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Modified method for finding the solution of balanced transportation problems: a power rank method

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The transportation problem is categorised an essential optimization problem in which a route is determined to transport a specific amount of quantity from an origin to a destinations with minimum total cost. In this paper, the authors introduce a novel method to find quick initial basic feasible solution for a balanced transportation problem. The new technique returns either the optimal solution or the solution closest to the optimal one. The proposed method is explained using a numerical problem and the results are compared with some existing methods.

Keywords: balance transportation problem, initial basic feasible solution, TGR method.

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Introduction

The major requirement in today's highly competitive world for the development of industries, communication, and information technologies is the delivery of raw materials/products from the point of production to the final utilization point at the lowest price. Therefore, transporting the products efficiently became a brittle problem for the companies. One of the most application based category of linear programming problem is the transportation problem (TP), also known as the physical distribution problem, which deals with the distribution of products from multiple origins to the multiple destinations. The main objective of TP is to transport products at the lowest price while complying with the requirements at destinations. This work originated from the work of Gaspard Monge and later developed by Leonid Kantorovich known as the "Monge−Kantorovich problem" [1]. TP was first modelled by Hitchcock [2], and the first methods for solving TP were developed by Dantzig [3] and Charnes et al. [4].

To start finding the optimal TP solution, a suitable initial basic feasible solution (IBFS) is required. The value of IBFS has a large impact on time for the optimal solution and hence on the solution time. Therefore, there is a need for better IBFS which should be closest to the optimal solution. Also, to find the optimal solution, generally preffered computation methods are Stepping Stone and Modified Distribution [5].

Many methods have been developed in the literature to find the initial basic feasible solution for TP. Putcha et. al. [6] pointed out the drawbacks of Northwest Corner Rule Method and Russell Method and proposed a method to overcome these drawbacks. Korukoglu and Balli [7] proposed an improved Vogel's approximation method. They chose three highest penalties instead of one and then calculated the cost for these three allocations. Ahmed et. al. [8] developed a technique named Row Distribution Indicator and Column Distribution Indicator to search for IBFS. Ahmed et. al. [9] proposed Incessant Allocation Method in which they allocate the cell with the minimum cost in the cost matrix and then adjust the supply and demand in a particular manner. Gupta and Anupum [10] and Gupta et. al. [11] proposed a method in the cost matrix is reduced in so that each row and column must contain at least one zero. For each cell having zero value, they calculated some specific values and allocate the cell with the largest value. Prajwal et. al. [12] proposed two methods; one is Continuous Allocation Method which is a sequential approach. The first allocation was made to the cell with the lowest cost and then move row-column wise to the cell with the lowest cost in the row or column of the currently allocated cell. The second method is Supply-Demand Reparation Method in which they select the row or column which has the highest supply and demand value and then select the least cost cell from that row or column for allocation. Karagul and Sahin [13] proposed a method named Karagul – Sahin Approximation Method. They tested their method on twenty four problems and compared it with six initial solution methods.

1. Mathematical modelling

1.1. Standard TP

The objective of the transportation problem is to minimize the transportation cost of a given commodity from its source to its destination. The maximum number of goods that can be sent from each source is limited while the number of goods that need to be shipped to the store must be met. The shipping cost from origin to destination is directly proportional to the number of goods shipped. Let us illustrate a typical transportation problem as given in Fig. 1, suppose that m manufacturing units supply some goods to n warehouses. Let manufacturing facility i ($i = 1, 2, \dots, m$) produces A_i units and the warehouses j ($j = 1, 2, \dots, n$) requires B_j units. The cost of shipping from manufacturing facility i to warehouse j is C_{ij}. The decision variables X_{ij} represent the amount of shipment from the manufacturing facility i to warehouse j.

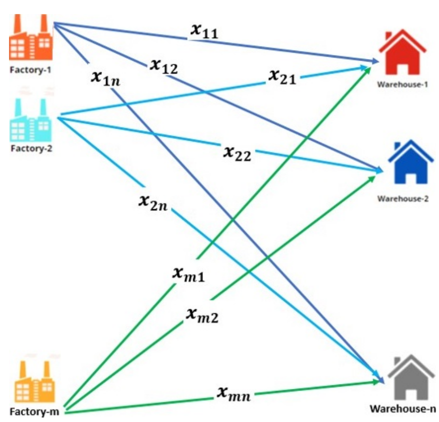

Fig. 1. Basic transportation problem

Table 1. Tabular representation of transportation problem

Source	Destination				Availability (A_i)
	D_1	D_2	$\cdots$	D_n	
S_1	C_{11}	C_{12}	$\cdots$	C_{1n}	(A_1)
S_2	C_{21}	C_{22}	$\cdots$	C_{2n}	(A_2)
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
Demand (B_j)	B_1	B_2	$\cdots$	B_n	

Mathematically, the problem can be stated as:

Minimize $Z = \sum_{i=1}^{m} \sum_{j=1}^{n}$ subject to the constraints

$$\sum_{j=1}^{n} X_{ij} = A_i, \quad i = 1, 2, \ldots, m,$$

$$\sum_{i=1}^{m} X_{ij} = B_j, \quad j = 1, 2, \ldots, n,$$

$$\sum_{i=1}^{m} A_i = \sum_{j=1}^{n} B_j$$

and $X_{ij} \geq 0$ for all $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$.

The problem can be stated in the tabular form 1 as given in Table 1.

1.2. Flowchart of the proposed method: power rank method

The detailed steps of the proposed method i. e. Power Rank method is given in the algorithm.

Step 1. Take a balanced TP i. e. if the sum of the supplies of all the sources is equal to the sum of the demands of all the destinations.

Step 2a. For every cell of the matrix, choose the smallest element in each row or column and subtract it from the cost in the cell. Continue the process till we get a zero in each row and column.

Step 2b. If we do not obtain a zero in each row or column, then take the corresponding row or column and subtract the smallest element from it.

Step 3. In the reduced matrix, identify the cell with the largest cost. Select the zeroes in the corresponding row and column of the largest cost element.

Step 4. For all cells marked zeroes, find the power rank by taking the average of all non-zero costs in the corresponding rows and columns of the reduced matrix.

$$\text{Power Rank}, (r_{ij}) = \frac{\text{Sum of all other cost elements in the corresponding row and column of the given cost matrix}}{\text{Number of cost added}}.$$

Step 5.

- If there is only one cell with largest power rank, select it and make the necessary allocation.
- If there are more than one cell with the same largest power rank, then choose the cell which has lowest quantity to allocate.

Step 6. If resulting matrix is a reduced matrix, go to Step 3, otherwise go to Step 2b and repeat the process untill all the allocations have been made.

1.3. Numerical problem

The alogorithm designed in this manuscript is explained in the following balanced transportation problem (Table 2) taken from the work of Patel and Bhathawala [14].

In the given numerical problem 1 as in Table 2, apply step 2 of the proposed algorithm to obtain the row reduced matrix as shown in Table 3.

After obtaining the reduced matrix, use step 3 of the flowchart the largest cost element $c_{33} = 39$ is selected. The power rank for the corresponding zeroes in the cells $(2, 3)$ and $(3, 2)$ are calculated using step 4 of the proposed flowchart as given below.

$$r_{23} = \frac{rc_{13} + rc_{23} + rc_{21} + rc_{24}}{4} = \frac{17 + 39 + 30 + 20}{4} = 26.5, \tag{1}$$

$$r_{32} = \frac{rc_{12} + rc_{31} + rc_{33} + rc_{34}}{4} = \frac{10 + 17 + 39 + 4}{4} = 17.5, \tag{2}$$

rc represents the cost in the reduced matrix.

Table 2. Numerical problem 1

	D_1	D_2	D_3	D_4	Supply
S_1	13	18	30	8	8
S_2	55	20	25	40	10
S_3	30	6	50	10	11
Demand	4	7	6	12	

Table 3. Reduced matrix of numerical problem 1

	D_1	D_2	D_3	D_4	Supply
S_1	0	10	17	0	8
S_2	30	0	0	20	10
S_3	17	0	39	4	11
Demand	4	7	6	12	

Table 4. Matrix with power rank for the first allocation

	D_1	D_2	D_3	D_4	Supply
S_1	0	10	17	0	8
S_2	30	0	[6] 0	20	4
S_3	17	0	39	4	11
Demand	4	7	0	12	

Table 5. Modified matrix after the first allocation

	D_1	D_2	D_4	Supply
S_1	0	10	0	8
S_2	30	0	20	4
S_3	17	0	4	11
Demand	4	7	12	

Table 6. Final allocations of numerical problem 1

	D_1	D_2	D_3	D_4	Supply
S_1	[4] 13	18	30	[4] 8	8
S_2	55	[4] 20	[6] 25	40	10
S_3	30	[3] 6	50	[8] 10	11
Demand	4	7	6	12	

Cell $(2, 3)$ is selected corresponding to the largest power rank which equals 26.5. According to step 5 of the flowchart, we allocate 6 to the cell $(2, 3)$ as shown in Table 4 which fully satisfies demand of the third destination leading to the removal of the third column as depicted in Table 5.

In the same way, we continue to apply the flowchart for further allocations, finally we get the final allocation table as given in Table 6.

The initial basic feasible solution of numerical problem 1 is $x_{11}=4$, $x_{14}=4$, $x_{22}=4$, $x_{23}=6$, $x_{32}=3$ and $x_{34}=8$ and the transporation cost is $4\cdot 13+4\cdot 8+4\cdot 20+6\cdot 25+3\cdot 6+8\cdot 10 = 412$.

2. Results and discussion

We have applied the proposed algorithm to various existing balanced TP. The comparison of the results obtained by northwest corner method (NWCM), least cost method (LCM), Vogel's approximation method (VAM), modified distribution method (MODI) and power rank method (proposed method) are given in Table 7. A visual comparison of the results is shown in Fig. 2–4.

Table 7 clearly shows that in all three problems the proposed method gives either the optimal solution or nearest to the optimal solution.

T a b l e 7. Results comparison of balanced transportation problems

Problem taken from	NWCM	LCM	VAM	MODI	Proposed method
Table 2 in [15, p. 7]	253	309	234	219	233
Example 1 in [14, p. 5697]	484	516	476	412	412
Example 1 in [16, p. 4]	1015	814	779	743	743

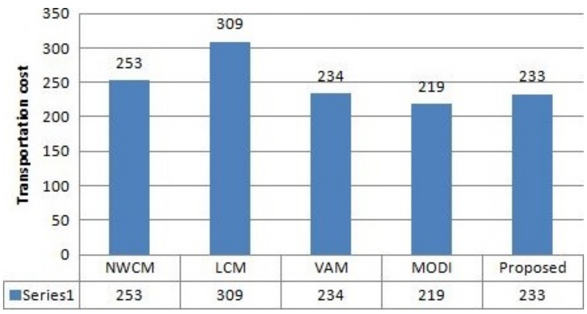

Fig. 2. Visual representation of results for problem 1 (Table 2 in [15, p. 7])

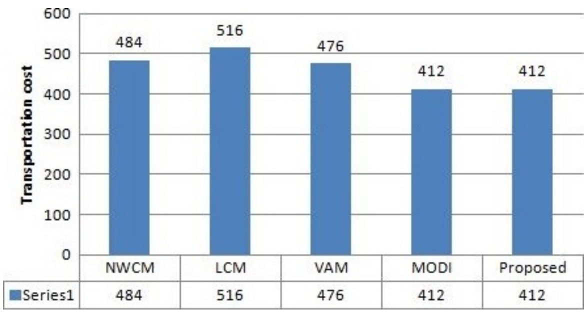

Fig. 3. Visual representation of results for problem 2 (example 1 in [14, p. 5697])

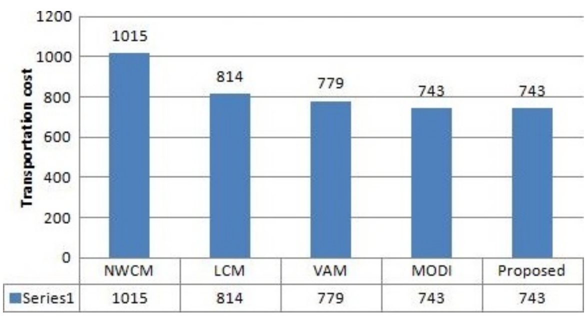

Fig. 4. Visual representation of results for problem 3 (example 1 in [16, p. 4])

Conclusion

This paper focused on the proposed modified method which is applicable to balanced transportation problems. Also, the computational effort of the proposed method is significally less compared to existing methods. To demonstrate the effectiveness of the proposed method, three different problems are detailed in Table 7. The proposed method gives the best IBFS in the problems as discussed in Fig. 2–4. The IBFS obtained by proposed technique is either equal to the optimal solution or nearest to the optimal solution as shown in Table 7.

Conflict of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Author's contributions

All the four authors have equally contributed for the research article.

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ВЫЧИСЛИТЕЛЬНЫЕ ТЕХНОЛОГИИ

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Модифицированный метод поиска решения сбалансированных транспортных задач: метод степенного ранга

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Аннотация

Задача транспортировки классифицируется как важная задача оптимизации, в которой определяется маршрут для перевозки определенного количества товара от пункта отправления до пункта назначения с минимальными общими затратами. В этой статье авторы представляют новый метод быстрого нахождения начальных базовых возможностей для решения сбалансированной транспортной задачи. Новый метод возвращает либо оптимальное решение, либо ближайшее к оптимальному решение. Предложенный метод иллюстрируется на примере численного решения, а полученные результаты сравниваются с некоторыми существующими методами.

Ключевые слова: сбалансированная транспортная задача, начальное базисное допустимое решение, метод TGR.

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