Building a three-dimensional maritime transport model to find the best solution by using the heuristic algorithm

Basher Faisal Mohammed ^{a*}, Obaid Mahmood Mohsin Alzawbaee ^b, Altaiyb Omer Ahmed Mohammed ^c

^a Phd Student, Sudan University Of Science And Technology

^b Business Administration Department, Chihan Universtiy-Suliamanya

^c Department of Statistics, Sudan University Of Science And Technology

Abstract

The aim of this research is to construct a three-dimensional maritime transport model to transport nonhomogeneous goods (k) and different transport modes (v) from their sources (i) to their destinations (j), while limiting the optimum quantities x_{ijk}^v to be transported at the lowest possible cost c_{ijk}^v and time t_{ijk}^v using the heuristic algorithm, Transport problems have been widely studied in computer science and process research and are one of the main problems of transport problems that are usually used to reduce the cost or times of transport of goods with a number of sources and a number of destinations and by means of transport to meet the conditions of supply and demand.

Transport models are a key tool in logistics and supply chain management to reduce costs, times or improve services, In this study Three algorithms were proposed to solve the transport matrix (Range(R), Arithmetic Mean(AM), Cost Slop(CO)), and this algorithm must meet the requirements of problem restrictions and goals to reach good solutions, and may sometimes be the optimal solutions so we will adopt any solutions that are the best and optimal through our findings in the application of heuristic algorithms and based on the final results can be based on the heuristic method., The research concluded that the best reasoning method is the (arithmetic mean(AM)) because it gave the best results in reducing the total (cost and time) before and after the optimization method (MODI), It also gave the cost inclination method less total costs and time higher than the method of arithmetic mean After conducting the optimization method(MODI)

Keywords: *Maritime Transportation Model, Heuristic Algorithms, Best Solution, Total Cost, Total Time.*

1. Introduction

Maritime transportation plays an important and significant role in the economic life of different countries, and is an influential factor in the economic development plan, and represents the backbone and main pillar of the foreign trade movement, as well as the transport and delivery of goods at the specified place and time, and there have been radical technological developments for shipping for a period between the Brussels Convention (1924-1968) and the Hamburg Convention in 1978, which led some to call it the technological revolution in maritime navigation, and one of the manifestations of this revolution is the participation of developing countries in the maritime transport of goods, which is one of the pillars of international trade at present, and the question of time and appointments is becoming increasingly important, especially as this trade process accelerates, Where international trade depends 85 percent on maritime transport movement [5],[3].

* Corresponding author

Email address: Basher_a@mauc.edu.iq (Basher Faisal Mohammed)

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Maritime transport adds an economic benefit (Spatial and Temporal), by transporting it from one place to another and is a distribution activity due to its main role in the process of exchange and distribution of goods locally, The transport service has become an important function at the external and internal level of the countries, especially the maritime transport function, and its importance is due to the fact that it contributes to the import and export of various types of goods using different types of ships, which leads to increased efficiency and achieving the desired objectives of the transport process in order to reach to the lowest possible transportation costs [9],[10].

There have been many differences between land and sea transport and classic transport models are not good for maritime transport, because of the difficult problems facing maritime transport and because they do not take into account the type and characteristics of different modes of transport for the transport of different goods as well, and due to the technological progress that has taken place over recent years, there has been a great need to build a model that will have an impact on the transfer of goods from the resources to the destinations requesting them and the introduction of new indicators and modern algorithms to find the best solutions to the problems of maritime transport [5].

2. Maritime Transport Model

Due to the progress in the Maritime transport sector for the transport of homogeneous goods or nonhomogeneous goods from sources i^{th} to the destinations requesting them j^{th} with different modes of transport, and the extensive technological progress that has taken place over recent years has caused a great need to build the maritime transport model and conduct theoretical and practical experiments on it, to get the best solutions to the problems facing this sector[2].

In order to build a mathematical model of maritime transport, all indicators of maritime transport must be taken into account through the introduction of new indicators such as nonhomogeneous vessels used in the transport of homogeneous goods, or nonhomogeneous goods by means of transport homogeneous vessels, and solving it practically, the model reflects all functions and theoretical constraints that can be easily implemented and controlled and measured their performance during the experiment, and that the results to be obtained empirically are the basis for evaluating the model therefore, must understand the parameters of shipping costs and times before starting to build a three-dimensional and multi-purpose maritime transportation model [6],[21].

3. Three-Dimensional Maritime Transport Model. (Modified)

Due to the progress in the maritime transport sector for the transport of (homogeneous and nonhomogeneous goods) and the multiplicity of modes of maritime transport and it varies in (speed and size). which has occurred over recent years caused a great need to build a maritime transport model, meet the requirements of the objectives which are the arrival of optimal quantities from the sources of its processing (i^{th}) to destinations requesting them (j^{th}) with the lowest total transport costs and transport times at the best possible solutions to the problems facing this sector [13].

In the problem of classic transport (two-dimensions) one commodity is transferred from all sources (i^{th}) to all destinations (j^{th}), the goal is to determine the quantities of (homogeneous goods) that are transported through methods so that the total cost of transport is reduced, and this model is considered inappropriate and impractical to solve maritime transport problems because businessmen and institutions have resorted to trade in different types of goods to increase the profits of their enterprises. The two-dimensional transport model has been developed into a more realistic and practical model, the three-dimensional maritime transport model, and the problem of three-dimensional transport arises when we need to transport nonhomogeneous goods from products from sources to the destinations requesting them, as well as the type of mode of transport or type of transport or of product and assuming it (k) Based on what was achieved through the study of two- three dimensional transport mode, the model of three dimensions and multi- stage and targets has been developed by building a model of two functions to the goal [1],[12].

The first objective is to reduce the total transport costs, and the second function (reducing the total transport time) of the Longest Active Transport Route for goods (nonhomogeneous) items and modes of transport (homogeneous) and different in terms of speed and size. So we have to analyze the impact of different types of ships and goods, so the standard third variable will determine the type of goods (k) that are nonhomogeneous and transported by the v -type ship transport [1],[12] ,The requirements for the construction of three-dimensional multi-goals maritime transport model are the lowest total cost and time and will be clarified as follows:

3.1. Total Cost Minimizing

When intended to import (homogeneous nonhomogeneous) goods) from different sources there are costs that add value to the goods, and costs do not add value to the goods, and these costs constitute a large percentage of the cost of importing goods, and therefore improving them is the challenge of transport problems to get the best competitive advantages in importing the goods from various sources and create a competitive advantage in the labor market [16].

By building and solving transport models, their distribution methods are determined and distribution centers or warehouses are identified near investors or customers, as well as determining means of transport, taking into account the costs of transporting one unit of products and may vary depending on the type of product or by weight and size. The aim of the transport models is to determine the quantities shipped from each source to each destination to reduce the total cost of shipping while meeting the constraints of supply and demand, as the transport problem has now become a standard application for industrial enterprises that have many distribution centers for their different goods [16],[4].

The cost matrix can be represented in the three-dimensions maritime transport model and as in (Table. 1)

Table(1): shows the cost matrix of the three-dimensions maritime transport model. (Prepared by the researcher)

Destinations												
distribution centers or warehouses		type vessel(v)	Products (k)	D1		D2		.....	Dm		supply for products	
				Required quantity	Shipping Time	Required quantity	shipping Time		Required quantity	shipping Time		
	Dt1	I	a	x11a	c11a	x12a	c12a	.....	x1ma	c1ma	O1a	
			b	x11b	c11b	x12b	c12b	.....	x1mb	c1mb	O1b	
			K	x11k	c11k	x12k	c12k	.....	x1mk	c1mk	O1k	
	Dt2	II	a	x12a	c12a	x22a	c22a	.....	x2ma	c2ma	O2a	
			b	x12b	c12b	x22b	c22b	.....	x2mb	c2mb	O2b	
			K	x12k	c12k	x22k	c22k	.....	x2mk	c2mk	O2k	
												
	Dtn	M	a	xn1a	cn1a	xn2a	cn2a	.....	xnma	cnma	Ona	
			b	xn1b	cn1b	xn2b	cn2b	.....	xnmb	cnmb	Onb	
			K	xn1k	cn1k	xn2k	cn2k	.....	xnmk	cnmk	Onk	
		demand for products		d1a		d2a		.....	dma			
				d1b		d2b		.....	dmb			
				d1k		d2k		.....	Dmk			

The rows represent distribution centers (i) and display parameters O_{ik} and the columns represent of requesting destinations (j) and parameters of request d_{jk} when the column intersects with the row the costs per unit must be registered (i,j) and x_{ijk}^v solution variables by sending a quantity of goods (k) from distribution centers (i) to the requesting destinations (j) and by means of transport type (v), based on the cost matrix in Table. 1 which has been clarified, the model can now be built in the following modified mathematical formula;

Objective function

$$Minz1 = \sum_{i=1}^n \sum_{j=1}^m \sum_{k=a}^K c_{ijk}^v x_{ijk}^v, \quad \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (1)$$

$$\sum_{i=1}^n x_{ijk}^v = O_{ik}, \quad \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (2)$$

$$\sum_{j=1}^m x_{ijk}^v = d_{jk}, \quad \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (3)$$

$$O_{ik} = d_{jk}, \quad \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (4)$$

$$x_{ijk} \geq 0 \quad \text{for all } i, j, k \quad (5)$$

The objective of equation (1) is to determine the minimum cost of transporting the goods of type (k) from different sources (i) to the requesting destinations (j) by means of transport type (v), and equation no.(2) represents the quantities offered from distribution centers (j) for the various requesting destinations (j) of the different products (k), equation no.(3) represents the quantities required by requesting destinations (j) of different products (k) of distribution centers (i), equation number (4) is the balance equation and the total quantities of product supply (k) of distribution centers (i) must be equal to the sum of the quantity of the requesting destinations (j), as well as the equation number (5) is a non-negative equation and must be equal to zero or greater or equal to zero and must be positive.

Where:

$$\text{Are model indicators for each : } i, j, k, v, \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\}$$

c_{ijk}^v : The cost of sending (goods) from distribution centers (i) to the destinations requesting them (j) for the product type (k) by means of transport (v)

x_{ijk}^v : Represents the number of units to be sent from distribution centers (i) to the requesting destinations (j) of the product type (k) by means of transport type (v)

o_{ik} : The quantity provided by distribution centers (i) of the goods (k)

d_{jk} : required quantities by the requesting destinations of the product type (k)

3.2. The Minimizing Total Time

Transport time considers special case and important source of real transport problems, and is suitable for a range of problems in which the total transfer time for goods is reduced from sources (i^{th}) to destinations (j^{th}) and by means of transport type (v), thus the time of transport is important of transport costs and when there is a need to transport products with a short storage period with the lowest total transport time for the active transport route. Therefore, it is possible to build a model that contains the objective function and according to the above, and in such situations instead of reducing the cost, the goal is to reduce the maximum time for the transport of all goods, and meet certain conditions with regard to availability in sources and requirements in destinations, so that the speed of delivery of goods is more important of the cost [20],[11],[14]. The time matrix can be represented in the three-dimensions maritime transport model as in (Table. 2)

Table(2): Represents Time Matrix For Three-Dimensions Maritime Transport Model. (Prepared by the researcher)

		Destinations									
distribution centers or warehouses	type vessel(v)	Products (k)	D1		D2		.....	Dm		supply for products	
			Required quantity	Shipping Time	Required quantity	shipping Time		Required quantity	shipping Time		
	Dt1	I	a	x11a	t11a	x12a	t12a	.....	x1ma	t1ma	O1a
			b	x11b	t11b	x12b	t12b	.....	x1mb	t1mb	O1b
			K	x11k	t11k	x12k	t12k	.....	x1mk	t1mk	O1k
	Dt2	II	a	x12a	t12a	x22a	t22a	.....	x2ma	t2ma	O2a
			b	x12b	t12b	x22b	t22b	.....	x2mb	t2mb	O2b
			K	x12k	t12k	x22k	t22k	.....	x2mk	t2mk	O2k
											
	Dtn	M	a	xn1a	tn1a	xn2a	tn2a	.....	xnma	tnma	Ona
			b	xn1b	tn1b	xn2b	tn2b	.....	xnmb	tnmb	Onb
K			xn1k	tn1k	xn2k	tn2k	.....	xnmk	tnmk	Onk	
demand for products			d1a		d2a	.....		dma			
			d1b		d2b	.....		dmb			
			d1k		d2k	.....		Dmk			

The objective function and limitations can be built for the lowest total time for the three-dimensions maritime transport model as in the following modified mathematical formula:

Objective Function:

$$MinZ2 = \sum_{i=1}^n \sum_{j=1}^m \sum_{k=a}^K t_{ijk^v} h_{ijk^v} , \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (6)$$

$$h_{ijk^v} = \left\{ \begin{array}{l} 1 \rightarrow \text{if } x_{ijk^v} > 0 \\ 0 \rightarrow \text{if } x_{ijk^v} = 0 \end{array} \right\} , \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (7)$$

Subject To:

$$\sum_{i=1}^n x_{ijk^v} = O_{ik} , \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (8)$$

$$\sum_{j=1}^m x_{ijk^v} = d_{jk} , \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (9)$$

$$O_{ik} = d_{jk} x_{ijk^v} \geq 0 , \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\} \quad (10)$$

$$x_{ijk} \geq 0 \text{ for all } i, j, k \quad (11)$$

Where

$$i, j, k, v: \text{ are model indicators for each } \left\{ \begin{array}{l} K = a, b, c, \dots, K \\ i = 1, 2, 3, \dots, n \\ j = 1, 2, 3, \dots, m \\ v = I, II, III, \dots, M \end{array} \right\}$$

t_{ijk^v} : The time to transfer, the transmission (goods) from distribution centers (i) to the destinations requesting them (j) for the product type (k) by means of transport type (v)

x_{ijk^v} : Represents the number of units to be sent from distribution centers (i) to the requesting destinations (j) of the product type (k) by means of transport type (v)

h_{ijk^v} : Represents a fixed function that shows the custom and non-specific transport route with quantities

x_{ijk^v}

O_{ik} : The quantity provided by distribution centers (i) of the commodity (k)

d_{jk} : Quantities required by the destinations requesting the product type (k) .

4. Heuristic Methods (Exploratory)

The term heuristic (exploration) stems from the Greek word (heuriskein) which means to find or discover, and uses the term (heuristic) for methods that find solutions between all possible solutions, but does not guarantee finding the best solution, and therefore can be considered approximate ways to reach the best solution or the best, these methods usually find a solution close to the best quickly and easily, and sometimes these methods can reach the best solution, called heuristic (exploratory) methods to prove that the best solution is the best solution among the range of available solutions, as it is considered an effective way to find solutions efficiently by verifying the results of their solution, and are often used when approximate solutions meet the requirements of problems and other solutions are not appropriate and necessary in the decision-making process[18].

heuristic (exploratory) methods are used to find the best or best solution to characterize a particular type of problem-solving methods and here are a large and varied number of practice and must be solved difficult problems, which come in efficiently and with certain calculation steps, and to come up with the construction of an algorithm for heuristic (exploratory) methods requires finding an effective method and action in an attempt to find good solutions, even if they are not ideal, and this type of method is characterized by practical speed and is no less important than the rest of the methods in terms of quality, and is called the solution obtained "heuristic" (exploratory) or approximate, and sometimes it takes long time that it is not applicable in many cases, so we often resort to use methods the inference algorithm to solve real optimization problems, as well as find good solutions to difficult problems in a reasonable time [18],[7],[19],[17].

The Heuristic algorithm (exploratory) tries to find a good solution, but not necessarily the optimal solution, this is what distinguishes the inference algorithm from the algorithms of the accurate classic methods, which relates to find the best solution to the problem, and the time it takes to solve, which is why it may be It is best to follow the heuristic algorithm [7],[8].

5. The Proposed Heuristic (Exploratory) Algorithm For Solving Transport Problems

A suggested Heuristic algorithm will be built by the researcher for the three-dimensional and multi-goals maritime transport model, and this algorithm must meet the requirements of problem restrictions and goals to reach good solutions, and may sometimes be the optimal solutions so we will adopt any solutions that are the best and optimal through our findings in the application of inference algorithms and based on the final results can be based on the heuristic method and meet their appropriate requirements and depending on the transport matrix for calculating the costs and times of the multi objective three-dimensional maritime transport model as explained earlier in (Table 1 and 2) [15],[22], and Based on the mathematical model shown in mathematical equations in the calculation of costs from equation (1 to 5), as well as the calculation of times from equation (6 to 11).

Basically the main problem is how to transport nonhomogeneous goods (k) from a group of sources (m) to requesting destinations (n) in a way that reduces the total cost, or time of transport, and by means of the means of transport of the ship type (v), and with the increasing pace of both industrial and economic development, the transfer of more goods are on the rise, these changes include an increase in the need for transportation, new ways of transporting nonhomogeneous goods, and at some point the task of controlling costs and times became too difficult to implement without specialized tools.

In this study, we will propose three new inference algorithms to find possible solutions that may result in optimal solutions through the results we will get as follow:

5.1. Measures Method of Central Tendency (Arithmetic Mean) (Am)

The arithmetic mean is one of the most important and best measures of **central tendency** and the most common and used in statistical analysis because of its characteristics and good statistical prescriptions, the arithmetic mean symbolizes it by the symbol $\bar{x}$.

Because one way does not take into account the costs or times when distributing variables (quantities of transported goods) may result in a preliminary solution that gives objective functional value far from the optimal level. One of these methods (NWCM), therefore we propose a method and alternative algorithm for the northwest corner method using a statistical tool called (AM) which may result in optimal and better solution than the basic primary solution accepted in the (NWCM) method, and the proposed method is characterized by its adoption in the allocation of optimal quantities that will be transferred from their main sources to the requesting destinations them by relying on the costs or times of transport per unit, and it may be given the especial mathematical formula for calculating the arithmetic mean of cost and times of the multi-target 3D transport matrix can be given through the following formulas;

$$\bar{C}_{ijk^v} = \frac{\sum_{i=1}^n \sum_{j=1}^m \sum_{k=a}^K C_{ijk^v}}{n}$$

$$\bar{T}_{ijk^v} = \frac{\sum_{i=1}^n \sum_{j=1}^m \sum_{k=a}^K t_{ijk^v}}{n}$$

Where:

$\bar{C}_{ijk^v}$: Is Symbol Representing The Arithmetic Mean Of The Transport Matrix Cost;

$\bar{T}_{ijk^v}$: Is A Symbol That Represents The Arithmetic Mean Of Transport Matrix Times.

C_{ijk^v} : Represents The Cost Of Transporting One Unit From The Source (I) To Destination (J) Of The Goods Type (K) And By Means Of Transport Type(V)

t_{ijk^v} : Represents The Time Of Transfer Of One Unit From The Source (I) To Destination (J) Of The Goods Type (K) By Mean Of Transport Type (V) .

n : Represents The Number Of Views (Values: Cost, Time)

In order to find the basic acceptable primary solution by the inference statistical algorithm and the measurement tool of the arithmetic mean (AM), we follow the following steps of the algorithm;

1. Find the arithmetic mean (AM) for all rows and columns of the transport matrix, and find one of maximum value.
2. Determine the row or column that has the maximum value (AM), and also determine the cell which has the least (cost, time) transfer in the row or corresponding column.
3. We allocate the maximum amount with the minimum (cost, time) of transport in this row or column.
4. Delete the row (or column) in which the quantities of goods are allocated from supply or demand.
5. Calculation of the arithmetic mean (AM) for the rest of the sub-transport matrix, and the allocation of the remaining quantities of goods in the remaining cells, and according to the followed procedures and the previous steps of step 1 to 4, until all rows and columns are allocated.
6. Calculation the total costs and times of the transport matrix for appropriate allocations using the original balanced transport matrix.

The interest in using central tendency and using one measure to calculate the cost and times of transporting goods from sources to the destinations requesting them is based entirely on the cost and times of the transfer of one unit, as opposed to methods that do not depend on its allocation(quantities of transported goods) the cost and times, this algorithm will be tested and programmed on a set of sample sizes and transport matrixes in the presence of available parameters (sources, requesting destinations,

miscellaneous goods, means of transport, costs, times) to reach the best possible solutions that may be better and closer to optimal solutions.

5.2. Method of Dispersion Measures (Range)

This method is based on the dispersion measures and on one of its measures, which is the range which is the difference between the largest value and the smallest value of the data and is given as follows;

$$R = \text{Max}(X) - \text{Min}(X)$$

By this measure, it is possible to obtain an acceptable or better basic solution in solving of the transport matrix for the transport of a variety of different goods (K) and by a variety of transport (V) from the sources (i) to the destinations requesting them (j), and the proposed mathematical formula for the multi- objectives dimensional transport matrix can be given for costs and times are as follows;

$$\Delta C_{ijk^v} = (\max C_{ijk^v}) - (\min C_{ijk^v})$$

$$\Delta T_{ijk^v} = (\max T_{ijk^v}) - (\min T_{ijk^v})$$

Where:

ΔC_{ijk^v} : Represents the range scale code for transport matrix.(Amount of cost change)

ΔT_{ijk}^v : Represents the range scale code for transport matrix (Amount of change for time)

$\max C_{ijk}^v$) : Represents the maximum value of the cost of transporting a single unit of sources (i) to destinations (j) for goods type (k) and by mean of transport type (v)

$\min C_{ijk}^v$) Represents the minimum value of the cost of transporting a single unit of sources (i) to destinations (j) for goods type (k) and by mean of transport type (v)

$\max t_{ijk}^v$: Represents the maximum value of the times when a single unit of sources (i) is transferred to destinations (j) for goods type (k) and by mean of transport type (v)

$\min t_{ijk}^v$: Represents the minimum value of the transporting time of a single unit of sources (i) is transferred to destinations (j) for goods type (k) and by mean of transport type (v)

To find the basic primary acceptable solution by the statistical inference algorithm and the range measurement tool (R) we follow the following steps of the algorithm;

1. Find (R) for each row as well as for each column and find the single largest value of the range.
2. We define the row or column that has the greatest value of the range (R) and also determine the cell with the lowest value of the (cost, time) of transport in the row or column.
3. Allocate the transferred maximum amounts in a cell that has the lowest (cost or time) of transport in this row or column.
4. Delete the row (or column) in which the quantities of goods are allocated from supply or demand.
5. Calculation the range (R) for the rest of the sub-transport matrix, allocate the remaining quantities of goods in the remaining cells, and make a new allocation after making the previous steps from step 1 to 4, until all rows and columns are completed.
6. Calculation the total costs and times of the transport matrix for possible allocations using the original balanced transport matrix.

5.3. Cost Slop Method (Csm)

In this method, it will depend on one of the dispersion measures, the range, which is defined as the difference between the largest and the smallest value of the data. We note that through the modified and proposed models and classic models used to find the basic acceptable primary solution (IBFS) depended on costs and times separately where they were calculated according to the steps of the solution to reach the best results in reducing costs and times. Thus, a third inference algorithm was established that takes into account costs and time when distributing goods from sources to the requesting destinations and according to the type of carrier used. A statistical inference algorithm has been relied upon to find an acceptable primary basic solution that may provide a better or optimal option than the previous algorithms studied earlier.

In this way, we will rely on calculating changes in costs ΔC , and calculating changes in times ΔT , and in order to clarify this see Figure.1, thus it is possible to rely on calculating cost slop of, which can be calculated by the following formula;

$$\frac{\Delta C}{\Delta T} = \text{COST SLOP}$$

ΔC : Represents cost changes known as the following formula:

$$\Delta C = \text{Max}(c) - \text{Min}(c)$$

ΔT : Represents cost changes known as the following formula:

$$\Delta T = \text{Max}(t) - \text{Min}(t)$$

Where:

ΔC : Represents Increase In Cost

ΔT : Represents A Reduction In Times.:

Fig(1): Represents cost slop

It is noted through (Fig. 1) that the small part (θ) that represents the curve of the total costs should be expanded, and looks like a straight line as in the figure above. Whenever the time is reduced to increase costs. After understanding the nature of the cost slope method and the mathematical formula for calculating it, it is possible to give the proposed mathematical formula for the multi-purpose 3D transport matrix for costs and times as follows;

$$\text{costslop} = \frac{\Delta C_{ijk^v}}{\Delta T_{ijk^v}}$$

Where:

ΔC_{ijk^v} : Represents the range scale code for transport matrix costs. (The amount of change to costs) and calculated according to the following formula;

$$\Delta C_{ijk^v} = (\max C_{ijk^v}) - (\min C_{ijk^v})$$

ΔT_{ijk^v} : Represents the range scale code for transport matrix times. (The amount of change for times), calculated according to the following formula:

$$\Delta T_{ijk^v} = (\max T_{ijk^v}) - (\min T_{ijk^v})$$

To find the basic primary solution acceptable by the statistical inference algorithm and the range measurement tool (CSM), we follow the following algorithm steps:

1. Find (ΔC_{ijk^v}) for each row as well as for each column.

2. Find (Δt_{ijk^v}) for each row as well as for each column.

3. Calculation the cost slope for each row and column according to the following formula $\frac{\Delta C_{ijk^v}}{\Delta T_{ijk^v}}$ and find the

single largest value of cost slop.

4. We define the row or column that contains the minimum cost slope (CSM) and also determine the cell with the minimum cost of transport in the row or column

5. Allocate the maximum transported amounts in a cell that has the lowest value (cost) of transport in this row or column.

6. Delete the row (or column) in which the quantities of goods are allocated from supply or demand.

7. Calculation the cost slop (CSM) for the rest of the sub-transport matrix, allocate the remaining quantities of goods in the remaining cells, and make a new allocation after the previous steps of step 1 to 6, until all rows and columns are met.

8. Calculation the total costs and times of the transport matrix for possible allocations using the original balanced transport matrix.

6. Case Study

The General Company for Food Trade in Iraq imports various types of food commodities to meet the need of the ration card annually and distributed to citizens and according to certain quantities, These goods are imported from international sources and according to the actual need of the destinations requesting them each year.

Note that the most important imported materials are (sugar, oil, wheat, rice), However, the applied side of the research focused on one substance (sugar) as a model for the application of the three-dimensional multi-purpose maritime transport model, According to the data available in the General Company for Food Trade for one year, Where (Table 3 and 4) shows the prices and time of the sea for sugar (per ton) from loading ports to destination ports, The table also shows the quantities available at the loading ports and the demand quantities at the destination ports by means of 16- and 20-knot vessel.

Table (3): Represents The Prices And Times Of Shipping Of Sugar From Loading Ports To Destination Ports By Means Of Transport (Ship) Of The First Type With A Speed Of 16 Knots

product	Vessel speed, knots:	port of departure	port of arrival				supply
			Iraq/Umm Qaser	Iraqi/Maqel	Iraq/khorAlzubair	Iraq/Fao	
a	16 knot	Brazil/santos	75\$	75.25\$	75.06\$	64.5\$	175237
			623h	625h	624h	533h	
		Thailand/bangkok	52\$	52.32\$	52.08\$	44.7\$	175236
			339h	341h	339h	292h	
		South Africa/durban	40\$	40.26\$	40.07\$	34\$	175236
			320h	322h	321h	273h	
		Mexico/Manzanillo	80\$	80.20\$	80.5\$	75.8\$	175236
			832h	834h	833h	789h	
		Guatemala/pto.Quetzal	85\$	85.23\$	85.06\$	71.25\$	175236
			780h	782h	781h	654h	
		Demmand	262854	96380	131426	385520	876181

Table (4): Represents The Prices And Times Of Shipping Of Sugar From Loading Ports To Destination Ports By Means Of Transport (Ship) Of The First Type With A Speed Of 20 Knots

product	Vessel speed, knots:	port of departure	port of arrival				supply
			Iraq/Umm Qaser	Iraqi/Maqel	Iraq/khorAlzubair	Iraq/Fao	
a	20 knot	Brazil/santos	75\$	75.25\$	75.06\$	64.5\$	175237
			499h	501	499	426h	
		Thailand/bangkok	52\$	52.32\$	52.08\$	44.7\$	175236
			271h	273	271h	234h	
		South Africa/durban	40\$	40.26\$	40.07\$	34\$	175236
			256h	258	257h	219h	
		Mexico/Manzanillo	80\$	80.20\$	80.5\$	75.8\$	175236
			666h	668h	666h	631h	
		Guatemala/pto.Quetzal	85\$	85.23\$	85.06\$	71.25\$	175236
			624h	626h	624h	523h	
		Demmand	262854	96380	131426	385520	876181

Through what was presented in (Table 3and, 4) data were entered on all the methods described previously and according to the steps of the algorithm, where the use of programming language Matlab in programming those algorithms and get the following results as shown in (Tale 5 and 6) :

Table (5): Represents The Results Of The Three Heuristic Methods Before And After The Use Of Optimization Methods (MODI Method) By 16 Knots Speed- Vessel

BEFOR MODI	Heuristic Methods			AFTER MODI	Heuristic Methods		
	Arithmetic Mean	Range	Cost Slop		Arithmetic Mean	Range	Cost Slop
F(x)	474636019	487831290	481943351	F(x)	474636019	467828092	467828092
C(x)	54703226	55545000	54975000	C(x)	54703226	53727000	53721000
T(x)	3920	4949	5162	T(x)	3920	3633	4145
t(x)	789	834	834	t(x)	789	832	834
Q(x)	175236	96380	96380	Q(x)	175236	175236	87618

Table (6): Represents The Results Of The Three Heuristic Methods Before And After The Use Of Optimization Methods (Modi Method) By 20 Knots Speed- Vessel

BEFOR MODI	Heuristic Methods			AFTER MODI	Heuristic Methods		
	Arithmetic Mean	Range	Cost Slop		Arithmetic Mean	Range	Cost Slop
F(X)	379728091	390513867	385537157	F(X)	379728091	374251959	374251959
C(x)	54703226	55510000	54955000	C(x)	54703226	53727000	53721000
T(x)	3136	3835	4129	T(x)	3136	2907	3317
t(x)	631	668	668	t(x)	631	666	668
Q(x)	175236	96380	96380	Q(x)	175236	175236	87618

The results in (Table 5 and 6) show that the heuristic method (arithmetic mean) gave the best results in reducing the total costs and times to transport sugar from the ports of departures to the ports of arrival where the total cost was (54703226 \$), and the total time (3920 hours) By means of transport vessel speed with 16 knots, as the total cost reached (54703226 \$), and the total time (3136 hours) by means of transport vessel speed with 20 knots. The research found that the solution obtained before the improvement process by MODI method is the best solution because the cost and time has not been reduced after the improvement process. The results also showed in Table (3 and 4) that the heuristic method (cost slope method) gave a best solution than the heuristic method (Athematic mean method) In terms of reduction of total costs, the total cost amounted to (53721000 \$) and a total time of (4145 hours), by means of transport vessel speed 16 knots, as the total cost of (53721000 \$) and a total time of (3317 hours), by means of transport ship speed with 20 knots. This is after the process of improvement by the method (MODI).

(Table 7 and 8) also show the optimal amounts of sugar to be transported from the ports of departure to the ports of arrival, which gave the best solution in reducing total costs and times, which is the arithmetic mean method.

Table (7): It Represents The Optimal Quantities To Be Transported By 16 Knot Speed Vessel, And By Arithmetic Mean Method

port of departure	port of arrival				supply
	Iraq/Umm Qaser	Iraq/khorAlzubair	Iraqi/Maqel	Iraq/Fao	
Brazil/santos	140189	0	0	35048	175237
Thailand/bangkok	122665	52571	0	0	175236
South Africa/durban	0	78856	96380	0	175236
Mexico/Manzanillo	0	0	0	175236	175236
Guatemala/pto.Quetzal	0	0	0	175236	175236
Demand	262854	131427	96380	385520	876181
	port of arrival				supply

Table(8): It Represents The Optimal Quantities To Be Transported By 20 Knot Speed Vessel, And By Arithmetic Mean Method

port of departure	port of arrival				supply
	Iraq/Umm Qaser	Iraq/khorAlzubair	Iraqi/Maqel	Iraq/Fao	
Brazil/santos	140189	0	0	35048	175237
Thailand/bangkok	122665	52571	0	0	175236
South Africa/durban	0	78856	96380	0	175236
Mexico/Manzanillo	0	0	0	175236	175236
Guatemala/pto.Quetzal	0	0	0	175236	175236
Demand	262854	131427	96380	385520	876181

As it is shown in (Table 9 and 10) optimal quantities to be transported from the sugar from the ports of departure to port of arrival, which gave the best optimal solutions in terms of reducing the total cost

Table(9): It Represents The Optimal Quantities To Be Transported By 16 Knot Speed Vessel, And By Cost Slop Method

Port Of Departure	Port Of Arrival				Supply
	Iraq/Umm Qaser	Iraq/khorAlzubair	Iraqi/Maqel	Iraq/Fao	
Brazil/santos	0	0	0	175237	175237
Thailand/bangkok	0	131427	8762	35047	175236
South Africa/durban	175236	0	0	0	175236
Mexico/Manzanillo	87618	0	87618	0	175236
Guatemala/pto.Quetzal	0	0	0	175236	175236
Demand	262854	131427	96380	385520	876181

Table(10): It Represents The Optimal Quantities To Be Transported By 20 Knot Speed Vessel, And By Cost Slop Method

Port Of Departure	Port Of Arrival				Supply
	Iraq/Umm Qaser	Iraq/khorAlzubair	Iraqi/Maqel	Iraq/Fao	
Brazil/santos	0	0	0	175237	175237
Thailand/bangkok	0	131427	8762	35047	175236
South Africa/durban	175236	0	0	0	175236
Mexico/Manzanillo	87618	0	87618	0	175236
Guatemala/pto.Quetzal	0	0	0	175236	175236
Demand	262854	131427	96380	385520	876181

7. Conclusion

Due to the inefficient use of the classic two-dimensional in maritime transport models and the inability to meet the requirements for the transport of homogeneous and nonhomogeneous goods by different modes of transport in terms of (type, speed, size), Which requires studying the subject. and build a more realistic model to transport the goods from its sources (i^{th}) to the requesting destinations of it (j^{th}) through the three-dimensional, multi-purpose of maritime transport model that has been built, where through this model can obtain optimal results by solving this model with the three heuristic algorithms proposed, and because this model is comprehensive for all requirements for the transport of nonhomogeneous goods (k) and modes of transport type (v), characterized by the calculation of two functions of the target, the first function is to calculate the minimum possible total cost of transporting goods, and the second function aims to calculate the minimum total time for the active transport path for the transport of goods the total time of the active transport route for the transport of goods, as this model can be applied in the case of data availability according to model variables and get optimal initial results., The research concluded that the best reasoning method is the (arithmetic mean(AM)) because it gave the best results in reducing the total (cost and time) before and after the optimization method (MODI), It also gave the (cost slop method) less total costs and time higher than the method of arithmetic mean After conducting the optimization method(MODI) .

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