. However, a transition to a new transportation method ensued, allowing for larger shipments at a more cost-effective rate. The shift in transportation methods for raw material allocation in the tofu industry yielded significant impacts. Previously, the constraints on shipment capacity led to high transportation costs and restricted availability of raw materials. Yet, with the adoption of the new transportation method, the industry gained the ability to transport raw

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materials in larger quantities with greater efficiency. This resulted in notable cost savings and created opportunities for scaling up production, enabling the industry to produce tofu in larger volumes. In addition to its positive impacts, it is important to acknowledge several limitations of this study. For instance, the transition in transportation methods may pose certain risks, such as increased chances of shipment failure or delays in raw material supply. Moreover, this transition may necessitate substantial initial investments to adapt to new infrastructure and logistics systems. Furthermore, this study may not have accounted for external factors that could influence the effects of the transportation method change, such as regulatory changes or fluctuations in fuel prices. Therefore, while there is potential for enhanced efficiency and profitability, it is crucial for the industry to conduct comprehensive evaluations and plan diligently before implementing such changes.

4. Conclusion

Based on the results of the research, it is expected that the implementation of transportation techniques in linear programming, such as the North West Corner (NWC) and Modified Distribution (MODI) methods, can assist industries in optimizing products transportation and lowering distribution costs. The cost to provide the initial transportation service was IDR 738,750 when determined by applying the North West Corner (NWC) approach, and IDR 691,750 when calculated using the Modified Distribution (MODI) technique. The cost for the second transportation service, determined using the North West Corner (NWC) technique, is IDR 663,000. The best cost in the Modified Distribution (MODI) computation is IDR 605,250. It is possible, based on the findings of the finished exploration, to It is expected that applying transportation techniques in linear programming, such as the North West Corner (NWC) and Modified Distribution (MODI), can assist producers in optimizing products transportation and lowering distribution costs.

The cost of the initial transportation service was IDR 738,750 when determined by applying the North West Corner (NWC) technique, and IDR 691,750 when calculated using the Modified Distribution (MODI) technique. The cost of the second transportation service was IDR 663,000 when calculated applying the North West Corner (NWC) technique. The best cost was determined by applying the Modified Distribution (MODI) technique.

The results of calculating transportation costs between two different methods can provide valuable insight for MSMEs in managing their operational costs. By choosing more efficient and economical transportation methods, MSMEs can increase their profitability and optimize resource use. In addition, a better understanding of transportation costs can also help MSMEs determine competitive selling prices, plan the distribution of raw materials more effectively, and increase the efficiency of their overall supply chain. Thus, the results of transportation cost calculations can encourage MSMEs to invest in infrastructure and technology that supports their operational efficiency, thereby increasing their competitiveness and business growth in the market.

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