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Optimizing Initial Basic Feasible Solutions for Transportation Problems: A Novel Approach Incorporating Second Least Cost as Penalty

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Abstract
Within the context of transportation issues, this study presents a novel way to generating an Initial Basic Feasible Solution. A superior initial solution is provided by the proposed method in comparison to the VAM method, which is extensively utilized. The proposed method is also user-friendly and requires less computational time. In spite of the fact that NWCM, LCM, and VAM (1958) are all recognized heuristic methods in the academic world, VAM is the method of choice due to its logical approach and superior results. In spite of the fact that research-level approaches have the potential to provide better results than VAM, they frequently involve more complexity and a longer amount of time spent computing. It is important to note that the recently released Maximum Range Column Method (MRCM) (2021) and the Revised Distribution Method (RDI) (2013) offer computation timeframes and simplicity that are comparable to those of the variance analysis method (VAM). The LCPD (Linesh Chungath Pandey Dixit) approach, which consistently beats VAM, RDI, and MRCM in terms of finding optimal solutions, is presented in the study. This research makes a significant contribution to the field by providing practitioners and researchers with a useful tool. It provides a method that is both efficient and accessible, and it offers improved performance in comparison to the strategies that are already in use.
Keywords: *Transportation, The LPCD, Novel Solution, Heuristic, traditional Methods*

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I. Introduction

The Transportation Problem (TP) is a distribution scenario involving the movement of products from multiple sources (eg.factories) to various destinations (eg.warehouses). The primary aim is to minimize the overall cost incurred during the transportation of these products. The overall demand from warehouses and the entire capacity available for supplying items from diverse sources are the two main restrictions governing this challenge. Regarding the foremost objective, the transportation problem is usually classified into two scenarios: the minimization and the maximization case (Yang and H. Bell, 1998). In the minimization transportation problem, the focus is on shipping commodities with the primary goal of minimizing the overall cost of transportation. If any company seeks to optimize its profits through the transportation of products from sources to destinations, it falls under the maximization case. The basic transportation problem was first studied by Hitchcock, (1941) and further developed by Koopmans, (1947), and finally placed in the framework of linear programming to be solved further using the simplex method proposed by Dantzig, (1951). The Simplex method is complex and proves to be inefficient for transportation, especially for large-scale transportation problems and also for the business extensions of the transportation problem models. The classification of the transportation problem is determined by its primary objective and how well the supply from sources aligns with the requirements at destinations (Charnes, 1953).When the supplied quantity matches the demanded quantity, it is termed as a balanced transportation problem(Andrews et al., 2014). Conversely, the situation where there is unbalanced transportation problem describes a situation where the quantity of supplies from sources does not match the number of demands from destinations. This incongruence can manifest in two ways: Either the number of demands surpasses the quantity of supplies, or the reverse is true. Either the number of demands surpasses the quantity of supplies, or the reverse is true. (Sultana et al., 2022)

The extensions of the transportation problem model have demonstrated their efficacy in attaining optimal solutions across several industries.For almost 200 years, people have been working hard to find an algorithm that can provide the best possible results without needing an initial fundamental workable solution. Therefore, Vogel's Approximation Method (VAM) and the Modified Distribution Method (MODI) or Stepping Stone Method (SSM) are widely acknowledged as the most effective approaches for achieving optimal solutions that meet all requirements and minimize transportation costs. Nevertheless, the practical implementation of transportation problems requires an algorithm that enables decision-makers to achieve optimized outcomes without computational intricacies and within a limited computational duration.

However, real-world transportation problems demand algorithms enabling swift and computationally simple decision-making processes for optimized results. Achieving an optimal solution for transportation problems involves a two-stage process. The fundamental steps to resolve a transportation problem are as follows:

1. Determine "The Initial Basic Feasible Solution (IBFS)".

2. Attain the optimal solution by utilizing IBFS value, which is subsequently assessed for optimality through two methods: the "Stepping-Stone Method" and the "MODI METHOD."

II. Literature Review

The transportation cost is the main concern in case of transportation problem, and it is to ascertain the lowest transportation cost under comparable circumstances in order to satisfy the restriction(Audy et al., 2011).The evolution of heuristic algorithms for solving transportation problems Adlakha and Kowalski, (2003), focusing on VAM and its variants. Beginning with Mathirajan and Meenakshi, (2004) experimental analysis of VAM and Total Opportunity Method (TOM), subsequent studies introduced enhancements such as Improved VAM (IVAM) and ASM-based methods. The review covers direct solution methods like Zero-Suffix and SAM-Method, emphasizing the need for further understanding. Innovations include the development of the New Algorithm (NMD) by Deshmukh, (2012)and the introduction of the Zero Point (Z-P) method by(Singh and Yadav, 2016).Girmay and Sharma, (2013) propose a heuristic approach to enhance VAM for imbalanced transportation problems, validating efficacy through numerical illustrations Samuel and Venkatachalapathy, (2013) detail the Improved Zero Point Method (IZPM) for solving unbalanced fuzzy transportation problems, emphasizing simplicity and numerical validation. Aramuthakannan and Kandasamy, (2013) introduce the Revised Distribution Method (RDI) for optimizing transportation problems, demonstrating its ability to maximize and minimize objective functions. Das et al., (2014) propose AVAM with penalty cost to improve feasible solutions and address computational errors in VAM. Ahmed et al., (2014) underscore the significance of linear programming, presenting the IBFS method as a new approach with improved solutions for transportation problems. Das et al., (2014) address VAM limitations, introducing LD-VAM as an improved algorithm for more efficient and optimal solutions. Rychard et al., (2015) evaluate and compare three heuristic algorithms, emphasizing the accuracy of HCM and RRAM in solving transportation problems. Kousalya and Malarvizhi, (2016) propose the Allocation Table Method (ATM) as a novel approach for obtaining initial basic feasible solutions, showcasing its superiority over traditional algorithms. Kousalya and Malarvizhi, (2016) introduce a novel procedure equivalent to VAM for achieving minimal costs in transportation problems. Vimala et al., (2016) introduce the OFSTF(Origin, First, Second,Third, and Fourth quadrants)method, checking its feasibility for transportation problems and highlighting its systematic procedure and easy implementation.

Hlatká et al., (2017) apply VAM to reduce operating costs in transport-logistics processes, confirming substantial improvements through operational research. Ekanayake et al., (2020) address transportation problems with the Modified Ant Colony Optimization Algorithm (MACOA), providing efficient initial solutions, especially for large-sized problems. Kalhoro et al., (2021) introduce the Maximum Range Column Method (MRCM) as an efficient Initial Basic Feasible Solution, surpassing traditional methods in reducing transportation costs. Sultana et al., (2022) conduct a comparative study on resource allocation in freight transportation, highlighting the efficiency of Faster Strongly Polynomial method (FSTP) and VAM-MODI in various scenarios.

Despite the availability of heuristic methods for obtaining an initial basic feasible solution in transportation problems, there remains a gap in the research concerning the efficiency, simplicity, and quickness of these methods. In this research work, we propose a novel IBFS technique, known as the LCPD(Linesh Chungath Pandey Dixit) method which was compared with the previous conventional methods like VAM, RDI, and MRCM etc . Finally it has been found that the LPCD is an efficient and accurate alternative substitute for the IBFS methods.

III. Material and Methods

When dealing with transportation problems that involve a known number of sources and destinations, it is usual practice to present the cost table as well as the supply and demand capacity in the form of a transportation array. As an illustration, let's take into consideration a transportation issue that involves three origins, namely A, B, and C, and four destinations, specifically D, E, F, and G. S1 through S3 are the designations given to the supply capacity of the various sources. The capacity of the destinations, on the other hand, are designated by the letters

D1 through D4. A visual representation of these particulars can be found in Table 1, which provides an indication of the costs (Ci,j) that are involved with moving commodities from a source "i" to a destination "j" per unit.
The purpose of this endeavor is to ascertain the optimal values for the decision variables, which are denoted by the letter X and reflect the total units of products that need to be transported from their origins to their final destinations. The goal is to reduce the overall cost of transportation as much as possible while taking into account supply and demand restrictions as well as non-negativity constraints. After removing the cells that are adjacent to one another, the total cost of transportation is determined by multiplying the per-unit costs by the best values of the choice variables in each cell of the transportation table. This process is repeated until the total cost of transportation occurs.

Table 1: Example Transportation problem array with 3 sources and 4 destinations

Destination / Source	**D**		**E**		**F**		**G**		**Supply**
A	X_1	C_{AD}	X_4	C_{AE}	X_7	C_{AF}	X_{10}	C_{AG}	**S1**
B	X_2	C_{BD}	X_5	C_{BE}	X_8	C_{BF}	X_{11}	C_{BG}	**S2**
C	X_3	C_{CD}	X_6	C_{CE}	X_9	C_{CF}	X_{12}	C_{CG}	**S3**
Demand	**D1**		**D2**		**D3**		**D4**		Balanced if Total supply = Total demand

3.1 Vogel's Approximation Method (VAM)

The VAM operates on the principle of penalty costs, where the cost of penalty is the difference between the highest and second-highest cell costs in a row or column. VAM allocates as much as possible to the cell with the lowest cost in the row or column with the greatest penalty cost. The procedure involves several steps:

1. Ensure the transportation problem is balanced by adjusting supply and demand if necessary.
2. Subtract the smallest cell cost from the next lower in the same row or column to determine the cost of penalty for each row and column.
3. Select the row or column that has the greatest penalty cost, then give the cell in that row or column with the lowest cost as much as you can. Make random choices if there are ties in fines or expenses.
4. Adjust the supply and demand based on the allocation, striking out exhausted rows or columns. If both are exhausted, eliminate both the row and column.
5. Recalculate penalty costs for the remaining rows and columns.
6. Repeat the process until all supply and demand requirements are met across various sources and destinations.

3.2 Revised Distribution Method (RDI)

The Revised Distribution Method involves the allocation of units in the transportation matrix by starting with the minimum demand or supply, assigning them to the cell with the lowest cost, and aiming to find an optimal solution for the transportation problem. The steps for this method are outlined below:
1. If supply and demand are not equal, make sure the transportation issue is balanced by modifying the overall supply and demand.
2. Determine the lowest number in the demand row and supply column. Select the value with the least associated cost if there is a tie.
3. Assign units according to the lower of the two available supply and demand, which are shown in the row and column, respectively..
4. Move on to the following minimal values in the supply and demand columns if the demand in the column is satisfied.
5. Repeat steps (3) and (4) until the total supply from various sources and the overall demand from different destinations are fulfilled.

3.3 Maximum Range Column Method (MRCM)

The Maximum Range Column Method focuses on identifying penalties or range costs (the difference between the higher and the lower costs in a column) within the transportation table columns. It opts for the maximum range for allocations. The method involves the following steps:
1. If there is an imbalance between the total supply and total demand, make sure the transportation issue is balanced.
2. Calculate the penalties or range costs for each column by determining the difference between the highest and the lowest costs.
3. Choose the column with the maximum range, and in case of a tie, select any row or column with the lowest range.

4. Allocate the minimum of the supply (s) and demand (d) to the cell with the lowest unit transportation cost out of the selected column or row.
5. Once a row or column is satisfied, no further consideration is needed for that specific row or column. If a row or column is satisfied, eliminate only one, assigning zero to the remaining row or column.
6. Repeat the process until all rows and columns are satisfied.

3.4 The Proposed the Linesh Chungath Pandey Dixit(LPCD) Method

Newly proposed the LCPD method calculates penalty costs by identifying the second least costly cells in each row and column. Subsequently, it give out as much as possible to the cell with the minimum cost in the row or column displaying the highest cost of penalty. The method involves the following steps:
1. Ensure the transportation problem is balanced. If the total supply does not match the total demand then it has to balance first.
2. Determine penalty costs with identifying the cells with the second least cost of all rows and columns.
3. Assign as much as you can to the cell in the chosen row or column that has the lowest cost. Find the row or column with the greatest second least cost value. Select the value with the lowest cost if there is a tie in the highest second least cost. If there is a tie in the minimum cost, the ties will be broken at random.
4. Adjust supply and demand based on the allocation and eliminate (strike out) the row or column in which either supply or demand is exhausted. If both are exhausted, eliminate both the row and column.
5. Reassess the second least cost value cells for the remaining rows and columns.
6. Repeat the procedure until the available supply from various sources and the total demand from various destinations are satisfied.

4. Step by Step Explanation of the Proposed the LCPD Method with Example

An example transportation problem is given in Table 2. In the example, the matrix size is 3x4. E-G are source points, and A-D are destination points.

Table 2: Example Transportation problem demonstrating proposed LCPD method.

Source \ Destination	**A**	**B**	**C**	**D**	**Supply**
E	3	6	8	4	**20**
F	6	1	2	5	**28**
G	7	8	3	9	**17**
Demand	**15**	**19**	**13**	**18**	

i) Find out the second least cost value in all the rows and columns.

Table 3: Example Transportation problem (second least cost)

Source \ Destination	**A**	**B**	**C**	**D**	**Supply**	**Row 2nd Least Cost Value**
E	3	6	8	4	**20**	4
F	6	1	2	5	**28**	2
G	7	8	3	9	**17**	7
Demand	**15**	**19**	**13**	**18**		
Column 2nd Least Cost Value	6	6	3	5		

ii) The Maximum 2nd Least Cost Value occurs in row G, the Least Cost Value (3) in row G is in Column C as shown in Table 3, The Maximum Allocation in this cell = min (13,17) =13, It satisfies demand of C and adjust the supply of G from 17 to 4 (17 - 13 = 4).

Table 4

Source \ Destination	**A**	**B**	**C**	**D**	**Supply**	**Row 2nd Least Cost Value**
E	3	6	~~8~~	4	**20**	4
F	6	1	~~2~~	5	**28**	5
G	7	8	3 (13)	9	**4**	8

Demand	**15**	**19**	**0**	**18**		
Column 2nd Least Cost Value	6	6		5		

iii) The Maximum 2nd Least Cost Value occurs in row G, The Least Cost Value in row G is in a Column A = 7, and The Maximum Allocation in this cell = min (15,4) =4, It satisfies the Supply of G and adjusts the Demand of A from 15 to 11 (15 - 4 = 11) as shown in table 5.

Table 5

Source \ Destination	**A**	**B**	**C**	**D**	**Supply**	**Row 2nd Least Cost Value**
E	3	6	~~8~~	4	**20**	4
F	6	1	~~2~~	5	**28**	5
G	7 (4)	~~8~~	3 (13)	~~9~~	**0**	
Demand	**11**	**19**	**0**	**18**		
Column 2nd Least Cost Value	6	6		5		

iv) The Maximum 2nd Least Cost Value occurs in column A & B. Select Column B as it has the least cost value, The Least Cost Value in column B is in Row F = 1, The Maximum Allocation in this cell = min (19, 28) = 19, It satisfies the Demand of B and adjusts the Supply of F from 28 to 9 (28 - 19 = 9) as shown in table (6).

Table 6

Source \ Destination	**A**	**B**	**C**	**D**	**Supply**
E	3 (11)	~~6~~	~~8~~	4	**9**
F	~~6~~	1 (19)	~~2~~	5	**9**
G	7 (4)	~~8~~	3 (13)	~~9~~	**0**
Demand	**0**	**0**	**0**	**18**	

v) Allocate Value to the remaining cells as shown in table (6) and eliminate the cells in which either supply or demand is exhausted as shown in table (7).

Table 7

Source \ Destination	**A**	**B**	**C**	**D**	**Supply**
E	3 (11)	~~6~~	~~8~~	4 (9)	**20**
F	~~6~~	1 (19)	~~2~~	5 (9)	**28**
G	7 (4)	~~8~~	3 (13)	~~9~~	**17**
Demand	**15**	**19**	**13**	**18**	

vi)Transportation Cost = (3 x 11) + (4 x 9) + (1 x 19) + (5 x 9) + (7 x 4) + (3 x 13)
= 33 + 36 + 19 + 45 + 28 + 39 = 200

The IBFS cost obtained by conventional methods (NWCM, LCM, VAM, RDI, MRCM and LCPD) Method is mentioned below in Table (8).

Table 8: Comparison of IBFS results using Various methods and the proposed LCPD method.

NWCM	**LCM**	**VAM**	**RDI**	**MRCM**	**LCPD**	**OPTIMAL**
273	231	204	267	208	200	200

IV. Results and Discussion

To demonstrate the efficiency of newly proposed the LCPD method over the traditional most popular method VAM and the research methods RDI & MRCM, we compared it with a set of 12 transportation problems as given in Singh et al., (2016) as a benchmark set of tests TPs which are taken from various research papers, online materials. The IBFS attained for test transportation problems are summarized in Table (9). In most problems, the LCPD method directly finds optimal solutions. The percentage comparison of the methods as to whether being able to obtain optimal solution directly or not are shown in Graph 1. The LCPD method directly attains the optimal solution for 10 test problems out of 12, whereas the optimality count for the MRCM, RDI, and VAM are 7, 5 and 0, respectively. The rank comparison of the methods to find the best IBFS is summarized in Table 10. The LCPD method obtains the best IBFS in 11 problems out of the 12, whereas the best IBFS count for MRCM, RDI and VAM are 8,5 and 0, respectively. The rank comparison of the methods is shown in Graph 2.

Table (9) IBFS using Proposed LCPD Method, MRCM, RDI and VAM

S.No.	Size	Optimal	LCPD	MRCM	RDI	VAM
1	3 x 4	412	412	412	412	476
2	3 x 4	743	743	743	743	779
3	5 x 5	59356	62484	60448	71710	68804
4	3 x 4	80	80	80	83	91
5	3 x 4	610	610	610	780	650
6	3 x 4	3460	3460	3460	3460	3520
7	4 x 3	76	76	80	76	80
8	3 x 4	506	506	506	506	542
9	3 x 4	200	200	208	267	204
10	3 x 3	148	148	152	170	150
11	3 x 4	180	188	327	272	224
12	3 x 5	172	172	172	178	175

Plots for the above can be seen in the figure 1,which showcases the percentage

Table (10): Rank comparison LCPD Method, MRCM, RDI and VAM

S.No.	Size	Optimal	LCPD	MRCM	RDI	VAM
1	3 x 4	412	1	1	1	4
2	3 x 4	743	1	1	1	4
3	5 x 5	59356	2	1	4	3
4	3 x 4	80	1	1	3	4
5	3 x 4	610	1	1	4	3
6	3 x 4	3460	1	1	1	4
7	4 x 3	76	1	3	1	3
8	3 x 4	506	1	1	1	4
9	3 x 4	200	1	3	4	2

10	3 x 3	148	1	3	4	2
11	3 x 4	180	1	4	3	2
12	3 x 5	172	1	1	4	3

Plots for the above can be seen in the Figure 2. which are showing the different Ranks for the applied optimal methods.

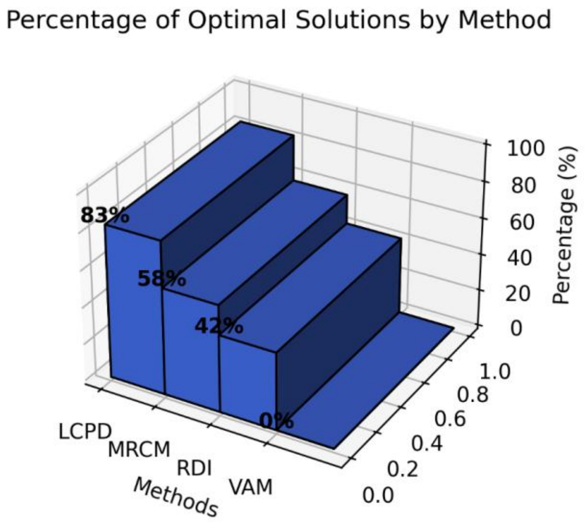

Figure 1 Optimal Comparison of IBFS Method

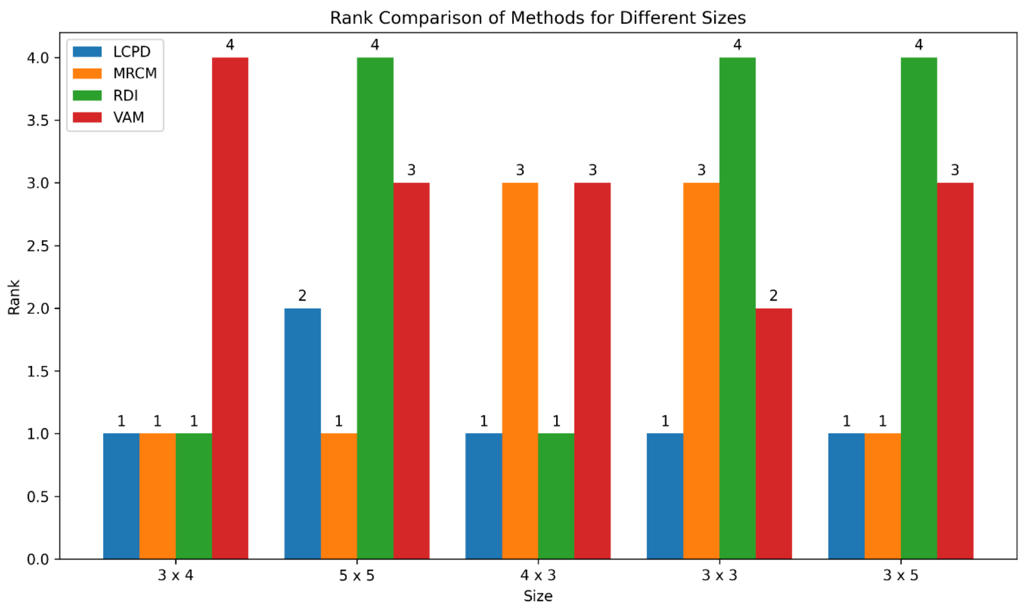

Figure 2 Rank chart of IBFS methods

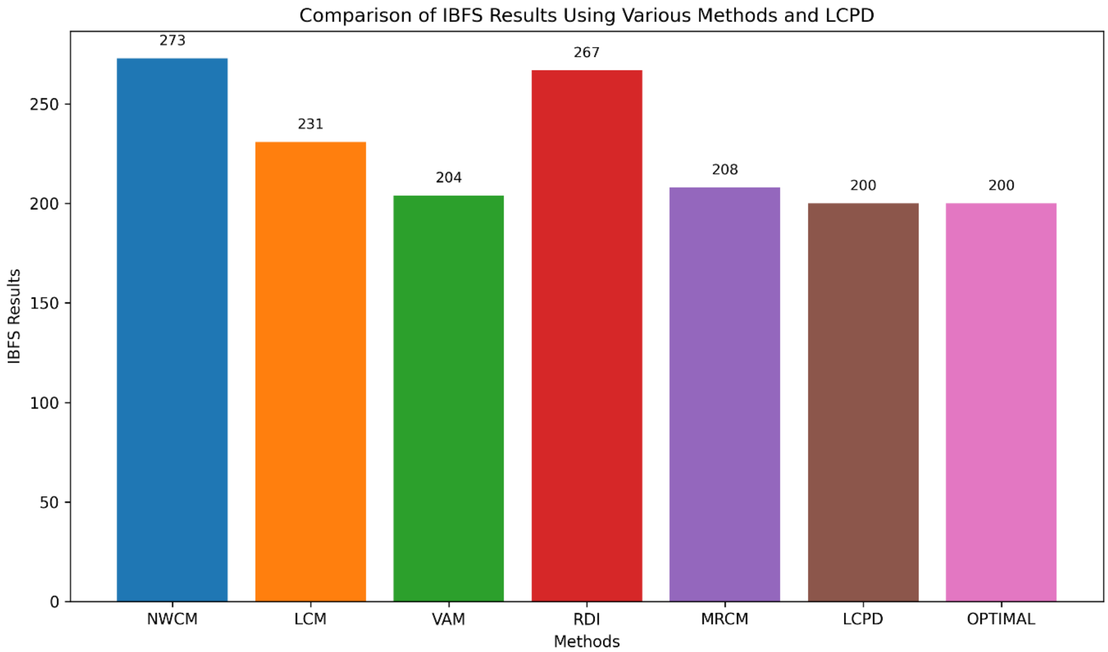

Figure 3 comparison of IBFS Results

V. Conclusion

The transportation problem (TP) is highly significant in the field of operations research because to its wide range of applications and crucial issues for decision-makers, which have a significant impact on a company's profitability. Among the several methods described in the literature, the Northwest, Least Cost, and Vogel's Approximation methods are particularly notable for determining an initial feasible solution to a Transportation Problem (TP). While many research-level techniques may provide more effective answers than VAM, they often involve intricate processes and require significant computational effort. Novel techniques such as MRCM (2021) and RDI (2013) have been suggested, showcasing their effectiveness through reduced computational requirements and superior outcomes compared to VAM in various scenarios. These proven methodologies, which aim to minimize overall costs, begin with an Initial Basic Feasible Solution (IBFS). Hence, the excellence of the IBFS is crucial in reducing the number of iterations required to achieve the ultimate ideal solution.

This study presents a new approach called the Initial Basic Feasible Solution (IBFS) method, which aims to offer a more accurate and efficient estimation of optimal solutions for transportation problems. This method outperforms established IBFS methods like VAM, as well as research approaches such as RDI and MRCM, in terms of precision and speed. The comprehensive findings emphasize the efficacy of the LCPD technique, showcasing its capacity to rapidly and accurately attain optimal or nearly ideal solutions compared to the other methods being evaluated. The results, which include the optimality percentage and the identification of the best Improved Breadth-First Search (IBFS), demonstrate that the newly proposed technique surpasses the performance of VAM, RDI, and MRCM. The LCPD method, known for its rapidity and precision in resolving transportation issues, exceeds conventional methods like NWCM, LCM, and VAM, and outperforms research methods such as RDI and MRCM. These findings offer a hopeful opportunity for researchers and decision-makers in the transportation business.

Competing Interests

The authors have stated that they do not have any competing interests.

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