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AN ANALYTICAL APPROACH OF STEPPING STONE AND NASH EQUILIBRIUM IN TRANSPORTATION AND GAME THEORY OPTIMIZATION

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ABSTRACT

Transportation problem is considered as the major problem in business due to cost and other issues happens during transportation of products. The stepping stone method is considered as the iterative techniquethat makes initial feasible solution to obtain the optimal solution in transportation problem. It is used as the optimization technique forgetting the optimum result in transportation from source city to destination city in petroleum refineries, textile mill industry and food product industry. The optimization technique helps in making use of differences in transport between two best choices for demand and supply. Strategies must be known in International Economic market for better understanding of opponents. Nash equilibrium method of game theory is used as the method optimal mixed strategy applied in the situation where the player wants to continue with the chosen strategies without any deviations from the incentive by considering the strategy of opponent. It can be applied in international economy market for obtaining the optimum solution by understanding the strategy. The main scope of the study analytical approach of stepping stone and Nash equilibrium in transportation and game theory optimization.

Keywords: *Optimization, The Stepping Stone method, Nash Equilibrium, Transportation, Game Theory*

1. INTRODUCTION

The Linear Programming classes, the transportation problem primarily concerns with logistics and how to make distribution of commodities more efficient than transportation of things. The quantity of supplies on hand and the quantities needed should be known in order to achieve the goal. The price of shipping a unit from its origin to its destination should also be known. The model is helpful for choosing the best shipping or transportation routes based on unit capacity and demand in a way that minimizes shipping or transportation costs (Wang et al., 2020). When two or more locations are being considered, the transportation model also aids in selecting new facilities for manufacturing plants in order to reduce production costs and overall transportation expenses.

Game theory is a formal mathematical study that helps us understand how different actors in a strategic position might cooperate and engage in conflict. It is a study of the manner in which participants compete with one another under predetermined circumstances. It is growing in importance as a field that may be used to forecast more significant trends, similar to economics, sociology, political science, and social sciences. A few areas where game theory can be used are businesses fighting for customers, political candidates vying for votes, bidders competing in an auction, competing specialists' incentives to diagnose a problem accurately, legislators' voting behaviour under pressure from internal groups (Roth & Wilson., 2019).

Through application of numerous optimization techniques and solution methodologies, the discipline of operational research has continued to help mitigating the negative effects, especially in the recent years. The paper provides the overview of recent research about the 'greening' freight transportation employing OR-based planning methods in addition to the fundamental ideas that support it. Though additional modes are quickly covered, the main emphasis is mostly on studies which have been reported for two widely utilized means of freight transportation around the world: road including electric and urban vehicles and maritime transportation (Bektas et al., 2019).

Industries, distribution centres, warehouses and factories have some strategies for whichimpacts costs in supply chain network design. As a result, businesses invest a lot of time and money into studying and weighing their options in order to select the best option. When choosing where to locate the industries and supply sources in relation to the destination city and the number of units for the specific products which is to be transported from every industry from origin city to destination city, companies can use the transportation model to help them minimize the overall cost in transportation while distribution of products from supply source to destination cities. The goal of the transportation model is to reduce the overall cost of moving items from origins to destination and it is applied in petroleum refineries textile mill industry and food product industries. Optimization of game theory problem using Nash equilibrium in international economy market.

1.1 Problem statement

The statement for problem is defined based upon the objectives and motivation of the research study is “Analytical approach of stepping stone and Nash equilibrium in transportation problem and game theory optimization”.

1.2 Objectives of the study

The main objectives of the study

- To solve transportation problems using data analytics
- To study the optimization problem solution for transportation problem and game theory problems.
- Application of complex transportation problem in the stepping stone method for getting optimum result
- To develop the approach of game theory problem using Nash Equilibrium for providing solution

2. LITERATURE REVIEW

Mahmood et al., (2020) to discover the best answer for the transportation model, a new method has been devised. In this method, we determined the standard deviation to the costs for every one of the rows and columns in the issue. Then, at that point, using 10 unique issues for transportation models with various dimensions, a comparison with Vogel's approximation strategy has been examined through the computation of transportation cost. The results showed that the suggested method was very efficient when compared to (VAM), with the overall cost of transportation issues by adopting the method being equal to or lower than the entire cost of (VAM). The proposed method is more effective at understanding and re-applying real-world transportation problems for the purpose of decision markers because it is a straight forward extension of the traditional method.

Liu et al., (2020) it can be difficult to establish extensive correspondences between semantically comparable images. The significant intra-class variation and background noise are two problems that frequently arise in existing methods. First, a source image's many pixels are matched with one target pixel that matches with one thing. Matching of background,the assignment of to the background pixel takes place. By using of global feature matching that maximise the correlation between the images in total for production of optimal matching matrix, we address the first problem. The matching matrix is subjected to the column problem and row problem restrictions in order to impose a balanced solution and so suppress the many-to-one matching. By using a staircase capability on the class initiation maps to re-weight the significance of pixels to four levels from fore front to foundation, we are able to address the second problem. By rephrasing the maximization issue as an optimal transport detailing and inserting the staircase weights into the optimal transport calculation to serve as exact distributions, the entire process is merged into a single optimal transport method. On four benchmark datasets, the suggested approach exhibits state-of-the-art performance.

Maity et al., (2019) in real-world operational research challenges, the double hesitant fluffy set accommodates imprecise, questionable, or fragmented data and information conditions that are difficult or impossible to address by the existing fuzzy techniques. Here, we use dual-hesitant fuzzy numbers to illustrate the idea of uncertainty in a transportation problem. Fuzzy uncertainty has been taken into consideration for transportation characteristics in the majority of research studies. However, we take into account the capacity of a decision maker to deliver the goods while formulating a mathematical model using the dual-hesitant fuzzy numbers. This study places particular emphasis on obtaining an optimal solution to a transportation problem with some constraints and uncertainty using the conventional method Vogel’s approximation method without the use of mathematics. To identify the best answer for type of transportation problem dual assistant fuzzy with some limits, an algorithm is created in this regard. The research approach is then demonstrated with the numerical examples to demonstrate its efficacy.

Chen et al., (2019) chemical industrial parks are vulnerable to cascading effects brought on by deliberate attacks since they are important infrastructure. Previous studies on security risk management have largely ignored the effect of safety barriers in favour of deploying security measures to thwart deliberate attacks. Safety barriers can lessen the potential repercussions and lessen the appeal of chemical industrial parks to terrorists looking to do the most destruction. According to a methodical approach, the potential impact of purposeful attacks is described as the expected loss, which is the sum of the likelihood that installations will be damaged and their impact. To combine security and safety resources and lower the risk of purposeful assaults, a consequence-based approach using a Dynamic Vulnerability Assessment Graph model is suggested. The DVAG model is created using dynamic graphs and takes into account the impact of safety barriers, security measures, and emergency response.

Darvishi et al., (2021) current methods for resolving linear programming issues and applications after introducing the ideas of grey numbers and grey systems. The merits and cons of various approaches and methods for solving the linear programming are also listed. Grey programming has developed from the past to the present. The dual theory models, simplex method, multi objective method, covered solutions, genetic algorithm, positioned solution, prediction model, whitening parameters, confidence degree, northwest model are the primary approaches for solving the problem by linear programming. This study looks into how different approaches for solving grey program that evolved and what uses they have found.

3. METHODOLOGY

For managerial decision-making in business, the service sector, government, and manufacturing, linear programming has been successfully used. It does have certain inherent restrictions, the most important of which is the linearity assumption. The output prices, fixed input constant, marginal returns, returns to scale constant, are required when using the linear objective function. We must use non-linear programming techniques when the objective function or restrictions have growing or decreasing returns to scale. When one of the profit or cost coefficients in a linear programming model acts as the random variable, nonlinearity also develops. In many cases, linear functions are utilized to model mathematical optimization problems. The easiest non-linear programming issues to solve are those involving quadratic functions and quadratic problems. In the real world, there are quite a few functional connections that are in fact quadratic. Kinetic energy, for instance, is proportional to the square of the velocity of an object, such as a rocket or an atomic particle. Quadratic functions can be used to approximate a variety of nonlinear interactions seen in nature. Transportation problems has numerous numbers of applications.

3.1 Vogel's Approximation Method

The Vogel's Approximation Method is commonly known as VAM, is an iterative process designed to distinguish the first functional solution to the transportation issue. Similar to the least-cost method, shipping costs are considered here as well, however from a general perspective. The process for applying Vogel's Approximation Technique to solve the transportation problem is illustrated in the flow chart. The iteration presented for each column and row shows how the difference between two least cost cells is first determined for each row and column. The biggest difference, which in this case is four, is then chosen.

3.2 Row Minima Method

The first row with the lowest cost cell is used up in the row minimum method. Our objective will be to distribute the most amount possible to either the first source or the demand at the destinations, or to satisfy both. The supply and demand must be balanced before this procedure may be repeated for all the other lowered transportation expenses.

3.3 Column Minima Method

While using the column minima method, we start with the first column and gradually move our allocations toward the column's lowest cost cell. The system is continued until the first destination centre is filled, the second destination centre's capacity is reached, or both of these events occur. If the demand from the first distribution centre is met, you can cross the first column and advance toward the right column. The 1th row must be crossed out and the first column must be taken into account as the remaining demand if the 1th factory's supply is satisfied. The last scenario is to allocate zero in the second-lowest row of the cost cell of the first column if the demand for the distribution centres and the 1th factories is met. As a result, to go to the second column, the with row and the columns are crossed off

3.4 Graphical Method

Only those games in which one player only has two strategies can use the graphic method. The sub-game method offers a straightforward approach, but if 'n' or' m' are large, a visual way is simple and relatively quick.

The steps in this procedure are listed below.

Step 1 - The 2xm or nx2 game matrices are partitioned into 2x2 submatrices.

Step 2 - The net benefit of A from the many potential strategies of B is then described with an equation by considering the probability of the two choices of the first player, let's say A, as P1 and (1- P1).

Step 3 - Two parallel lines on the graph depicted the boundaries of the first player's two other strategies.

Step 4 - The gain equations for various subgames are then shown on the graph in step (iv).

Step 5 - In the scenario where player A is maximized, the point where the minimal expected gain is maximized is found. This will be the intersection's highest point-out for the gain lines in the "Lower Envelop." When player B is minimized, the minimum maximum loss point is appropriate. At the junction of the equations in the "Higher Envelop," this will be where the slope is lowest.

3.5 Linear Programming Technique

If the objective functionand constraint functionthat are linear in the optimization problem used in game theory is known as Linear programming technique. In actuality, a convex polygon's maximum or minimum value of the linear function is determined using the linear programming technique. This convex polygon actually depicts some inequality graphically. Restrictions on the variables used in the functions. In some circumstances, linear programming might produce the greatest results. There are numerous methods for resolving linear programming issues, such as those using the simplex algorithm, affine scaling, the Karmarkar method, the criss-cross algorithm, etc. The application of linear programming and game theory together has been the subject of extensive research. In the majority of these research, linear programming has been used to solve a game. In other words, the Nash equilibrium of the game is determined. Multi objective optimization and single objective optimization are types of Nash equilibrium.

Every matrix puzzle has at least one solution. In general, a dual linear programming issue can be used to describe a positive-matrix game. Hence, the simplex algorithm can identify the solution(s) to a matrix puzzle. The procedures for applying the linear programming method to solve a simulated game.

These are some simplex algorithms:

1. Establish the game's matrix.
2. If the answer is crystal clear, mark it as the problem's obtained solution.
3. Verify the rows' and columns' relative dominance.

In this phase, all dominated rows and columns should be removed.

4. Verify that the game's volume is positive. To accomplish this, simply multiply all matrix entries by the result of subtracting the greatest negative element from 1. If there is any added value, think of it as k.
5. Assume that the game's m 9 n matrix is G. The n-component row vector and the entries and m component column vector of all the entries are considered.
6. Run the simplex algorithm until no indicators are pointing in the right direction. Determine the dual linear programming problem's optimal solutions.
7. It is possible to determine the main matrix's responses.
Consider about the 3 x 3 matrix

$$\begin{bmatrix} a_{11} & a_{12} & a_{11} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

3.6 TheStepping Stone Method

The Stepping Stone Procedure is utilized to evaluate whether the underlying, functional arrangement found utilizing some strategy is great. Utilizing the Most minimal expense Procedure, Vogel's Estimation Strategy, or the North-West Corner. Considering the goal capability, the stepping stone methodology is a way for deciding the capability of any non-essential factors or empty cell. We calculate the impact on the transportation cost of assigning one unit to the vacant cell using the stepping stone method. This approach allows us for determining the answer is optimal or not.

Making sure that the total number of cells involved is considered to be equivalent precisely to m plus n -1 where n is the quantity of the segments and m is equal to the quantity of lines, is a vital condition prior to tackling for optimality. The unfilled cell is first picked, and afterward a closed path or loop a closed way that begins in the vacant cell and returns again to a similar void cell is constructed. The accompanying circumstances ought to be remembered while laying out a shut circle: At the point when cells are picked in a closed path way, just a single cell is left vacant or involved while the rest are all being used. At the point when two cells are used sequentially, they are either in a similar line or section. No line or section might incorporate three sequential involved cells. In the closed path or loop, the start and last cells are either in a similar line or section. Movement is restricted to the horizontal and vertical planes. Once the loop has been made, place or sign alternately on each corner cell of the loop, starting with the empty cell. Continue until all of the vacant cells have been evaluated. The best answer has now been found if all computed changes are positive, equal to, or larger than zero.

1) Choose one of the following hot determining the initial feasible solution: Minimal Technique using North-West Corner Rule Matrix
2) Verification of total occupied cells that exactly equal to the formula m+n-1, when using the Vogel Approximation Method
3) Decide on an empty cell. The closed path is traced starting from the empty cell and ending at the selected vacant cell, starting from this cell and ending at this cell.
4) Place plus and minus symbols alternately on the cell corner for tracing the closed path that starts with plus symbol at vacant cell that will be used for evaluation.
5) Include transportation unit expenses for each cell that was traced along the closed path. This will result in a net change in cost.
6) Carry out the step 3 to step 5 again to analyse every vacant cell.

7) Verify each net change in the unit transportation costs' indication. An ideal solution has been found if all the computed net changes are higher than or equal to zero. If not, proceed to step 8 as there are ways to enhance the current solution and lower the overall cost of transportation.

3.8 Nash Equilibrium

In game theory optimization, the Nash equilibrium is a situation where a player will adhere to their picked methodology regardless of having no great explanation to transform it subsequent to adopting the rival's strategy into account. To find the Nash equilibrium in a game, one would have to display out every one of the possible results to show up at the best doable methodology. This would dissect the potential systems that the two players could choose in a two-player game. A Nash equilibrium has occurred on the off chance that neither one of the players changes their methodology subsequent to realizing the real factors. Nash equilibrium is huge on the grounds that it empowers an individual to pick the ideal result in a situation by considering both their own decisions and those of different gatherings. Nash equilibrium can be utilized in numerous everyday issues, for example, strategies, home deals, sociologies, etc. To decide Nash equilibrium, no specific recipe exists. The compensation of every procedure and the best strategy to take still up in the air by recreating a few situations inside a specific game.

The equilibrium point is where none of the game's participants tend to change. The Nash equilibrium is referred as the game action profile under the assumption that other players' actions remain constant, each change makes each player's state worse. In other words, it is an action profile that assumes constant actions from other players and does not encourage players to alter their conditions. The Nash equilibrium idea is used to examine the outcomes of multiple decision-makers interacting strategically. Nash equilibrium is a method for anticipating the outcomes of dependent decisions that are made concurrently by a number of participants.

4. ANALYSIS AND FINDINGS

This Section includes analysis and findings of optimization technique for transportation and game theory problem. The special case of the linear programming problem, the classical transportation problem uses its model to determine the number of units of a commodity of goods should be shipped from different origins to different destinations while satisfying supply and demand constraints and minimizing the overall cost of transportation.

4.1 The Stepping Stone Method

Determine that maximum number of units is assigned to the empty cell with net changes in cost of largest negative value. The number of units that can be transported to the incoming cell is represented by smallest value on the closed path starts from the negative location. The empty and other cells are included in drawing the closed path which is denoted by + sign are added to this number. From the cells on the closed path denoted by a minus sign, deduct this amount.

Table 4.1 Optimal Solution in Petroleum Refineries - The Stepping Stone Method

	Destination					
	City	**Bengaluru**	**Chennai**	**Delhi**	**Ernakulam**	**Supply**

Origin	Hyderabad	235 (10)	220 (45)	75 (30)	60 (20)	105
	Mumbai	70 (45)	80	65	50	45
	Demand	55	45	30	20	150

The increase in transportation cost of reallocation is + 235 – 220 +75 +60 – 70 = 80

Table 4.2 Unoccupied Cells- The Stepping Stone Method

Unoccupied Cells	Increase in cost / reallocation	Optimal Solution
Mumbai to Bengaluru	+ 235 – 220 +75 +60 – 70 = 80	Transportation Cost Increases
Mumbai to Ernakulam	+ 235 – 220 +75 +60 -50 = 100	Transportation Cost Increases
Hyderabad to Chennai	+ 235 -80 +75 +60 – 70 = 240	Transportation Cost Increases
Mumbai to Delhi	+ 235 – 220 -80 +65 = 0	Neither increase nor decrease of transportation cost

Minimum Transportation Cost = 235 x 10 + 220 x 45 + 75 x 30 + 60 x 20 + 80 x 45
= ₹ 19300

Table 4.3Optimal Solution in Food Industry- The Stepping Stone Method

	Destination					
Origin	**City**	**Bengaluru**	**Chennai**	**Delhi**	**Ernakulam**	**Supply**
	Mumbai	500 (30)	380 (55)	210 (25)	340 (40)	95
	Gujarat	420 (35)	630	230	290	90
	Demand	65	55	25	40	185

Table 4.4 Unoccupied Cells- The Stepping Stone Method

Unoccupied Cells	Increase in cost / reallocation	Optimal Solution

Mumbai to Bengaluru	-380 + 210 -340 +420 -290 = -380	Transportation Cost Decreases
Gujarat to Chennai	+500 – 380 +210 +420 – 230 = 520	Transportation Cost Increases
Gujarat to Delhi	+500 – 380 +210 - 340 + 420 = 410	Transportation Cost Increases

Total Minimum cost = 500 x 30 + 420 x 35 + 380 x 55 +210 x 25 + 340 x 40

Total Minimum cost = ₹ 69, 450

Table 4.5 Optimal Solution in Food Industry- The Stepping Stone Method

Origin	**Destination**					
	City	**Bengaluru**	**Chennai**	**Delhi**	**Ernakulam**	**Supply**
	Hyderabad	580 (30)	600 (40)	190 (15)	320 (25)	70
	Mumbai	490 (10)	480	220	280	50
	Demand	40	40	15	25	120

Table 4.6 Unoccupied Cells - The Stepping Stone Method

Unoccupied Cells	**Increase in cost / reallocation**	**Optimal Solution**
Mumbai to Chennai	+580-600+190-320+490 = 340	Transportation Cost Increases
Mumbai to Delhi	+580-600+490-190-480 = -200	Transportation Cost decreases
Hyderabad to Chennai	+580-480+490-190-220 = 180	Transportation Cost Increases

Total Minimal Cost = 580 x 30 + 600 x 40 + 190 x 15 + 320 x 25 + 490 x 10

Total Minimal Cost = ₹ 57,150

Findings:

- The total minimal cost value obtained after the last iteration by Stepping Stone method for transportation problem in petroleum refineries is ₹ 19300.
- The total minimal cost value obtained after the last iteration by Stepping Stone method for transportation problem in textile mill industry is ₹ 69,450.
- The total minimal cost value obtained after the last iteration by Stepping Stone method for transportation problem in food industry were ₹ 57,150.

The main objective of the study is reduction of transportation cost and the number of iterations for updating the optimal solution transportation problem without finding any initial type of basic feasible solutions and optimal solution for game theory problems. The objective can be achieved by the proposed optimization method for transportation problems that include The Stepping Stone method. The use of Nash equilibrium and Bi-Criteria method. As the part of our research work the transportation problem with different types of applications like petroleum refineries textile mill industries are solved by The Stepping stone method.

The most used approaches to solving transportation problems, was examined in this chapter. Using the suggested Stepping Stone improved the procedure for obtaining Transportation Problem solutions. To obtain an ideal solution, Stepping Stone was therefore only taken into account for a limited number of repetitions. Stepping Stone notably obtains a more effective ideal solution for complex transportation issues and significantly lowers the number of iterations, CPU usage, and computational difficulties for the optimal solution.

4.2 Nash Equilibrium

People from diverse backgrounds have varied perspectives on issues in the actual world. A million dollars means significantly less to a billionaire than it does to an average worker. While some people may be self-centred and just think about their personal payoff, others may be cooperative and regard their shared payoff equally to their own. Even if it is a Nash equilibrium, we cannot force all of the participants to stick with one single choice. Because each have various perspectives on this game, they just select the option that best serves their interests, regardless of what those interests may be. We can simply give the reward varied weights to put this concept into practice. If your payment and your opponent's payoff have weights of 1 and 0, respectively, you would make your decision based solely on your own payoff and without regard to your opponent's payoff. If your reward and your opponent's payoff have weights of 0.8 and 0.2, respectively, what your opponent gets adds 20% to your overall payoff. The weight may occasionally be negative, such as -0.7 for your payment and -0.3 for your opponent. Because of the weight distribution, your opponent's gain is equivalent to a loss for you because it produces negative utility.

A case when Nash equilibrium results in a poorer outcome for both participants is the prisoner's dilemma. And many more are developed to show the "strange" result derived by Nash equilibrium. Due to the fact that, by definition, Nash equilibrium only restricts unilateral deviation and not conjoint cooperation. It might make sense from the perspective of just one person, but it wouldn't make sense from the perspective of both players combined. This bi-criteria approach comes to mind as a result. It can support some of the choices where Nash equilibrium fails, and it has weight for the pay-out for both parties. Additionally, after weighing, Nash equilibrium once more successfully explains the data.

In conclusion, Nash equilibrium might not always be the optimal option in real-world games, particularly in one-shot or risky games (Starmer, 2000). Nash equilibrium may be effective in repeated games because it may encourage players to collaborate and build on prior knowledge in order to get greater rewards for both parties.

Almost every industry and academic discipline uses game theory. Because of its broad applicability, it is a diverse and significant theory to understand. Below are some academic areas where game theory has a direct bearingTo resolve the important problems in economic models with the help of mathematical methods like game theory for the revolutionised economy market. The research study includes, neoclassical economics had trouble handling imperfect competition and entrepreneurial foresight. Game theory shifted focus from steady-state equilibrium to the workings of the market. The popular tool used in economy by the economist for analysing the oligopoly behaviour of firms referred as game theory. When the business can participate in the particular behaviours searches price fixing and collusion the game theory problems help in forecasting the potential effect.

5. CONCLUSION

The proposed optimization method Stepping stone method is used for getting minimal transportation cost than the other existing methods for transportation problems. The transportation problem solutions finding techniques, was used in this study because it typically yields results that are close to the ideal ones. When the player aware of the approaches of opponents states with the Nash equilibrium where it sticks with the selected strategies well you do not have any incentive or to perform any things. Several real-world scenarios can be applied to the Nash equilibrium to discover the optimum outcome depending on your selections and the knowledge of your opponent's decisions.

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