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The Novel Efficient Method to Solve Balanced and Unbalanced Profit Maximization in Transportation Problems

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Abstract: Organizations must plan how to get their commodities from production centers to consumers' homes with the least amount of transportation expense to maximize profit. The Transportation Problem (TP) approach is used to evaluate and reduce the cost of transportation. There are two types of TPs. Such as cost minimization TP and profit maximization TP. Typically, the transportation technique is employed for minimization but the objective function should be maximized rather than minimized in several categories of TPs. By changing the maximizing problem into the minimization problem, these types of issues may be resolved in literature. By deducting the unit costs from the table's greatest unit cost, maximizing is changed into minimization. The first step in achieving an optimal solution is to find the initial basic feasible solution (IBFS). North-West Conner, Least Cost, and Vogel's Approximation Methods can be used to find IBFS. The optimal solution can be obtained by using only Modified Distribution (MODI) and Stepping Stone Methods. This study proposes a novel direct method to find an optimal or near-optimal solution to profit maximization TPs. In this proposed method, maximization TP is not needed to convert minimization TP. This method is very easy and it has less implementation. In the end, by solving several illustrative examples, we compare the proposed method's results with other existing methods.

Keywords: Cost Minimization, Profit Maximization, Unit Cost, Optimal Solution, Transportation Problem

1. Introduction

The TP was arguably one of the earliest important issues researched in the use of linear programming techniques. By formulating a linear model, the issue may be described, and the simplex technique can be used to resolve it. Commodities are becoming more and more necessary in today's quick-paced world. As a result, the value of transportation is crucial to society. Transport determines the earnings and success of businesses that carry items from one location to another. The TP model is one of the well-known operations research models that focuses on determining the number of goods that should be transported from a collective of distributors to a collective of warehouses via the road network to satisfy the demand in the warehouses while generating the highest profit or the least expensive, based on the type of issue.

Among the many various kinds of transportation models that exist now, Hitchcock [13] first presented the most basic one in 1941. It was elaborated upon by Koopmans [33] in 1949 and Dantzig [5] in 1951. Since then, several extensions to transportation models and approaches have been developed. The two solutions for TP are the Initial Basic Feasible Solution (IBFS) and the Optimal Solution (OS). Several heuristic strategies, such as the Least Cost Method (LCM) [34], the North-West Corner Method (NWCM) [16], and Vogel's Approximation Method (VAM) [20], are used to derive IBFS and heuristic techniques including the MODI and the Stepping Stone Method for obtaining OS. In 2016, Ahmed, M. M., Khan, A. R., Ahmed, F. and Uddin, Md. S. [3] proposed the Incessant Allocation Method for Solving TPs. Haleemah J. K. [18] introduced a novel technique to solve the Maximization of TPs in 2021. The transportation model was solved in 2019 by A. Seethalakshmy and N. Srinivasan [30] using a novel algorithm to maximize profit for the company. In 2016, S. K. Prabha [21] proposed a new algorithm for maximizing the profit of the TP in a fuzzy environment by using the Method of Magnitude ranking method and Yager's Ranking Method where fuzzy quantities are converted into crisp quantities. Sharmistha J., Barun D., Goutam P., and Manoranjan M. [14] published a paper called "Profit Maximization Solid TP with Gaussian Type-2 Fuzzy Environments" in 2018. W. K. Abdelbasset [1] proposed many solutions to maximizing transportation problems in 2022. Furthermore, since the transportation approach is typically employed for minimization, this research sees them as two distinct factors. In 2016, P. K. Giri, M. K. Maiti, and M. Maiti [12] proposed the maximization of profits using fuzzy measures to address a solid TP under budget constraints. In 2016, Bimal S., Amrit D., and Uttam K. B. [32] introduced a new idea on TP in which they optimize the profit and reduce the transportation time when transferring an amount quantity from a source to the destination. D. Santhosh Kumar and G. Charles Robinson [22] proposed a method called profit maximization of balanced fuzzy TP using Yager's ranking method in 2018. Moreover, S. F. Kader [17], A. K. Azad [19], E. M. U. S. B. Ekanayake [5–11], Z. A. M. S. Juman [15, 16], E. M. D. B. Ekanayake [4], K. P. O. Niluminda [23–28], Joseph Ackora-Prah [2] proposed different types of technology to solve TPs. In this paper main objective is to propose a new alternative method to address the profit maximization TPs. Section 1 discusses some basic definitions. The transportation model formulation is shown in section 2. The proposed algorithm and its comparative analysis of examples are represented in sections 3 and 4 respectively. Finally, the conclusion of this research will be discussed in the last section.

2. Basic Definitions

Definition 1: Sources and Destinations

Demanding nodes or destination nodes in a TP are the places where items are provided from sources. Sources are the places in a TP from which commodities are dispersed to the necessary points.

Definition 2: Supply Limit and Demand Requirement

The word "demand requirement" refers to the amount of a commodity needed to satisfy the demands of a demanding node, while the term "source's supply limit" refers to the quantity of an item needed to meet demand at each demand node.

Definition 3: Balanced & Unbalanced Transportation Problem

If the entire supply and demand are equal, a TP is said to be in balance.

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

When there is a discrepancy between the overall supply and demand, an unbalanced TP occurs.

$$\sum_{i=1}^{m} a_i \neq \sum_{j=1}^{n} b_j$$

Definition 4: Initial Basic Feasible Solution (IBFS) and Optimal Solution

A feasible solution in which the number (total) of allocations equals (m + n - 1) in a TP with m sources and n destinations is referred to as an IBFS. While a basic feasible solution may fulfill all of the sources and destination constraints, it may not always provide the lowest solution. There may be more than one fundamental workable option, but the optimal solution is the one with the lowest overall transit cost.

3. Model Representation of the Profit Maximization Transportation Problem

Consider a scenario in which a specific item is typically produced at m manufacturing plants, referred to as sources, denoted by $S_1, S_2, \ldots, S_m$ with respective capacities of $a_1, a_2, \ldots, a_m$ and transported to n fulfillment centers, referred to as destinations, denoted by $D_1, D_2, \ldots, D_n$ with respective needs $b_1, b_2, \ldots, b_n$.

Assume that x_{ij} and p_{ij}, respectively, represent the amount communicated and the profit, from the i^{th} source to the j^{th} destination. Where $i = 1, 2, \ldots, m$ & $j = 1, 2, \ldots, n$.

Mathematical Formulation of TP:

$$Max\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} p_{ij}$$

Subject to:

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

$$\sum_{i=1}^{m} x_{ij} = b_j \, , j = 1, 2, \ldots, n \;\; x_{ij} \geq 0 \; ; \forall\, i = 1, 2, \ldots, m \;\&\; j = 1, 2, \ldots, n$$

Table 1. *An illustration of the transportation issue on a table.*

Destination → / **Source ↓**	D_1	D_2	⋯	D_n	**Supply (a_i)**
S_1	p_{11}	p_{12}	⋯	p_{1n}	a_1
S_2	p_{21}	p_{22}	⋯	p_{2n}	a_2
⋮	⋮	⋮	⋯	⋮	⋮
S_m	p_{m1}	p_{m2}	⋯	p_{mn}	a_m
Demand (b_j)	b_1	b_2	⋯	b_n	

4. Research Methodology

The proposed new algorithm is explained in this section. The suggested approach can be used to resolve both balanced and unbalanced profit maximization TPs. Using this method, the optimum or nearly optimum solution can be found. The steps in the suggested procedure are as follows:

Step 1: If the Transportation Table (TT) is unbalanced, balance it by adding a dummy row or column.

Step 2: Select the cell that has the maximum profit (P_{ij}) and allocate the maximum allocated value (x_{ij}) to that cell.

Step 3: Adjust the supply and demand value according to the allocated value in the previous step.

Step 4: If the supply or demand is satisfied in a selected cell, then cross out that row or column.

Step 5: Select the maximum profit value in not crossing out a row or column in the previous step and repeat steps 2 to 4.

Step 6: After all the supplies and demands are satisfied, calculate the total transportation profit.

The flow chart representation of the proposed algorithm is shown in Figure 1.

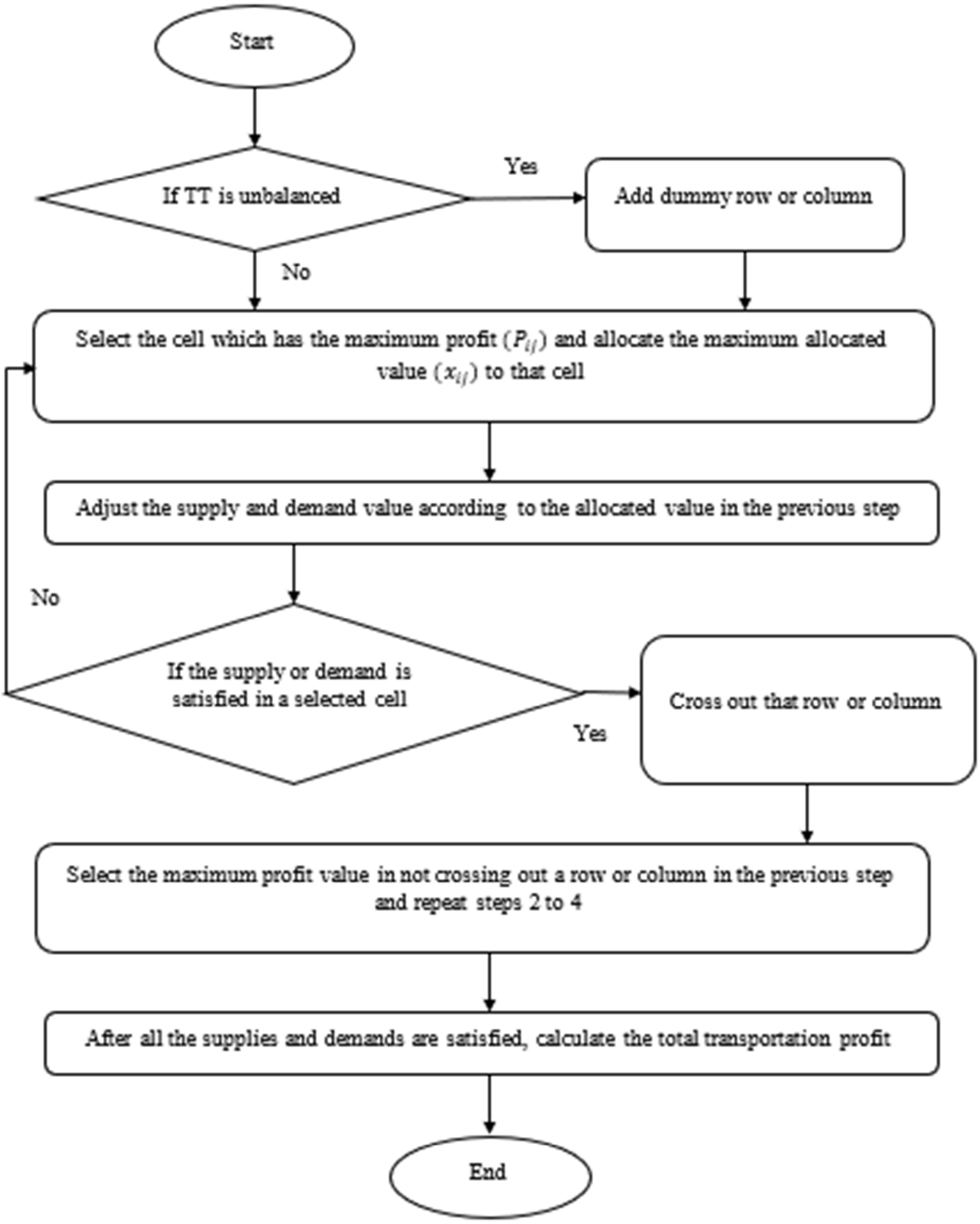

Figure 1. *Flow chart of Proposed Algorithm.*

5. Results and Discussion

In this section, the newly proposed approach will be utilized to examine the profit-maximizing of both Balanced Transportation Problems (BTP) and Unbalanced Transportation Problems (UBTP). Some of the examples are selected from the literature and some of them are randomly generated balanced and unbalanced TPs (RBTP & RUBTP). After that, the output results will be compared to an optimal solution.

Ex. 1: Profit Maximized Balanced Transportation Problem – 1 (BTP-1) [3].

Table 2. *Initial Balanced Transportation Table of Ex. 1.*

	D1	D2	D3	D4	Supply
S1	16	14	11	25	140
S2	18	29	12	27	180
S3	14	23	16	12	70
Demand	60	100	150	80	

Steps 2 – 5:

Table 3. *Iteration_1 of Ex. 1.*

	D1	D2	D3	D4	Supply
S1	16	14	11	25	140
S2	18	(100)*29	12	27	180,80
S3	14	23	16	12	70
Demand	60	100,0	150	80	

Table 4. *Iteration_2 of Ex. 1.*

	D1	D2	D3	D4	Supply
S1	16	14	11	25	140
S2	18	(100)*29	12	(80)*27	180,80,0
S3	14	23	16	12	70
Demand	60	100,0	150	80,0	

Table 5. *Iteration_3 of Ex. 1.*

	D1	D2	D3	D4	Supply
S1	16	14	11	25	140
S2	18	(100)*29	12	(80)*27	180,80,0
S3	14	23	(70)*16	12	70,0
Demand	60	100,0	150,80	80,0	

Table 6. *Iteration_4 of Ex. 1.*

	D1	D2	D3	D4	Supply
S1	(60)*16	14	11	25	140,80
S2	18	(100)*29	12	(80)*27	180,80,0
S3	14	23	(70)*16	12	70,0
Demand	60,0	100,0	150,80	80,0	

Table 7. *Final Transportation Table of Ex. 1 with all allocation.*

	D1	D2	D3	D4	Supply
S1	(60)*16	14	(80)*11	25	140,80,0
S2	18	(100)*29	12	(80)*27	180,80,0
S3	14	23	(70)*16	12	70,0
Demand	60,0	100,0	150,80,0	80,0	

Step 6:

Total transportation cost = (16*60) + (11*80) + (29*100) + (27*80) + (16*70) = 8020

VAM = 8000

Optimal = 8020

Ex. 2: Randomly Generated Profit Maximized Unbalanced Transportation Problem – 1 (RUBTP-1)

Table 8. *Initial Balanced Transportation Table of Ex. 2.*

	D1	D2	D3	D4	Supply
S1	10	8	5	9	13
S2	12	13	6	11	16
S3	8	7	10	6	3
Demand	2	10	14	4	

Steps 2 – 5:

Table 9. *Iteration_1 of Ex. 2.*

	D1	D2	D3	D4	D/D	Supply
S1	10	8	5	9	0	13
S2	12	13	6	11	0	16
S3	8	7	10	6	0	3
Demand	2	10	14	4	2	

Table 10. *Iteration_2 of Ex. 2.*

	D1	D2	D3	D4	D/D	Supply
S1	10	8	5	9	0	13
S2	12	(10)*13	6	11	0	16,6
S3	8	7	10	6	0	3
Demand	2	10,0	14	4	2	

Table 11. *Iteration_3 of Ex. 2.*

	D1	D2	D3	D4	D/D	Supply
S1	10	8	5	9	0	13
S2	(2)*12	(10)*13	6	(4)*11	0	16,6,4,0
S3	8	7	10	6	0	3
Demand	2,0	10,0	14	4,0	2	

Table 12. *Iteration_4 of Ex. 2.*

	D1	D2	D3	D4	D/D	Supply
S1	10	8	5	9	0	13
S2	(2)*12	(10)*13	6	(4)*11	0	16,6,4,0
S3	8	7	(3)*10	6	0	3,0
Demand	2,0	10,0	14,11	4,0	2	

Table 13. *Iteration_5 of Ex. 2.*

	D1	D2	D3	D4	D/D	Supply
S1	10	8	(11)*5	9	(2)*0	13,2,0
S2	(2)*12	(10)*13	6	(4)*11	0	16,6,4,0
S3	8	7	(3)*10	6	0	3,0
Demand	2,0	10,0	14,11,0	4,0	2,0	

Step 6: Total transportation cost = (5*11) + (0*2) + (12*2) + (13*10) + (11*4) + (10*3) = 283

VAM = 283

Optimal = 283

In the preceding examples, both balanced and unbalanced TPs are presented. For example, BTP and RUTP. The suggested strategy delivers an optimal solution in every TP and a better result when compared to the VAM method.

A Comparison of the Proposed Algorithm

This study compares the findings to determine the efficacy of the proposed technique. Table 14 compares profit maximized Balanced Transportation Problems (BTPs) with NWCM, LCM, VAM, and the Proposed New Method (Niluminda's Method) for five examples from the literature. In this case, the results are also compared to the best answer (Optimal Solution).

Table 14. *Comparative analysis of profit maximized Balanced Transportation Problems (BTPs).*

Problem No (Ahmed et al., 2016)	NWCM	LCM	VAM	Niluminda's Method	Optimal
BTP-1	5570	8020	8000	8020	8020
BTP-2	468	654	662	662	662
BTP-3	137	232	232	232	232
BTP-4	36795	46760	46760	46700	46760
BTP-5	28150	33800	34050	34050	34050

Figure 2 depicts the findings of the bar charts that were used to display the comparative results from Table 14 in greater depth.

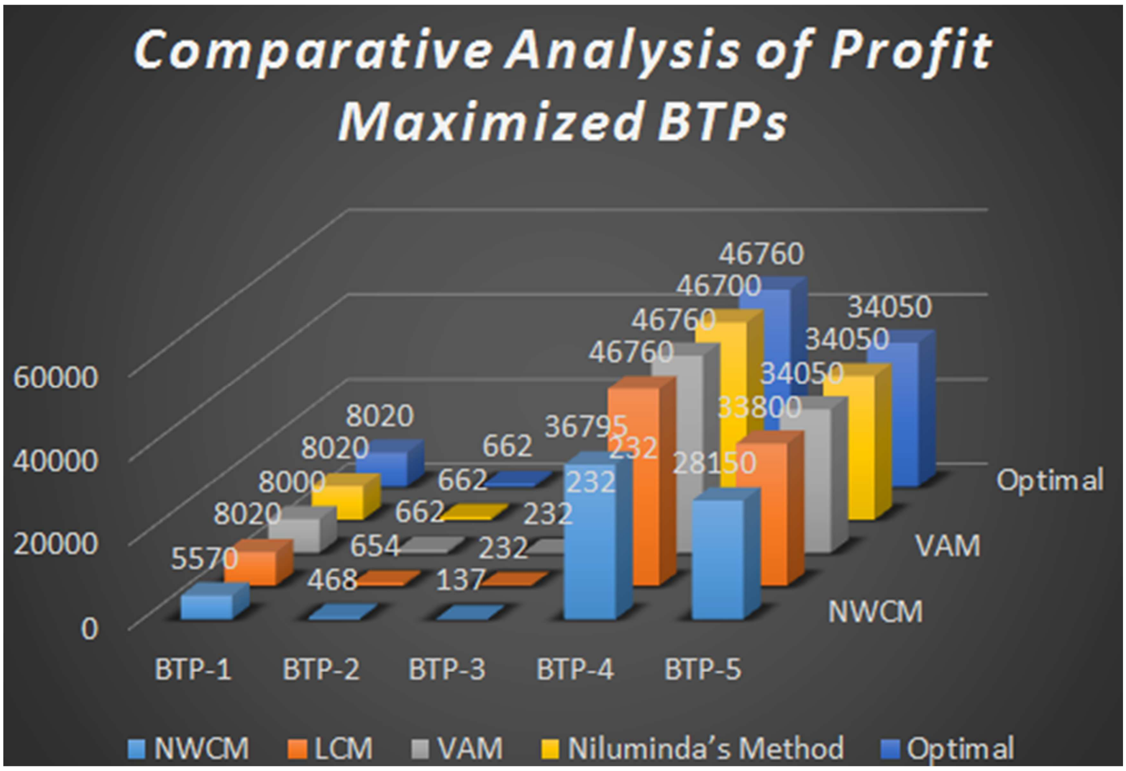

Figure 2. *Comparative Analysis of Profit Maximized TPs.*

Table 14 shows that the new technique outperforms NWCM, LCM, and VAM in every circumstance where an increase in efficiency is possible. Four out of five examples provide the optimal solution, while the remaining occurrences provide a near-optimal solution. Appendix A contains the numerical data from Table 14. Table 15 Compares randomly produced profit-maximizing Balanced and Unbalanced TPs (BTPs & UBTPs) with NWCM, LCM, VAM, and Niluminda's Method for ten examples, and Figure 3 depicts its graphical depiction.

Table 15. *Comparative analysis of randomly generated profits maximized Balanced and Unbalanced Transportation Problems (BTPs & UBTPs).*

Problem No	NWCM	LCM	VAM	Niluminda's Method	Optimal
RBTP-1	5320	5500	5500	5500	5500
RBTP-2	56300	67600	68100	68100	68100
RBTP-3	518	763	761	763	763
RBTP-4	645	846	856	856	856
RBTP-5	202	291	291	291	291
RUTP-1	222	283	283	283	283
RUTP-2	992	1343	1353	1353	1353
RUTP-3	680	1000	1000	1000	1000
RUTP-4	451	565	565	565	565
RUTP-5	966	1182	1190	1190	1190

Figure 3 depicts the findings of the bar graphs used to display the comparative results from Table 15 in greater depth. Appendix B contains the numerical data from Table 15.

According to the statistics shown above (Table 15, Figure 3), the novel strategy outperforms the current ones. In this article, ten instances were examined, and each situation produces the best results. Table 15 compares ten randomly produced RBTPs and RUTPs.

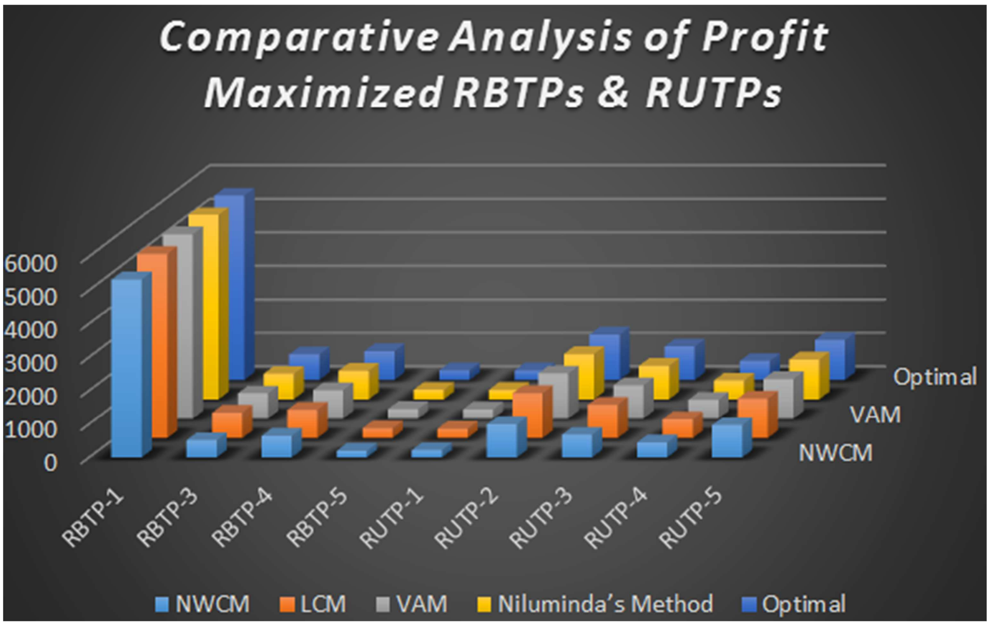

Figure 3. *Comparative Analysis of Randomly Generated Profit Maximized TPs.*

6. Conclusion

This study proposed a novel approach to solve both balanced and unbalanced profit-maximized transportation problems. The optimal or near-optimal solution can be found using this proposed method. The transportation technique is often used for minimization, although in some types of TPs, the target function should be maximized rather than minimized. These sorts of challenges may be overcome in literature by converting the maximizing problem to the minimization problem. Maximization TP is not required to convert minimization TP in this suggested technique. The optimal or near-optimal solution can be directly found using this proposed technique. This approach is simple and requires little implementation.

This strategy was utilized to resolve 15 issues in this study. Five of them are drawn from the literature, while the remaining ten are selected at random. These 15 problems were evaluated in comparison to other available approaches. As a result, this indicates that the innovative technology is successful in terms of solution quality when compared to the methods tested in this research.

Appendix

Table A1. *Data sets for Balanced Profit Maximize TPs.*

Problem No [3]	Data
BTP-1	$c_{ij} = \{16,14,11,25; 18,29,12,27; 14,23,16,12\}$ $s_i = \{140, 180, 70\}$ $d_j = \{60, 100, 150, 80\}$
BTP-2	$c_{ij} = \{14,19,7,5; 16,6,12,9; 6,16,5,20\}$ $s_i = \{10, 12, 18\}$ $d_j = \{9, 14, 7, 10\}$
BTP-3	$c_{ij} = \{6,4,1,5; 8,9,2,7; 4,3,6,2\}$ $s_i = \{14, 18, 7\}$ $d_j = \{6, 10, 15, 8\}$
BTP-4	$c_{ij} = \{35,22,33,16,20,12; 14,21,28,30,15,24; 55,18,17,29,26,19;$ $21,16,15,17,31,28; 45,23,16,11,22,50\}$ $s_i = \{320, 180, 200, 300, 300\}$ $d_j = \{225, 225, 200, 200, 275, 175\}$
BTP-5	$c_{ij} = \{10,18,2; 9,8,20; 14,21,7; 12,2,25\}$ $s_i = \{500, 250, 350, 600\}$ $d_j = \{300, 600, 800\}$

Table A2. *Data sets for Randomly Generated Balanced and Unbalanced Profit Maximize TPs.*

Problem No	Data
RBTP-1	$c_{ij} = \{48,56,42; 54,50,52; 46,44,58\}$ $s_i = \{15, 60, 25\}$ $d_j = \{50, 20, 30\}$
RBTP-2	$c_{ij} = \{200,360,40; 180,160,400; 280,420,140; 240,40,500\}$ $s_i = \{50, 25, 35, 60\}$ $d_j = \{30, 60, 80\}$
RBTP-3	$c_{ij} = \{15,13,10,24; 17,28,11,26; 13,22,15,11\}$ $s_i = \{14, 18, 7\}$ $d_j = \{6, 10, 15, 8\}$
RBTP-4	$c_{ij} = \{17,22,10,8; 19,9,15,12; 9,19,8,23\}$

Problem No	Data
	$s_i = \{11, 13, 20\}$ $d_j = \{10, 15, 8, 11\}$
RBTP-5	$c_{ij} = \{8,6,3,7; 10,11,4,9; 6,5,8,4\}$ $s_i = \{15, 18, 5\}$ $d_j = \{4, 12, 16, 6\}$
RUTP-1	$c_{ij} = \{10,8,5,9; 12,13,6,11; 8,7,10,6\}$ $s_i = \{13, 16, 3\}$ $d_j = \{2, 10, 14, 4\}$
RUTP-2	$c_{ij} = \{20,25,13,11; 22,12,18,15; 12,22,11,26\}$ $s_i = \{16, 18, 25\}$ $d_j = \{15, 20, 13, 16\}$
RUTP-3	$c_{ij} = \{14,12,9,23; 16,27,10,25; 12,21,14,10\}$ $s_i = \{18, 22, 11\}$ $d_j = \{10, 14, 19, 12\}$
RUTP-4	$c_{ij} = \{11,9,6,10; 13,14,7,12; 9,8,11,7\}$ $s_i = \{19, 22, 9\}$ $d_j = \{8, 16, 20, 10\}$
RUTP-5	$c_{ij} = \{25,30,18,16; 27,17,23,20; 17,27,16,31\}$ $s_i = \{11, 13, 19\}$ $d_j = \{10, 15, 8, 11\}$

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