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Effectiveness of Initial Solution Methods in Terms of Logistics Costs: A Maritime Supply Chain Application Based on Marble Exports

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Abstract

This study compares three widely used initial solution methods for transportation problems—the Northwest Corner Method, Least Cost Method, and Vogel's Approximation Method—within the context of maritime transportation. The research employs a two-stage methodology: first, determining the optimal solution via Linear Programming; second, generating initial solutions using the three methods. The dataset comprises marble exports transported by sea from the Western Mediterranean Region in 2024, provided by the Western Mediterranean Exporters Association. Analysis was conducted using Microsoft Excel and its Solver add-in. Results indicate that Vogel's Approximation Method yields an initial solution closest to the optimal. Consequently, the methods are ranked as follows for maritime transportation problems: Vogel's Approximation Method first, Least Cost Method second, and Northwest Corner Method third. These findings offer practical guidance to maritime sector practitioners and decision-makers by aiding in the selection of the most efficient method in terms of time and resource optimization when solving transportation problems.

Key words: Optimization, Maritime Logistics, Supply Chain Management, Transportation Problems.

JEL Code: C61, Q56, R40, L91

1. Introduction

Supply chain management (SCM) is a strategic function that enables businesses to become competitive by transforming both their internal processes and their relationships with other stakeholders in the supply chain into a harmonious and high-performance structure (Gürler et al., 2011). Within this framework, logistics management, which is one of the main sub-components of FPM, is

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responsible for the effective coordination of logistics activities such as transportation, warehousing, customs clearance and insurance (CSCMP, 2013). Therefore, logistics management plays a critical role in ensuring the overall effectiveness of the supply chain (Islam et al., 2023).

The concept of transportation is defined as the process of spatial displacement of individuals or cargoes in a fast, economical and safe manner to provide a certain benefit (Gülsün & Erkayman, 2018). This process is carried out through transportation systems with unique network structures and infrastructures such as roads, railways, maritime and airways. The utilization rates of these systems in the world, Türkiye and the Western Mediterranean Region, which constitutes the universe of the study, are shown in Table 1.

Table 1. Preference Rates of Transportation Modes by Three Geographical Regions

Mode of Transport	Western Mediterranean Region (%)	Türkiye (%)	World (%)
Air	0,1	0,4	1,1
Maritime	58,2	86,6	49,9
Rail	0,6	0,8	7,0
Road	40,0	12,3	19,8

Source: (UNCTAD, 2021; UTIKAD, 2022; Western Mediterranean Exporters Association [BAIB], arge@baib.gov.tr, 20.01.2025)

According to the data in Table 1, the most preferred mode of freight transportation by weight is maritime transportation worldwide, in Türkiye and in the Western Mediterranean Region. At all three geographical levels, air transportation stands out as the mode with the lowest utilization rate. Especially in the Western Mediterranean Region, road transportation stands out with a 40% utilization rate, which is significantly higher than the Türkiye and World averages. On the other hand, the utilization rates of rail transportation in Türkiye and the Western Mediterranean Region remain well below the world average. The biggest factor in the emergence of the situation in Table 1 is that maritime transportation is cheaper than other modes of transportation. (Takım & Ersungur, 2015).

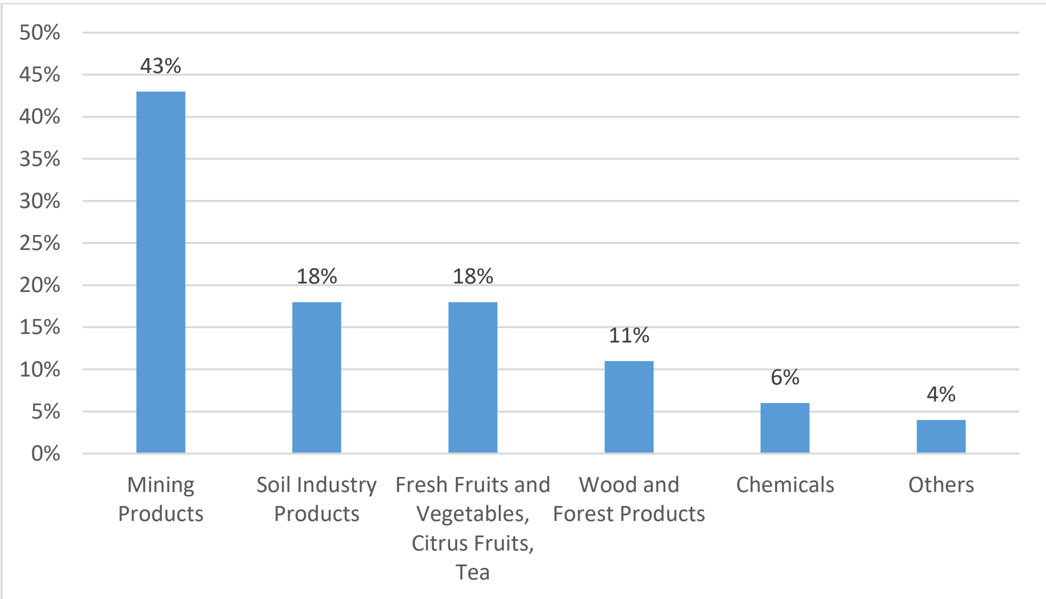
In this context, transportation, which is an important component of logistics activities, plays an indispensable function in terms of both logistics management and overall supply chain efficiency. Especially the transportation sector, which is positioned within the service sector, is a determining factor in the timely and economical provision of logistics services (Yorulmaz ve Birgün 2016). Transportation activities aim to move the products and services demanded within the scope of the supply chain at the lowest cost and effectively (Akgüngör & Demirel, 2024).

In the light of all this data, transportation activities come to the forefront in the distribution of costs in logistics processes. While logistics costs constitute between 4% and 20% of the sales price of the final product (MÜSİAD, 2014), transportation activities have the largest share in these costs. In fact, transportation-related costs play a decisive role in the cost structure of the supply chain, accounting for approximately one-third of total logistics costs (Rajesh et al., 2015). Therefore, any cost optimization in transportation processes not only increases the competitiveness and profitability of businesses but also contributes positively to the national economy.

The Western Mediterranean Region, defined as TR61 within the scope of the Statistical Classification of Territorial Units (NUTS) in Türkiye, consists of the provinces of Antalya, Burdur and Isparta. This region, which constitutes the universe of the study, accounts for approximately 1.3% of Türkiye's total export revenue according to 2024 data (TurkStat, 2024).

The sectoral distribution of products exported from the Western Mediterranean Region in terms of quantity is presented in Figure 1. When the data in the figures are analyzed, it is seen that the highest exports from the region are realized in the mining sector. This sector has a significant weight compared to other sectors, accounting for 43% of total exports.

Figure 1. Sectoral Quantity Distribution of Western Mediterranean Region Exports



Source: (Western Mediterranean Exporters Association [BAIB], arge@baib.gov.tr, 20.01.2025)

Figure 2 shows the sectoral distribution of exports by sea from the Western Mediterranean Region. According to the data in the figure, it is seen that the product groups exported via maritime transportation are concentrated in the mining sector

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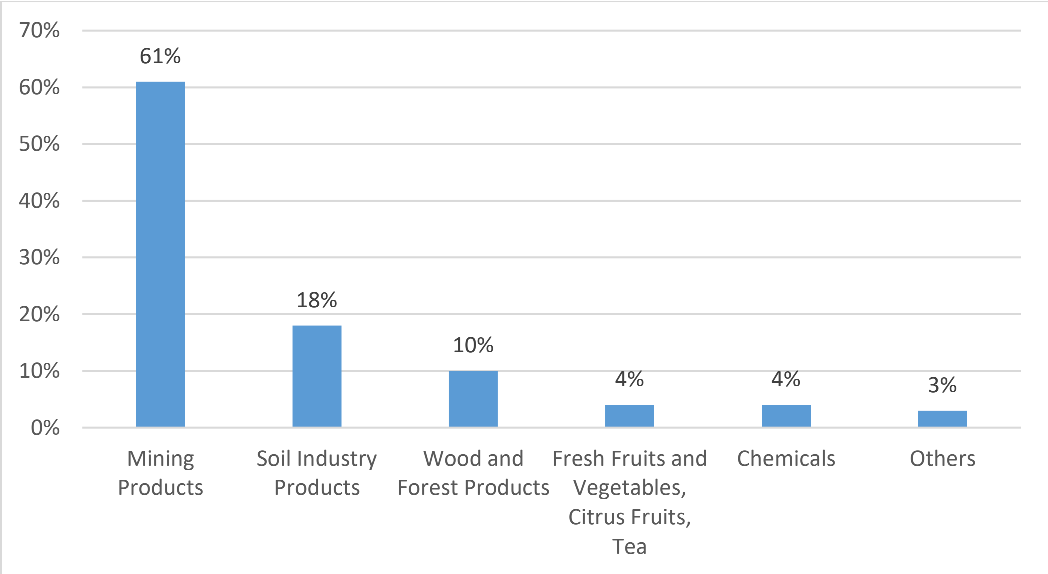
with a high rate of 61%. This situation reveals that mining products in the region are largely transported to international markets via maritime transportation.

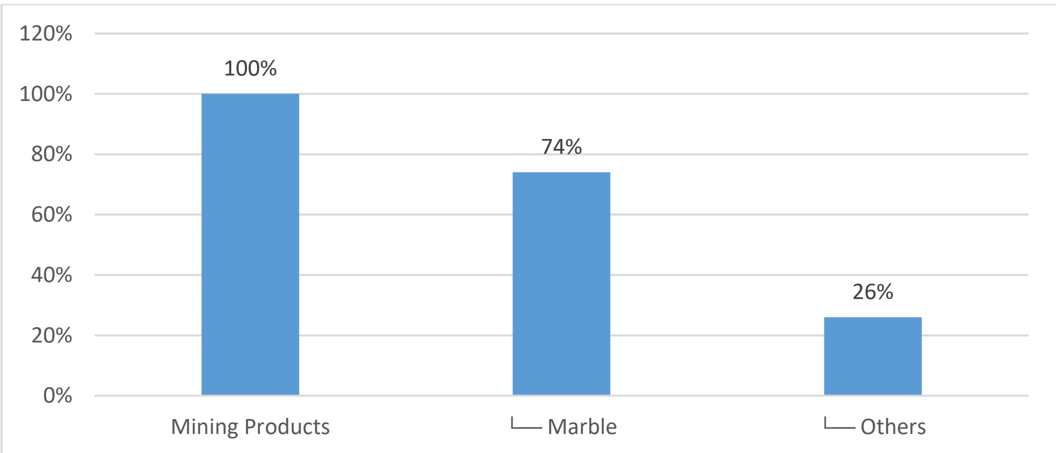
Figure 2. Sectoral Quantity Distribution of Products Exported by Sea from the Western Mediterranean Region



Source: (Western Mediterranean Exporters Association [BAIB], arge@baib.gov.tr, 20.01.2025)

Figure 3 shows that marble products have the highest share with 74% when the exports of the products belonging to the mining sector in the Western Mediterranean Region are analyzed on the basis of quantity exported by sea.

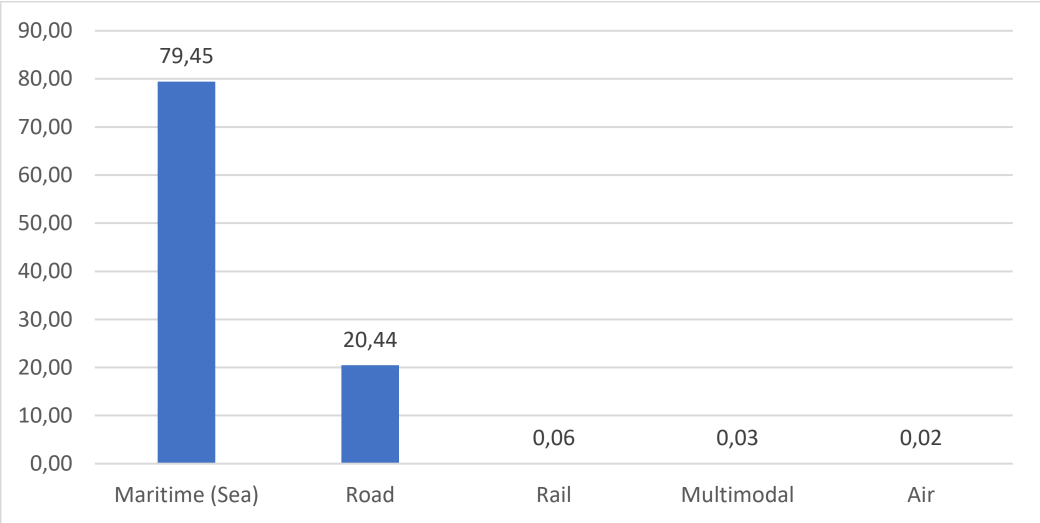
Figure 3. Quantity Distribution of Marble Products Exported by Sea in the Western Mediterranean Mining Sector



Source: (Western Mediterranean Exporters Association [BAIB], arge@baib.gov.tr, 20.01.2025)

Figure 4 shows that approximately 80% of the marble products exported from the Western Mediterranean Region are shipped by sea.

Figure 4. Distribution of Marble Exported from Western Mediterranean by Transportation Modes



Source: (Western Mediterranean Exporters Association [BAIB], arge@baib.gov.tr, 20.01.2025)

This study focuses on the optimization of transportation costs, which have an important share in logistics costs, and is designed in two stages. Excel and Excel Solver applications were used in the study. In the first stage, the current situation was optimized by Linear Programming Method. In the second stage, the methods aiming to find solutions to transportation problems with the lowest cost are examined. The Vogel Approach Model, Least Cost Method and Least Squares Method used in the initial solution phase are discussed comparatively. The effectiveness of these methods has been evaluated by analyzing their effects on total cost, and inferences have been made to determine the most appropriate approach. At this stage, the necessary data for the application process of the study was obtained from the Western Mediterranean Exporters Association via e-mail. Within the scope of maritime transportation, which is the most preferred mode of transportation in foreign trade, the application was carried out on the marble product, where 80% of the total amount of marble exported from the Western Mediterranean Region is transported by sea.

2. Literature Review

Since 2020, recent studies on transportation problems have been comparing initial solution methods such as the Northwest Corner Method (NWCM), the Least

Cost Method (LCM) and the Vogel Approximation Method (VAM) and examining the effects of these methods on cost optimization. The common finding of these studies is that the lowest transportation cost is generally achieved with VAM.

For example, Rafi and Islam (2020) compared NWCM, LCM, VAM, Row Minimum and Column Minimum methods and stated that VAM offers the most effective results in terms of initial solution. Dimasuharto and Subagyo (2021) compared the three methods and emphasized that the most appropriate result was achieved with VAM in the analysis of the distribution of 3 kg cylinders of an Indonesian company. Similarly, Olayiwola et al. (2022) analyzed the distribution costs of a company in Ibadan, Nigeria, and showed that VAM provided the lowest cost. Awogbemi et al. (2022), on the other hand, demonstrated the cost superiority of VAM in transportation problems with unbalanced supply and demand. However, it cannot be said that a single method is superior in all studies. As a matter of fact, Akbar et al. (2023) stated that in some special cases, the NWCM can provide more effective results. Haryadi and Hasanah (2024), in their study on optimizing the distribution activities of a rice milling factory in Indonesia, also stated that VAM is the most advantageous method in terms of cost. Coşkun et al. (2024) evaluated Steppingstone, Modified Distribution and various hybrid models in addition to classical methods and found that hybrid models are more successful in cost optimization. Finally, Abdelwali (2024) compared NWCM, LCM, VAM and Artificial Bee Colony (ABC) algorithm and showed that ABC algorithm, which is a meta-heuristic approach, can be an alternative to classical methods.

Although this extensive literature provides important insights into the effectiveness of initial solution methods in transportation problems, there is no study that evaluates these methods for maritime transportation. In this context, the present study makes an original contribution by comparing the near optimality of NWCM, LCM and VAM methods on a real and actual data set of marble exports by sea from the Western Mediterranean Region. Moreover, by using Excel Solver tool, an accessible and practical solution proposal is developed and contributes directly to regional transportation problems.

The main objective of this study is to analyze the proximity of the initial solution methods used in transportation problems to the optimum solution in the light of real data and to guide decision makers and practitioners in the selection of methods in terms of cost effectiveness. Thus, it is aimed to provide concrete and applicable contributions to the optimization of regional trade and logistics processes.

3. Methodology

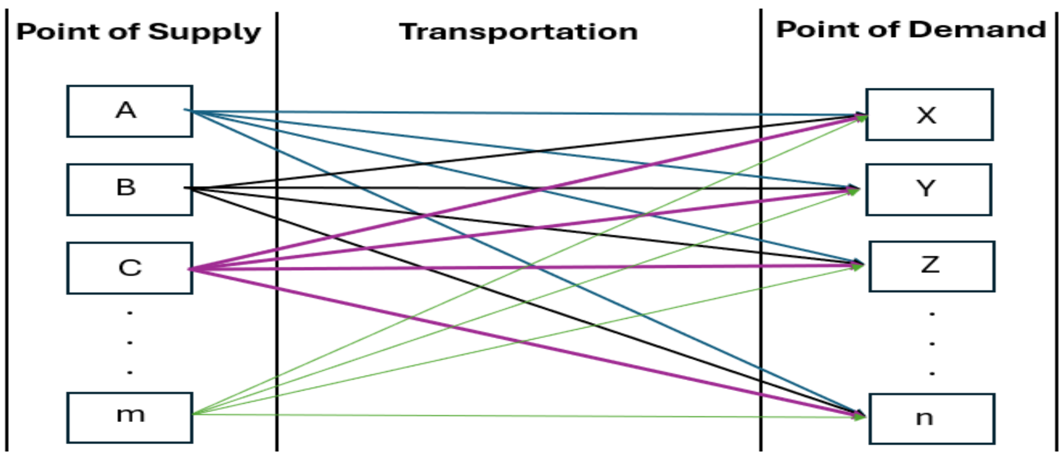
Research Model

Transportation problems are the problem of transporting resources with certain supply and demand capacities to destinations in the most cost-effective way. (Timor, 2010) A visual model of this type of problem is shown in Figure 5.

Population and Sample

The population of this study consists of all products exported by sea from the Western Mediterranean Region. However, only the marble product exported by sea was selected as the sample of the study and the analysis was carried out only on the marble product.

Figure 5. Visual Model of the Study



Data Set

The purpose of this study is to compare the near optimality of the Northwest Corner Method; the Least Cost Method and the Vogel Approximation Model used in the initial solution phase of transportation problems. Based on the results obtained, the preferability ranking of these methods for the initial solution is determined. The methodology of the study is shown in Figure 6.

Data on marble products exported from the Western Mediterranean Region in kilograms for the year 2024 were obtained from the Western Mediterranean Exporters' Association via the e-mail address "arge@baib.gov.tr" on January 20, 2025.

Data Analysis

The data obtained from the Western Mediterranean Exporters' Association were evaluated in two stages.

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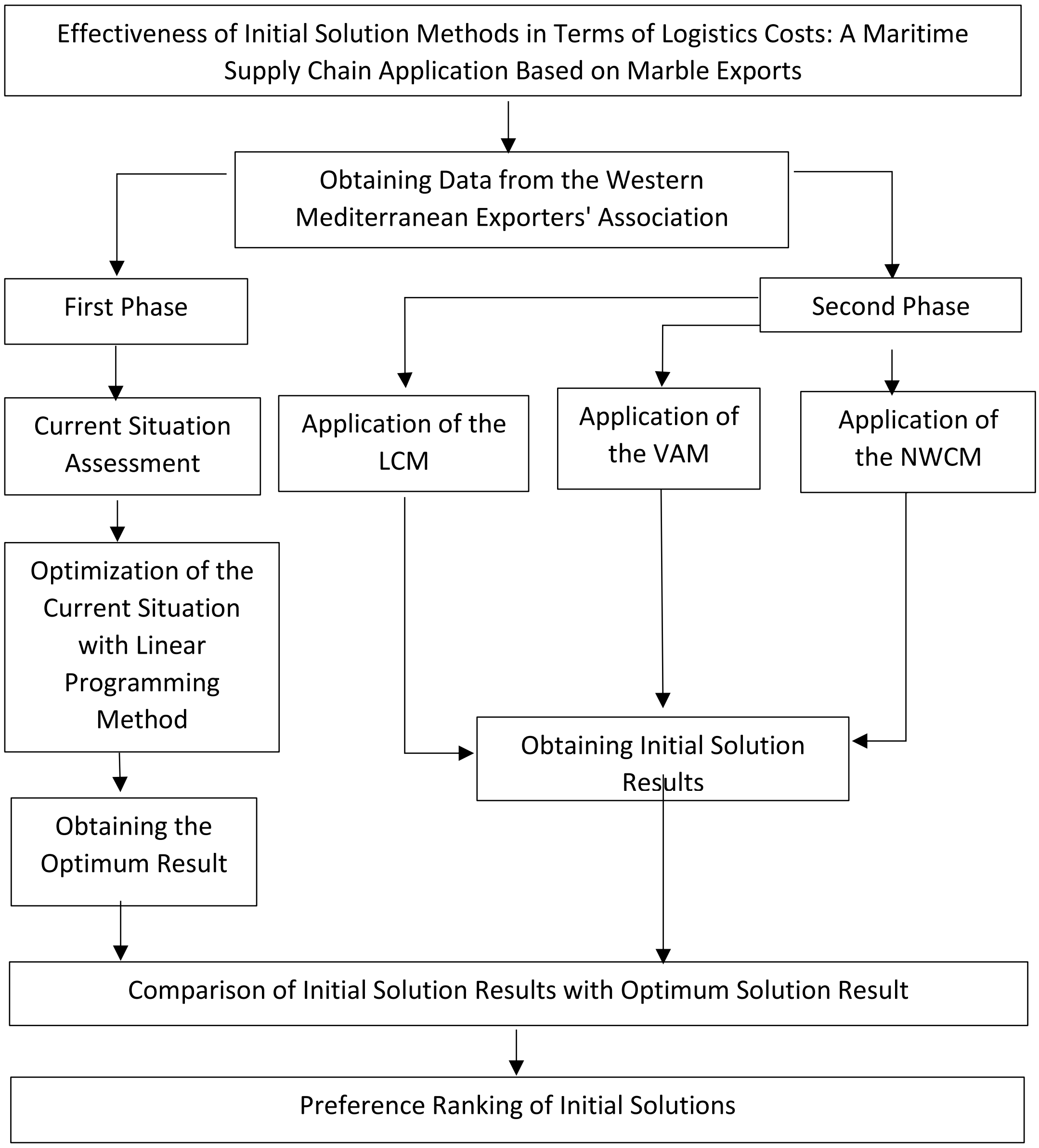
In the first stage, the current situation was analyzed. In this context, the total maritime transportation cost was calculated using Excel software, considering the shipment quantities between the customs offices of origin and export countries and the unit transportation costs for these routes. In this calculation, the *SUMPRODUCT* function shown in Formula 1 was used. Then, to determine the proximity of the transportation problem to the optimum solution, a Linear Programming Model was applied using the Excel Solver tool and the optimum transportation cost was reached.

=SUMPRODUCT (array1, [array2], [array3], ...) (1)

Figure 6. Methodology of the Study



In the second stage, the Vogel Approximation Method, the Least Cost Method and the Northwest Corner Method were applied to generate the initial solution of the transportation problems. Initial solution costs were calculated separately for each method. These cost values were compared with the optimum cost value obtained by the Linear Programming method in the first stage; thus, the level of proximity of the initial solution methods to the optimum solution was evaluated and their preferability ranking was made accordingly. The following limitations were taken into consideration in this process:

- This study is limited to the marble products exported by sea from the Western Mediterranean Region.
- Due to the limited capacity of Excel Solver to evaluate a limited number of decision variables, the analysis is limited to the top six countries to which the marble products exported from the Western Mediterranean Region are mostly shipped and the customs offices of exit for these countries.
- For the marble products exported from the Western Mediterranean Region by sea, the estimated values of the unit transportation cost (USD/ton) between the departure customs offices and the export countries were tried to be determined in accordance with today's conditions. In this context, ChatGPT, an artificial intelligence tool, was utilized since enterprises refrain from sharing their corporate cost information (See Table 1). This approach was preferred to support the data reliability of the study.

The application steps for the Vogel Approximation Method, the Northwest Corner Method and the Least Cost Method, which constitute the initial solution in the optimization of transportation problems, are presented in Table 2.

The Linear Programming Model, which assumes of the principles of Certainty, Summability, Divisibility, Linearity (or Constant Proportional Variation) and Positivity, consists of three basic formulas in its classical form (See Formulas 2, 3 and 4) (Timor, 2010).

Table 2. Appliction Steps for VAM, NWCM, LCM

Step No	VAM	NWCM	LCM
1	In the whole table, the two lowest costs in each Row and Column are selected and opportunity costs are calculated by taking the difference between these costs.	In the whole table, the two lowest costs in each Row and Column are selected and opportunity costs are calculated by taking the difference between these costs.	From the top left corner of the whole table, the highest amount is assigned by considering the supply and demand amounts.
2	The rows and columns are examined and the cell with the lowest cost in the row or column with the highest	The rows and columns are examined and the cell with the lowest cost in the row or column with the highest opportunity cost is assigned	The row or column whose Supply and Demand amounts are met is eliminated. Also, if the supply and demand amounts in the assigned cell

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	opportunity cost is assigned to the highest amount, considering the supply and demand amounts.	to the highest amount, considering the supply and demand amounts.	are the same, both row and column can be eliminated.
3	The fully loaded row/column is discarded. However, if a row and column are satisfied at the same time, only one of them is eliminated and the other is assigned a value of zero.	This process continues until the supply and demand quantities in all rows and columns are met.	The assignment process continues with the next lowest cost cell, considering the supply and demand quantities in the row and column.
4	The first three steps continue until the supply and demand quantities in all rows and columns are met.		The first three steps continue until the supply and demand quantities in all rows and columns are met.

Source: (Timor, 2010; Alkubaisi, 2015)

Objective Function : $$Z_{Max} \text{ or } Z_{Min} = \sum_{j=1}^{n} c_j x_j \quad (2)$$

Constraints : $$\sum_{i=1}^{m} \sum_{J=1}^{n} a_{ij} x_j \leq b_i \quad (3)$$

Positivity Constraint : $$(x_j \geq 0, \quad i = 1, 2, 3, \dots, m; \quad j = 1, 2, 3, \dots, n) \quad (4)$$

4. Research and Findings

In this section, the stages of the study and the findings are presented.

First Phase Applications

At this stage, the current period was optimized by Linear Programming Method, and the minimum cost value was reached. Excel Solver add-in was used in this process.

Current Situation Calculation

Table 3 presents the estimated unit maritime transportation costs (USD/ton) for marble products exported by sea from the Western Mediterranean Region between customs offices and export countries as of 2025.

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Table 3. Estimated Maritime Transportation Costs between Customs Directorates and Export Countries in 2025 (USD/ton)

Customs Directorates	China People's Republic	Saudi Arabia	United States	India	Libya	United Arab Emirates
Tekirdağ	75	62	125	68	56	70
Aliağa	72	60	120	65	54	68
Mersin	80	59	115	62	50	65
Derince	76	63	130	70	58	72
İskenderun	71	58	118	64	52	67
Antalya	77	61	128	69	55	71
Gemlik	82	64	135	72	60	73
İzmir	73	57	120	63	51	66
Ambarlı	81	62	130	68	57	70

Source: (OpenAI, 2025)

In the current period, the quantities of marble sent by sea from the customs directorates to export countries, the total quantities of marble leaving the customs directorates (supply quantity) and the quantities of marble demanded by the relevant countries (demand quantity) are presented in Table 4 (Western Mediterranean Exporters' Association [BAIB], arge@baib.gov.tr, 20.01.2025). In addition, the product quantities in Table 4 and the unit transportation costs given in Table 3 were multiplied by using Formula 1 in the Excel program and because of these calculations, the total transportation cost for the current period was determined as USD 67,147,013.

Table 4. Shipment Quantities (Tons) and Cost Value (USD) in the Current Period

Customs Directorates	China People's Republic	Saudi Arabia	United States	India	Libya	United Arab Emirates	Supply
Tekirdağ	288.905	37.975	16.411	28.765	0	6438	378.493
Aliağa	79.175	32.036	57.900	3028	19.921	12.185	204.245
Mersin	58.779	5.960	20	11.478	0	283	76.520
Derince	167.620	0	2	0	0	0	167.622
İskenderun	72	27	0	291	0	53	443
Antalya	18.310	0	103	74	0	0	18.486
Gemlik	6.936	0	85	905	0	0	7.926
İzmir	13.509	78	200	0	979	0	14.767
Ambarlı	3.672	8	5	6	52	3	3.746
Demand	636.977	76.084	74.726	44.546	20.953	18.962	872.248
Current Cost (USD)					**67.147.013**		

Source: (Western Mediterranean Exporters Association [BAIB], arge@baib.gov.tr, 20.01.2025)

Application of Linear Programming Method (LP)

In this part of the study, the Linear Programming model (Özkan, 2025) developed for fresh fruit and vegetable products exported by sea from the Western Mediterranean Region (See Formulas 5, 6, 7, 8 and 9) was applied to marble products in order to determine the proximity of the Northwest Corner Method, Least Cost Method and Vogel Method, which constitute the initial solution stage of the current period optimization and transportation problems, to the optimum solution. The optimum/minimum cost value obtained because of the Linear Programming Model solved with Excel Solver is USD 66.079.755 as seen in Table 5.

Notations

i	:	[1,2,3, …, m] Customs offices where the marble product exits
j	:	[1,2,3, …, n] Countries where the marble product is shipped
x_{ij}	:	Quantity of Marble product sent from "i" customs directorate to "j" country
c_{ij}	:	Unit transportation cost value of marble product sent from "i" customs directorate to "j" country (USD/Ton)
t_j	:	Demand for marble products in country "j"
a_i	:	Quantity of marble product exiting at "i" customs office (supply quantity)

Objective Function :

$$Z_{Min} = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij}\, c_{ij} \qquad (5)$$

Objective Function :

$$x_{ij} \qquad (6)$$

Constraints :

Demand Constraint :

$$\sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \geq t_j \qquad (7)$$

Supply Constraint :

$$\sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \leq a_i \qquad (8)$$

Positivity Constraint :

$$(x_{ij} \geq 0\,, \quad i = 1,2,3,\ldots,m; \quad j = 1,2,3,\ldots,n) \qquad (9)$$

Table 5. Linear Programming Shipment Quantities (Tons) and Achieved Cost Values (USD)

Customs Directorates	China People's Republic	Saudi Arabia	United States	India	Libya	United Arab Emirates	Supply
Tekirdağ	264.668	31.159	0	42.752	20.953	18.962	378.493
Aliağa	204.245	0	0	0	0	0	204.245
Mersin	0	0	74.726	1.794	0	0	76.520
Derince	167.622	0	0	0	0	0	167.622
İskenderun	443	0	0	0	0	0	443
Antalya	0	18.486	0	0	0	0	18.486
Gemlik	0	7.926	0	0	0	0	7.926
İzmir	0	14.767	0	0	0	0	14.767
Ambarlı	0	3.746	0	0	0	0	3.746
Demand	636.977	76.084	74.726	44.546	20.953	18.962	872.248
Cost Value (USD)				66.079.755			

Second Phase Applications

At this stage, Northwest Corner Method, Least Cost Method, Vogel Approach Model initial solution methods used for optimization of transportation problems were applied. Excel program was used in the application process.

Application of the Northwest Corner Method (NWCM)

Table 6 presents the application results of the Northwest Corner Method. The shipment quantities in Table 6 and the unit cost values given in Table 3 were multiplied by using Formula 1 in the Excel program and the total cost value was calculated as USD 67,420,324.

Table 6. Northwest Corner Method Shipment Quantities (Tons) and Achieved Cost Value (USD)

Customs Directorate	China People's Republic	Saudi Arabia	United States	India	Libya	United Arab Emirates	Supply
Tekirdağ	378.493	0	0	0	0	0	378.493
Aliağa	204.245	0	0	0	0	0	204.245
Mersin	54.239	22.281	0	0	0	0	76.520
Derince	0	53.803	74.726	39.092	0	0	167.622
İskenderun	0	0	0	443	0	0	443
Antalya	0	0	0	5.011	13.475	0	18.486
Gemlik	0	0	0	0	7.477	449	7.926
İzmir	0	0	0	0	0	14767	14.767
Ambarlı	0	0	0	0	0	3746	3746
Demand	636.977	76.084	74.726	44.546	20.953	18.962	872.248
Cost Value (USD)				67.420.324			

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Application of the Least Cost Method (LCM)

Table 7 shows the amount of marble shipped from customs offices to export countries within the scope of the application results of the Least Cost Method. The shipment quantities in Table 7 and the unit cost values given in Table 3 were multiplied by using Formula 1 in the Excel program and as a result of this process, the total cost value was calculated as USD 66.903.990.

Table 7. Least Cost Method Shipment Quantity (Tons) and Achieved Cost Value (USD)

Customs Directorate	China People's Republic	Saudi Arabia	United States	India	Libya	United Arab Emirates	Supply
Tekirdağ	378.493	0	0	0	0	0	378.493
Aliağa	135.430	5.308	0	44.546	0	18.962	204.245
Mersin	0	55.568	0	0	20.953	0	76.520
Derince	123.054	0	44.568	0	0	0	167.622
İskenderun	0	443	0	0	0	0	443
Antalya	0	0	18.486	0	0	0	18.486
Gemlik	0	0	7.926	0	0	0	7.926
İzmir	0	14.767	0	0	0	0	14.767
Ambarlı	0	0	3.746	0	0	0	3.746
Demand	636.977	76.084	74.726	44.546	20.953	18.962	872.248
Cost Value (USD)					66.903.990		

Appication of the Vogel Approach Model (VAM)

Table 8 presents the shipment quantities and total cost value obtained as a result of the 12-step application of the Vogel Approach Model (See Appendix 1). The total cost is calculated by multiplying the unit costs in Table 3 by the shipment quantities in Table 8 using Formula 1. As a result of this calculation, the total cost value was found to be USD 66,265,126.

Table 8. Vogel Approach Model Shipment Quantities (Tons) and Achieved Cost Value (USD)

Customs Directorate	China People's Republic	Saudi Arabia	United States	India	Libya	United Arab Emirates	Supply
Tekirdağ	378.493	0	0	0	0	0	378.493
Aliağa	140.534	0	63.711	0	0	0	204.245
Mersin	0	0	0	44.546	20.953	11.022	76.520
Derince	117.950	49.672	0	0	0	0	167.622
İskenderun	0	0	443	0	0	0	443

Antalya	0	18.486	0	0	0	0	18.486
Gemlik	0	7.926	0	0	0	0	7.926
İzmir	0	0	10.573	0	0	4.194	14.767
Ambarlı	0	0	0	0	0	3.746	3.746
Demand	636.977	76.084	74.726	44.546	20.953	18.962	872.248
	Cost Value (USD)				66.265.126		

Table 9 presents a comparison of the current period's cost value; the optimum cost value obtained as a result of the Linear Programming Model and the cost values of the classical initial solutions. According to the findings obtained from Table 9;

The cost value obtained with the Vogel Approach Model was realized USD185.371 above the optimum cost value.

- The cost obtained as a result of the Least Cost Method is USD824.236 higher than the optimum cost value.
- The current period's cost value is USD1.067.258 more than the optimum cost value.
- The cost value obtained with the Northwest Corner Method is USD1.340.569 above the optimum cost value and is also higher than the current period cost value.

Table 9. Comparison of Cost Values of the Methods Used in Practice

Method	Cost Values (USD)
Linear Programming Method (A)	66.079.755
Vogel Approach Model (B)	66.265.126
Least Cost Method (C)	66.903.990
Current Status (D)	67.147.013
Northwest Corner Method (E)	67.420.324
B-A	185.371
C-A	824.236
D-A	1.067.258
E-A	1.340.569

In line with the findings obtained in Table 9, the ranking of the initial solution methods for transportation problems according to their proximity to the optimum solution is given in Table 10. As a result of this ranking, it is determined that the Vogel Approximation Method is the closest initial solution method to the optimum solution.

Table 10. Ranking of Initial Solution Methods According to Their Proximity to the Optimum Solution

Initial Solution Method	Ranking by Proximity to the Optimum Solution
Vogel Approach Model (B)	1
Least Cost Method (C)	2
Northwest Corner Method (E)	3

5. Conclusions

In this study, the transportation problem of marble products exported by sea from the Western Mediterranean Region is analyzed with three different initial solution methods: Northwest Corner Method, Least Cost Method and Vogel Approximation Model. The results obtained are compared in terms of the closeness of each method to the optimum solution found by linear programming and the effectiveness of the methods is ranked.

The findings of the analysis show that the Vogel Approach Model provides the most efficient initial solution in terms of total cost and gives the closest results to the optimum solution. This finding is in line with similar studies in the literature by Rafi and Islam (2020), Dimasuharto and Subagyo (2021), Olayiwola et al. (2022) and Haryadi and Hasanah (2024). Moreover, Awogbemi et al. (2022) emphasized that the Vogel Approach Model provides cost advantage under unbalanced supply-demand conditions, while Akbar et al. (2023) pointed out the effectiveness of the Northwest Corner Method in certain situations. On the other hand, Coşkun et al. (2024) reported that hybrid models developed by Coşkun et al. (2024) are more successful in cost optimization compared to classical methods.

In general, there is a consensus in the literature that the Vogel Approximation Model often gives the best results among the initial solution methods for transportation problems. However, it should not be ignored that there may be differences in the performance of the methods depending on the structural characteristics of the problem.

The Excel Solver-based linear programming approach used in this study has been found to be an effective tool for solving transportation problems in terms of both accessibility and performance. This once again demonstrates the importance of computer-aided optimization techniques in practical applications.

Considering the logistics infrastructure and maritime export potential of the Western Mediterranean Region, it is evaluated that cost-effective transportation solutions will provide significant contributions to the regional economy. Moreover, by comparing different methods, the decisive effect of the solution approach used in transportation planning on the results is clearly demonstrated.

As a result, it is recommended that future work should focus on developing more comprehensive and dynamic transportation solutions by integrating classical methods with hybrid models and artificial intelligence-based optimization techniques

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Appendix 1. Excel Application of the Vogel Approximation Method

Customs Directorates	PRC	SA	USA	IN	LY	UAE
Tekirdağ	75	62	125	68	56	70
Aliağa	72	60	120	65	54	68
Mersin	80	59	115	62	50	65
Derince	76	63	130	70	58	72
İskenderun	71	58	118	64	52	67
Antalya	77	61	128	69	55	71
Gemlik	82	64	135	72	60	73
İzmir	73	57	120	63	51	66
Ambarlı	81	62	130	68	57	70
1. Step	71	57	115	62	50	65
	72	58	118	63	51	66
	1	1	3	1	1	1
2. Step	71	57	115	62	0	65
	72	58	118	63	0	66
	1	1	3	1	0	1
3. Step	71	57	115	62	0	65
	72	58	118	63	0	66
	1	1	3	1	0	1
4. Step	71	57	115	62	0	65
	72	58	118	63	0	66
	1	1	3	1	0	1
5. Step	71	0	115	62	0	65
	72	0	118	63	0	66
	1	0	3	1	0	1
6. Step	71	0	115	0	0	65
	72	0	118	0	0	66
	1	0	3	0	0	1
7. Step	71	0	118	0	0	66
	72	0	120	0	0	67
	1	0	2	0	0	1
8. Step	71	0	118	0	0	66
	72	0	120	0	0	67
	1	0	2	0	0	1
9. Step	71	0	118	0	0	0
	72	0	120	0	0	0
	1	0	2	0	0	0
10. Step	71	0	118	0	0	0
	72	0	120	0	0	0
	1	0	2	0	0	0
11. Step	71	0	118	0	0	0
	72	0	120	0	0	0
	1	0	2	0	0	0
12. Step	0	0	118	0	0	0
	0	0	120	0	0	0
	0	0	2	0	0	0

Customs Directorates	1. Step			2. Step			3. Step			4. Step		
Tekirdağ	56	62	6	62	68	6	62	68	6	62	68	6
Aliağa	54	60	6	60	65	5	60	65	5	60	65	5
Mersin	50	59	9	59	62	3	59	62	3	59	62	3
Derince	58	63	5	63	70	7	63	70	7	63	70	7
İskenderun	52	58	6	58	64	6	58	64	6	58	64	6
Antalya	55	61	6	61	69	8	0	0	0	0	0	0
Gemlik	60	64	4	64	72	8	64	72	8	0	0	0
İzmir	51	57	6	57	63	6	57	63	6	57	63	6
Ambarlı	57	62	5	62	68	6	62	68	6	62	68	6

Customs Directorates	5. Step			6. Step			7. Step			8. Step		
Tekirdağ	68	70	2	70	75	5	70	75	5	70	75	5
Aliağa	65	68	3	68	72	4	68	72	4	68	72	4
Mersin	62	65	3	65	80	15	0	0	0	0	0	0
Derince	70	72	2	72	76	4	72	76	4	72	76	4
İskenderun	64	67	3	67	71	4	67	71	4	67	71	4
Antalya	0	0	0	0	0	0	0	0	0	0	0	0
Gemlik	0	0	0	0	0	0	0	0	0	0	0	0
İzmir	63	66	3	66	73	7	66	73	7	66	73	7
Ambarlı	68	70	2	70	81	11	70	81	11	0	0	0

Customs Directorates	9. Step			10. Step			11. Step			12. Step		
Tekirdağ	75	125	50	75	125	50	0	0	0	0	0	0
Aliağa	72	120	48	72	120	48	72	120	48	120	0	120
Mersin	0	0	0	0	0	0	0	0	0	0	0	0
Derince	76	130	54	0	0	0	0	0	0	0	0	0
İskenderun	71	118	47	71	118	47	71	118	47	118	0	118
Antalya	0	0	0	0	0	0	0	0	0	0	0	0
Gemlik	0	0	0	0	0	0	0	0	0	0	0	0
İzmir	73	120	47	73	120	47	73	120	47	120	0	120
Ambarlı	0	0	0	0	0	0	0	0	0	0	0	0