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Zero Next to Zero (ZnZ) Method: A New Approach for Solving Transportation Problem

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ABSTRACT

Transportation Problem (TP) plays the role in cost planning for distributing the commodities from the sources to the destinations. Initial Basic Feasible Solution (IBFS) is the first step to the way of obtaining an optimal solution. There are various algorithms to find IBFS. The best solution method gives optimal cost with the least iteration. In this paper, a new solution procedure namely Zero next to Zero (ZnZ) method has been proposed to determine the IBFS for TP**.** The aim is to obtain a total transportation cost that is similar or close to the optimal solution with the least iteration. The performance of the proposed algorithm is evaluated using two characteristics and compared with the existing algorithms available in the literature. The comparison results indicate that the proposed approach yields better results by taking comparatively very less effort and computation.

Keywords: Initial Basic Feasible Solution, Sequence of Allocation, Average Relative Deviation, Zero next to Zero, Optimum solution.

Mathematical Subject Classification (2010): 90B50, 90C08

1. Introduction

The transportation problem is one of the oldest and most important applications of linear programming problems. It deals with shipping a single homogeneous product from several sources to numerous terminuses. The objective of this problem is to decide the amount of product transported from sources to terminuses satisfying supply and demand constraints to diminish total transportation cost. Gaspard Monge [1] published the first publication about the Transportation Model in the ‘Memoires de l'Academie des Sciences de l'Institut de France’ in 1781.

In the 1930s, Tolstoǐ [2] was one of the first to study the transportation problem mathematically. The standard form of the problem was first formulated, along with a constructive solution, by Hitchcock [3] in 1941. His work entitled ‘The Distribution of a Product from several sources to Numerous Localities’ gives the origin for the Hitchcock Transportation Problem analogous to Monge’s formulation.

In 1947, Koopmans [4] also presented his historic study based on his World War II time experience called ‘Optimum Utilization of the Transportation System’. Because of this and the work done earlier by Hitchcock, the classical case is often referred to as the Hitchcock-Koopmans Transportation Problem. Efficient methods of solution derived from the simplex algorithm were developed, primarily by Dantzig [5] and then by Charnes, Cooper, and Henderson [6].

IBFS plays an important role to find the way out in obtaining an optimal solution. A good number of methods are available in the literature to find an IBFS of TP. But the previous methods related to it did not always provide the satisfying result all the time. It varies for different solution procedures and also for different examples. Some of them require a little more time to find an IBFS, but the solutions are good in terms of minimizing total transportation costs. Some of them produce a very good IBFS and most often directly the optimal solution but it takes comparatively more effort and computation. Still, there is no unique method that will calculate the optimal solution of all TP. So it is necessary to develop an algorithm that will provide better results.

Considering this in this research, we have proposed ZnZ method that will compute the optimal solution for the transportation problem. The proposed algorithm will be illustrated with a numerical example to make the proposed method very clear and well understandable. We also calculate the Average Relative Deviation (ARD) to determine the average performance of various techniques and Percentage of Optimal Solution (POS) with respect to the optimal solution over several numbers of randomly selected problems from some reputed journals.

2. Literature review

Transportation Problem has been the subject of hundreds research papers since the year of its development. We have gone through a number of research papers related to transportation problem. Out of them some of the recent works cited below are the source of inspiration to do the research work. Charnes and Cooper [7] presented a straightforward method for obtaining an initial basic feasible solution of a transportation problem which is named as North West Corner Method (NWCM) where the basic variables are selected from the North West Corner cell and then the next developed method is Least Cost Method (LCM) consists in allocating as much as possible in the lowest cost cell of the Transportation Table. Reinfeld and Vogel [8] introduced Vogel’s Approximation Method (VAM) by defining penalty as the difference of lowest and next to lowest cost in each row and column of a transportation table and allocate to the minimum cost cell corresponding to highest penalty. Kasana and Kumar [9] proposed Extremum Difference Method (EDM) where they define the penalty as the differences of the highest and lowest unit transportation cost in each row and column and allocate as like as the VAM procedure.

Russell [10] proposed Russel’s Approximation Method (RAM) where he determines the penalty for each cell of the transportation table by subtracting corresponding row and column maximum element of every cell from the respective element. Then he makes maximum possible allocation to the cell having the smallest penalty. Khan et al. [11], used TOCM of Kirca and Satir [12] and define the pointer cost as the sum of all entries in the respective row or column of the TOCM and then assign to the least cost cell corresponding to the highest pointer cost. Rashid [13] proposed another heuristic and term as ‘Average Cost Method (ACM)’ where he defines the penalty as the average cost of each row and column and allocate as like as the VAM procedure.

3. Network representation of TP

We represent each source and destination by a node, the amount of supply at source i by

S_i, the amount of demand at destination j by d_j, the unit transportation cost between source i and destination j by c_{ij} and the amount transported from source i to destination j by x_{ij}. The lines joining the source and destination denote the route through which the product is transported. Then the general transportation problem can be signified by the network as in the following Figure 1.

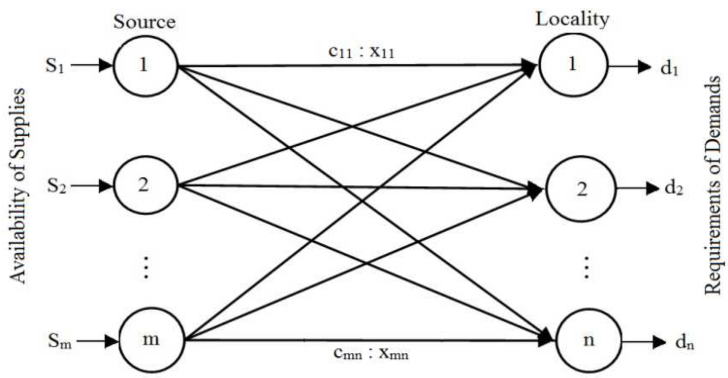

Figure 1. Network Representation of Transportation Problem

Using the above data, the mathematical form of the balanced transportation problem can be expressed as finding a set of x_{ij}'s, $i=1,2,\ldots\ldots,m$; $j=1,2,\ldots\ldots,n$ to

$$\text{Minimize} \quad z=\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}\,x_{ij}\,.$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}=S_i \quad ; \quad i=1,2,\ldots\ldots,m$$

$$\sum_{i=1}^{m} x_{ij}=d_j \quad ; \quad j=1,2,\ldots\ldots,n$$

$$x_{ij}\geq 0\,; \quad \text{for all } i \text{ and } j\,.$$

4. Proposed algorithm

The proposed ZnZ method for determining the IBFS of TP consists of the following steps:

- Step 1 : Form the Transportation matrix from the given transportation problem.
- Step 2 : Check whether the transportation problem is balanced or not, if not, make it balanced.
- Step 3 : Select the least cost $C_{ij} > 0$ of each row and subtract it from each cost member of the corresponding row.
- Step 4 : Mark the cell containing zero and next to zero of each row obtained in Step 3.
- Step 5 : Compute the sequence of allocations to the cell marked in Step 4 so that all the cells are selected satisfying supply and demand restrictions.
- Step 6 : Assign as many units as possible to the cell according to the sequences made in Step 5 until all the rows and columns are exhausted.

Step 7 : Finally calculate the total transportation cost for the feasible allocations as sum of the product of original balanced transportation matrix cost and corresponding assigned value.

5. Numerical illustration

To justify the efficiency of the proposed approach and to test the performance of the various techniques for solving transportation problems we choose the following twenty five sample examples, selected at random from some reputed peer reviewed journals, which are listed in the following Table 1.

Table 1: Sample transportation problem with source

Balanced Transportation Problems	
Example-1: [Ref No. 14] $[c_{ij}]_{3x4}$=[13 18 30 8; 55 20 25 40; 30 6 50 10]; $[s_i]_{3x1}$=[8, 10, 11]; $[d_j]_{1x4}$=[4, 7, 6, 12].	**Example-13**: [Ref No.26] $[c_{ij}]_{4x5}$=[4 9 8 10 12; 6 10 3 2 3; 3 5 6 3 2; 2 4 4 5 3] ; $[s_i]_{4x1}$=[80, 60, 40, 20]; $[d_j]_{1x5}$=[60, 60, 30, 40, 10].
Example-2: [Ref No. 15] $[c_{ij}]_{3x3}$=[4 3 5; 6 5 4; 8 10 7]; $[s_i]_{3x1}$=[90, 80, 100]; $[d_j]_{1x3}$=[70, 120, 80].	**Example-14**: [Ref No. 27] $[c_{ij}]_{4x6}$=[7 10 7 4 7 8; 5 1 5 5 3 3; 4 3 7 9 1 9; 4 6 9 0 0 8]; $[s_i]_{4x1}$=[5, 6, 2, 9]; $[d_j]_{1x6}$=[4, 4, 6, 2, 4, 2].
Example-3: [Ref No. 16] $[c_{ij}]_{3x3}$=[15 7 25; 8 12 14; 17 19 21]; $[s_i]_{3x1}$=[12, 17, 7]; $[d_j]_{1x3}$=[12, 10, 14].	**Example-15**: [Ref No. 28] $[c_{ij}]_{4x6}$=[9 12 9 6 9 10; 7 3 7 7 5 5; 6 5 9 11 3 11; 6 8 11 2 2 10]; $[s_i]_{4x1}$=[5, 6, 2, 9]; $[d_j]_{1x6}$=[4, 4, 6, 2, 4, 2].
Example-4: [Ref No. 17] $[c_{ij}]_{3x4}$=[3 6 8 4; 6 1 2 5; 7 8 3 9]; $[s_i]_{3x1}$=[20, 28, 17]; $[d_j]_{1x4}$=[15, 19, 13, 18].	**Example-16**: [Ref No. 29] $[c_{ij}]_{5x5}$=[8 8 2 10 2; 11 4 10 9 4; 5 2 2 11 10; 10 6 6 5 2; 8 11 8 6 4]; $[s_i]_{5x1}$=[40, 70, 35, 90, 85]; $[d_j]_{1x5}$=[80, 55, 60, 80, 45].
Example-5: [Ref No.18] $[c_{ij}]_{3x4}$=[6 1 9 3; 11 5 2 8; 10 12 4 7]; $[s_i]_{3x1}$=[70, 55, 90]; $[d_j]_{1x4}$=[85, 35, 50, 45].	**Example-18**: [Ref No. 30] $[c_{ij}]_{5x6}$=[5 3 7 3 8 5; 5 6 12 5 7 11; 2 8 3 4 8 2; 9 6 10 5 10 9; 5 3 7 3 8 5]; $[s_i]_{5x1}$=[3, 4, 2, 8, 3]; $[d_j]_{1x6}$=[3, 4, 6, 2, 1, 4].
Example-6: [Ref No. 19] $[c_{ij}]_{3x4}$=[10 2 20 11; 12 7 9 20; 4 14 16 18]; $[s_i]_{3x1}$=[15, 25, 10]; $[d_j]_{1x4}$=[5, 15, 15, 15].	**Example-19**: [Ref No. 31] $[c_{ij}]_{5x7}$=[12 7 3 8 10 6 6; 6 9 7 12 8 12 4; 10 12 8 4 9 9 3; 8 5 11 6 7 9 3; 7 6 8 11 9 5 6]; $[s_i]_{5x1}$=[60, 80, 70, 100, 90]; $[d_j]_{1x7}$=[20, 30, 40, 70, 60, 80, 100].
Example-7: [Ref No. 20] $[c_{ij}]_{3x5}$=[4 1 2 4 4; 2 3 2 2 3; 3 5 2 4 4]; $[s_i]_{3x1}$=[60, 35, 40]; $[d_j]_{1x5}$=[22, 45, 20, 18, 30].	**Example-20**: [Ref No. 32] $[c_{ij}]_{6x6}$=[12 4 13 18 9 2; 9 16 10 7 15 11; 4 9 10 8 9 7; 9 3 12 6 4 5; 7 11 5 18 2 7; 16 8 4 5 1 10]; $[s_i]_{6x1}$=[120, 80, 50, 90, 100, 60]; $[d_j]_{1x6}$=[75, 85, 140, 40, 95, 65].
Example-8: [Ref No. 21] $[c_{ij}]_{4x3}$=[2 7 4; 3 3 1; 5 4 7; 1 6 2];	**Example-21**: [Ref No. 33] $[c_{ij}]_{3x4}$=[6 5 8 8; 5 11 9 7; 8 9 7 13];

$[s_i]_{3x1}$=[5, 8, 7, 14]; $[d_j]_{1x3}$=[7, 9, 18].	$[s_i]_{3x1}$=[30, 40, 50]; $[d_j]_{1x4}$=[35, 28, 32, 25].
Example-9: [Ref No. 22] $[c_{ij}]_{4x4}$=[7 5 9 11; 4 3 8 6; 3 8 10 5; 2 6 7 3]; $[s_i]_{4x1}$=[30, 25, 20, 15]; $[d_j]_{1x4}$=[30, 30, 20, 10].	**Example-22**: [Ref No.34] $[c_{ij}]_{3x3}$=[4 8 11; 6 3 8; 7 6 5]; $[s_i]_{3x1}$=[12,10, 9]; $[d_j]_{1x3}$=[13, 8, 10].
Example-10: [Ref No. 23] $[c_{ij}]_{4x4}$=[5 3 6 10; 6 8 10 7; 3 1 6 7; 8 2 10 12]; $[s_i]_{4x1}$=[30, 10, 20, 10]; $[d_j]_{1x4}$=[20, 25, 15, 10].	**Example-23**: [Ref No.35] $[c_{ij}]_{4x6}$=[1 2 1 4 5 2; 3 3 2 1 4 3; 4 2 5 9 6 2; 3 1 7 3 4 6]; $[s_i]_{4x1}$=[30,50, 75, 20]; $[d_j]_{1x6}$=[20, 40, 30, 10, 50, 25].
Example-11: [Ref No. 24] $[c_{ij}]_{4x5}$=[7 6 4 5 9; 8 5 6 7 8; 6 8 9 6 5; 5 7 7 8 6]; $[s_i]_{4x1}$=[40, 30, 20, 10]; $[d_j]_{1x4}$=[30, 30, 15, 20, 5].	**Example-24**: [Ref No. 12] $[c_{ij}]_{3x4}$=[15 27 13 19; 18 21 24 14; 21 15 16 17]; $[s_i]_{3x1}$=[40, 40, 20]; $[d_j]_{1x4}$=[30, 20, 30, 30].
Example-12: [Ref No. 25] $[c_{ij}]_{4x5}$=[4 3 1 2 6; 5 2 3 4 5; 3 5 6 3 2; 2 4 4 5 3]; $[s_i]_{4x1}$=[80, 60, 40, 20]; $[d_j]_{1x4}$=[60, 60, 30, 40, 10].	**Example-25**: [Ref No.26] $[c_{ij}]_{3x4}$=[21 16 25 13; 17 18 14 23; 32 27 18 41]; $[s_i]_{3x1}$=[11, 13, 19]; $[d_j]_{1x4}$=[6, 10, 12, 15].
Example-17: [Ref No. 10] $[c_{ij}]_{5x5}$=[73 40 9 79 20; 62 93 96 8 13; 96 65 80 50 65; 57 58 29 12 87; 56 23 87 18 12] ; $[s_i]_{5x1}$=[8, 7, 9, 3, 5] ; $[d_j]_{1x5}$=[6, 8, 10, 4, 4].	

6. Illustrative solution of an example

Solution of **Example 1** is illustrated in this section with an aim to make the readers acquainted with the proposed approach.

Table 2: Selection of row minimum of each row

Source	**Destinations**				**Supply**	**Row minimum**
	D1	**D2**	**D3**	**D4**		
S1	13	18	30	8	8	8
S2	55	20	25	40	10	20
S3	30	6	50	10	11	6
Demand	4	7	6	12	29	

The following Table 3 shows the result after subtracting the row minimum of each row and the cell containing zero and next to zero of each row.

Table 3: Selection of zero and next to zero

Source	Destinations				Supply
	D1	D2	D3	D4	
S1	5	10	22	0	8
S2	35	0	5	20	10
S3	24	0	44	4	11
Demand	4	7	6	12	29

Sequence of allocation: $a_{11} > a_{14} > a_{34} > a_{32} > a_{22} > a_{23}$
The following Table 4 shows the allocation of the problem.

Table 4: Allocation Table

Source	Destinations				Supply
	D1	D2	D3	D4	
S1	4 5	10	22	4 8	8
S2	35	4 0	6 5	10	10
S3	24	3 0	44	8 11	11
Demand	4	7	6	12	

Therefore, total transportation cost $=13\times4+ 8\times4+20\times4+25\times6+6\times3+ 10\times8$
$= 412$

7. Comparison table of initial basic feasible solution

Table 5 show the comparison of different solutions, Percentage of Optimum Solution (POS) and Average Relative Deviation (ARD) [36] obtained by various methods by means of twenty five sample examples given in Table 1.

Table 5: A Comparative study of different solutions

Ex. No.	Opt. Sol.	NWCM	LCM	VAM	EDM	RAM	TOCM-Sum	ACM	ZnZ Method
1	412	484	516	476	476	412	412	412	412
2	1390	1500	1450	1500	1390	1390	1440	1500	1390
3	425	545	433	425	439	425	439	439	425
4	200	273	231	204	218	200	200	200	200
5	1160	1265	1165	1220	1165	1165	1280	1280	1160

6	435	520	475	475	475	475	520	460	435
7	290	363	295	290	295	295	290	318	290
8	76	102	83	76	80	82	76	76	76
9	410	540	435	470	415	420	455	455	410
10	285	425	310	285	295	285	285	285	285
11	510	635	510	510	510	510	510	515	510
12	420	670	420	420	420	420	420	420	420
13	800	1110	950	860	800	840	820	820	800
14	68	95	70	68	68	71	79	109	68
15	112	139	114	112	112	115	123	153	112
16	1475	1870	1685	1505	1685	1730	1545	1555	1475
17	1102	1994	1123	1104	1102	1103	1127	1363	1102
18	116	129	134	116	121	118	123	118	127
19	1900	3180	2080	1920	2070	1930	2100	1940	2100
20	2170	4285	2455	2310	2580	2700	2170	2570	2170
21	770	1076	824	770	770	770	770	770	770
22	131	131	131	131	131	131	131	131	131
23	430	740	470	450	450	460	430	430	510
24	1480	1990	1480	450	1480	1480	1480	1480	1480
25	796	1095	922	796	796	796	796	796	796
POS		**4%**	**16%**	**52%**	**44%**	**44%**	**52%**	**40%**	**88%**
ARD		**0.370**	**0.081**	**0.034**	**0.055**	**0.039**	**0.044**	**0.084**	**0.015**

8. Graphical presentation

The following Chart 1 shows the percentage of optimum solution and Chart 2 displays the average relative deviation yielded by different solution procedure by means of twenty five sample examples given in Table 1.

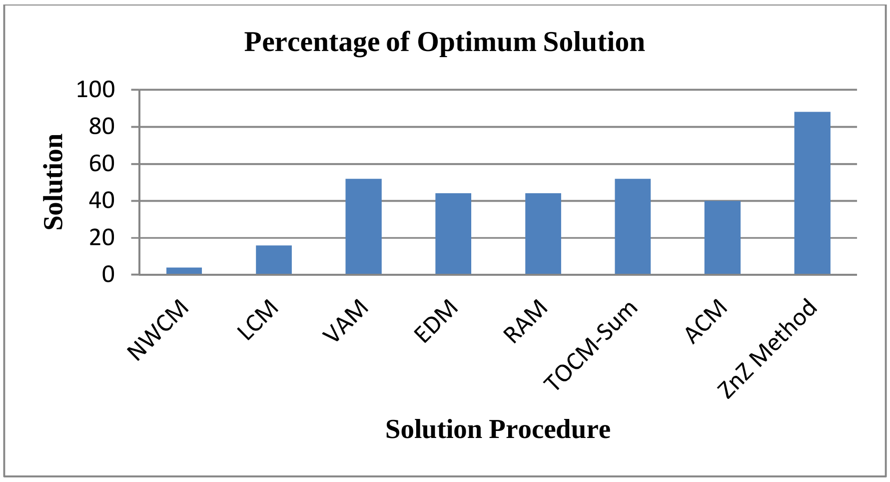

Chart 1: Percentage of Optimal Solution

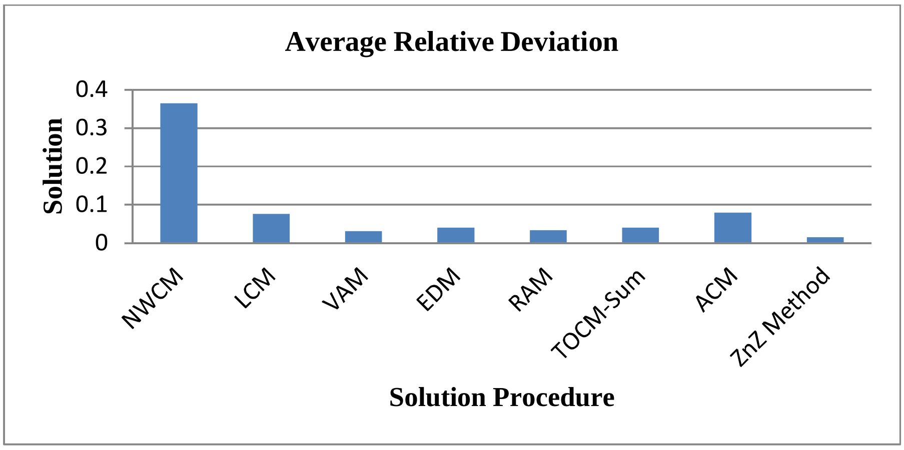

Chart 2: Average Relative Deviation

9. Conclusion

This paper proposed a new effective and computationally very simple approach named as ZnZ method to determine the IBFS of TP which is similar or very closer to the optimal solution. Comparative study given in Table 5 shows that the proposed approach perform better than NWCM, LCM, VAM, EDM, RAM, TOCM-SUM and ACM over the Twenty Five numerical examples, selected at random from some peer-reviewed journals.

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