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Optimization Techniques for Solving Multi-Objective Transportation Problem: A Comparative Analysis

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ABSTRACT

Efficient transportation planning requires balancing economic performance, operational efficiency, and environmental responsibility. In real-life transportation systems, transportation planner frequently need to include more than one conflicting factors like minimizing transportation cost, minimizing transportation time, and environmental impact. Traditional single-objective models are not sufficient to handle these complex requirements. Therefore the need for efficient multi-objective optimization techniques has become increasingly significant. The proposed study focuses to solve a "Multi-Objective Transportation Problem (MOTP)" by different optimization techniques namely, Weighted Sum Method and Goal Programming Method. For each method, the mathematical models have been formulated and solved using secondary data in similar scenarios for fair comparison of methods. For each method, the solutions vary based on the prioritization of objectives. The results shows that the Weighted Sum Method gives different results when the weights vary, which means it is sensitive to weight selection. Goal Programming proves to be more flexible and consistent by assigning prioritization and targets. A comparative analysis has been performed by focusing on the ability to find compromise solution, effectiveness of each method, efficiency in getting optimal results and practical applicability of the methods. As seen from the analysis, the multiobjective optimization offers more realistic solution as compared to single-objective optimization techniques. This could help decision makers in transportation and logistic planning.

Keywords: *Optimization, Multi-Objective Transportation, Weighted Sum, Goal Programming, Optimal Solution.*

1 Introduction

The mode of transportation is an important element in the movement of goods from one point to another point. Transportation problem forms an integral part of the distribution network, logistics, supply chain management and affect the level of efficiency in the entire process of transportation. In most instances, all traditional transportation planning models seek to optimize a single criterion, mainly transportation cost. But in the real-world situations, decision makers must balance several objectives simultaneously, including minimizing cost, reducing delivery time, and reducing negative environmental impact. The Multi-Objective Transportation Problem (MOTP) is an useful method in such situations because it facilitates optimization among several criteria while offering insight into possible trade- offs. Recent developments in research show that studies have evolved from single objective models to multi-objective models.

The development of practical and effective solutions for multi-objective transportation challenges has received more attention in recent years. Researchers have proposed several approaches to deal with the complexity of handling multiple objectives simultaneously. These approaches aim to provide balanced solutions by considering different aspects of the problem. Different optimization techniques can produce different solutions depending on how they handle trade-offs among objectives. Thus, there is a need to analyze and compare appropriate methods that will give reliable and realistic results. In this research, two methods, Weighted Sum Method and Goal Programming Method, which are widely accepted methods for dealing with multiple objective problems, have been selected and their performance analyzed while solving Multi-Objective Transportation Problem. Both methods have different approaches and can result in different answers based on the priorities and preferences of the decision maker. the objective of analyzing them is to find out which one performs better under the same conditions.

Even though the Weighted Sum Method and Goal Programming Method have been extensively applied to solve the multi-objective optimization problem, there is very limited literature regarding the comparative study of both the methods in solving multi-objective transportation problem with respect to economic, operational, and environmental goals simultaneously. This paper seeks to solve this problem by testing and comparing two optimization methods

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namely, “Weighted Sum Method” and “Goal Programming”. The research will help in understanding how the various weights and targets affect the solution of the problem and what compromises are possible between different objectives. At the same time, the inclusion of such objective as carbon emissions helps in introducing the aspect of sustainability in the decision making process.

The main contribution of this research is to analyze the ability of these methods to deal with conflicting objectives of transportation cost, delivery time, and carbon emission. Furthermore, the study gives information on how to make tradeoffs between economic efficiency, transportation time, and the environment. By taking into account carbon dioxide emissions along with conventional transportation criteria, the research ensures that decisions will be made in a sustainable manner. Such information will be helpful for logistics managers, transportation planners, and other supply chain decision makers while making choices regarding optimization techniques.

2 Review of Literature

The existing literature regarding transportation problems highlights an increased emphasis on the ability to handle more than one objective simultaneously. Various techniques have been examined by researchers in order to find balance solution in complex situations.

Bazaraa, Sherali, and Shetty [1] elaborate on the concept of optimization as well as elaborate the concept of Non-Linear Programming when the interrelationship variables is difficult to understand. The book covers several techniques used in complicated optimization instances. In addition, there is the mention of practical issues which are not always simple and thus require non-linear methods for their solution. Marler and Arora [4] provided a comprehensive review of multi-objective optimization techniques and reviewed the theoretical concepts involved in formulating multiple objectives into one function. The authors pointed out that while this technique is simple and very popular, it has limitations that it might not always be able to determine all possible optimal solutions, specially when there are complicated trade-offs between multiple objectives.

Nomani et al. [5] proposes new ”Weighted Goal Programming” technique for solving MOTP. It emphasizes the need for attaining an equal solution that remains close to the optimal value for all objectives. This technique has proven efficient whether or not the criteria weights were explicitly identified. Findings have shown that the use of this method yielded better results than the existing ones. Jagtap and Kawale [3] studied multi-dimensional multi-objective transportation problems using ”Goal Programming Method”. Their approach focused on setting priority levels for different goals and minimizing deviations from these targets. The study demonstrated that goal programming is effective in handling multiple conflicting objectives and provides satisfactory solutions based on decision-maker preferences. Jain et. al [2] used used ”Lexicographic Goal Programming” for solving the MOTP through ordering of the objectives according to their priority. This technique tries to minimize both cost and time one at a time without changing the output of higher priority objective. Deviation variable was also used to show the proximity of the solutions obtained to the required goal. By checking different priority orders, the findings of this approach indicated that this approach is able to produce satisfactory results.

Shrivastava and Rajput [7] used the Weighted Sum Method, where weights are assigned to different objectives. Their results indicated that this method is useful for balancing cost, time, and risk, but the final solution depends heavily on the choice of weights. In another study, Shrivastava and Rajput [8] applied the ”Lexicographic Method” to solve multi-objective transportation problems. The findings of their study indicate that the above technique insures that the most important objective is prioritized, thus ensuring reduced cost, time while minimizing carbon emission. The problem is that the method heavily depends on the hierarchy of objectives. Shrivastava and Dwivedi [6] discussed the conversion of multi-objective transportation problem into single objective problem by using the ”Weighted Sum Method” and revised simplex method is used to solve the problem. The study emphasized the computational efficiency of this methodology, but it did mention that the resulting solution depends on the weight assigned to objectives. Shrivastava and Rajput [9] provides a novel approach to deal with multi-objective transportation problems by using statistical methods. By combining cost, time and emissions of carbon into one figure, “Arithmetic, Geometric, and Harmonic Means” were used. Different outcomes have been achieved from each mean which indicates clear contradiction between time, fuel consumption and costs. It is a flexible, effective, and straightforward approach.

From the above literature, it is obvious that a number of approaches have been applied to the problem of dealing with transportation problems that involve multiple objectives. The type of result depends upon the approach adopted, whereby, some approaches tend to be basic while others complex.

3 Motivation and Objectives

This study is inspired by the necessity of finding effective method that would assist in solving practical cases of multi-objective transportation problems. In transportation management, decision-makers are expected to take into consideration several conflicting objectives, like reduction of cost, time, and adverse effects on the environment. Such considerations cannot be accommodated using conventional single-objective optimization techniques because of their limitation in dealing with real-life conditions. Thus, it is necessary to resort to other methodologies in solving such problems. This study focuses on the Weighted Sum Method and Goal Programming to evaluate their effectiveness in managing multiple objectives and generating practical solutions. The aim of this study is to support improved and informed decision-making in transportation planning by identifying suitable optimization approaches.

- To evaluate the role of each method of solving Multi-Objective Transportation Problem in minimizing transportation cost while simultaneously reducing time and carbon emission.
- To analyze the efficiency and effectiveness of these methods.
- To determine the significant difference in the Optimal solution obtained by these methods.
- To analyze trade-offs between conflicting objectives.
- To provide practical insights and recommendations that can support decision-makers in logistics, supplychain management, and transportation planning.

4 Data and Variables

This study follows a comparative optimization approach to assess the efficiency of approaches used in solving the "multi objective transportation problem." This analysis involves the Weighted Sum Method, and Goal Programming Method, which are chosen in order to understand how these approaches address several conflicting objectives within transportation management, including cost, delivery time, and environmental impacts, among others. The process starts with data collection and mathematical model formulation that represents all objectives and constraints in an organized and systematic way.

This study is based on secondary data which will be the main dataset to conduct the analysis. Data have been sourced from a previously published paper by Shrivastava and Rajput [8], that is dealing with transportation planning in agriculture sector in Madhya Pradesh. The chosen dataset depicts a real transportation scenario wherein there is transportation of agriculture products from farms to the processing units. The chosen dataset can be considered an agro-based transportation network, consisting of four agriculture farms situated in different cities of Madhya Pradesh namely, Indore, Bhopal, Jabalpur, and Gwalior and three processing plants located in Ujjain, Sagar, Rewa. The four farms are the supply nodes as agriculture products are available here. On the other hand, the three processing plants represents the demand nodes since the products need to be transported to these plants. The dataset has important factors such as transportation cost, which represents the cost involved in moving one unit of the product from every farm to every plant, transportation time shows the time needed to move products from each farm to each plant and carbon emission represent the environmental impact of transporting one unit of product between source to destination, during the transportation process. Hence, this dataset is well suited for the current analysis, as all factors are captured. So the use of this dataset supports a fair comparison of optimization techniques in real-world transportation scenario.

Table 1: *Sources and Destinations*

Sources			Destination		
Farm	**City**	**Supply**	**Plant**	**City**	**Demand**
A	Indore	40	X	Ujjain	60
B	Bhopal	50	Y	Sagar	50
C	Jabalpur	60	Z	Rewa	70
D	Gwalior	30			

Table 2: Objective Matrix of Transportation Problem

Source→ Destination	Cost (Rs Per Ton) (Z_1)	Time (Hours) (Z_2)	Carbon Emissions (Kg CO_2 Per ton) (Z_3)
Farm A →Plant X	500	5	20
Farm A →Plant Y	700	7	30
Farm A →Plant Z	600	6	25
Farm B →Plant X	550	6	22
Farm B →Plant Y	650	5	28
Farm B →Plant Z	750	8	35
Farm C →Plant X	800	9	40
Farm C →Plant Y	600	6	25
Farm C →Plant Z	500	5	20
Farm D →Plant X	700	8	30
Farm D →Plant Y	900	10	45
Farm D →Plant Z	650	7	28

5 Mathematical Formulation of Multi-Objective Transportation Problem

The "Multi-Objective Transportation Problem (MOTP)" handles the optimal allocations of products that transfers from several source to several destination while simultaneously optimizing several conflicting objectives.

Notation:

$$i = 1, 2,....., m \text{ (index for farms)}$$
$$j = 1, 2,....., n \text{ (index for plants)}$$
$$k = 1, 2,....., K \text{ (index for objectives)}$$

Parameters:

- a_i denote supply available at farm i
- b_j denote demand required at plant j
- c_{ij}^k denote unit transported from farm i to plant j for objective k

Decision Variables: The amount of goods that is delivered from supply center to demand points. It indicates how much quantity should be shipped along each possible route to meet demand efficiently. Let x_{ij} is the quantity transported from farm i to plant j

Objective Functions: The objective function will be the minimizing multiple objective functions:

$$Z_k = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}^k x_{ij}\ , \quad k = 1, 2, 3, ..., K$$

So the way to express the problem as:

$$\text{Minimize } (Z_1, Z_2, Z_3, ..., Z_K)$$

- **Cost Objective**

$$\text{Minimize } Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} x_{ij}$$

Here C_{ij} is per unit cost of products transported from farm i to plant j.

$$\text{Minimize } Z_1 = 500x_{AX} + 700x_{AY} + 600x_{AZ} + 550x_{BX} + 650x_{BY} + 750x_{BZ} + 800x_{CX} + 600x_{CY} + 500x_{CZ} + 700x_{DX} + 900x_{DY} + 650x_{DZ}$$

- **Time Objective**

$$\text{Minimize } Z_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}x_{ij}$$

Here T_{ij} is delivery time from farm i to plant j.

$$\text{Minimize } Z_2 = 5x_{AX} + 7x_{AY} + 6x_{AZ} + 6x_{BX} + 5x_{BY} + 8x_{BZ} + 9x_{CX} + 6x_{CY} + 5x_{CZ} + 8x_{DX} + 10x_{DY} + 7x_{DZ}$$

- **Carbon Emission Objective**

$$\text{Minimize } Z_3 = \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}x_{ij}$$

Here *Eij* is Carbon emission from farm i to plant j.

$$\text{Minimize } Z_3 = 20x_{AX} + 30x_{AY} + 25x_{AZ} + 22x_{BX} + 28x_{BY} + 35x_{BZ} + 40x_{CX} + 25x_{CY} + 20x_{CZ} + 30x_{DX} + 45x_{DY} + 28x_{DZ}$$

Constraints: Constraints represents the requirements that the model's solution must meet. Supply constraints, demand constraints, and non-negativity constraints, are used in transportation problems which ensure that the solution is feasible, practical, and consistent with real-world requirements.

Supply Constraints: Each farm cannot supply more than its capacity

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

$$x_{AX} + x_{AY} + x_{AZ} \le 40$$

$$x_{BX} + x_{BY} + x_{BZ} \le 50$$

$$x_{CX} + x_{CY} + x_{CZ} \le 60$$

$$x_{DX} + x_{DY} + x_{DZ} \le 30$$

Demand Constraints: Each plant must receive its required demand

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

$$x_{AX} + x_{BX} + x_{CX} + x_{DX} = 60$$

$$x_{AY} + x_{BY} + x_{CY} + x_{DY} = 50$$

$$x_{AZ} + x_{BZ} + x_{CZ} + x_{DZ} = 70$$

Non-Negativity Constraints: The quantity of goods transported cannot be negative

$$x_{ij} \ge 0,\ \forall\, i, j$$

$$x_{AX}, x_{AY}, x_{AZ}, x_{BX}, x_{BY}, x_{BZ}, x_{CX}, x_{CY}, x_{CZ}, x_{DX}, x_{DY}, x_{DZ} \ge 0$$

It is essential to note that before attempting to solve a Multi Objective Transportation Problem MOTP it is important to test whether the problem is either balanced or unbalanced A transportation problem is said to be balanced when the total supply is equal to the total demand This is important because it ensures that a feasible solution is achieved In this study the total supply in all sources is 180 units and the total demand in all destinations is also 180 Because these two values are equal So the transportation problem is balance

6 Weighted Sum Method

"In the Weighted Sum Method, single objective function is formulated by giving a weight to each objective" according to their importance [6].

- Each objective is first normalized so that differences in measurement units do not affect the results.
- Suitable weights are assigned to each objective based on their importance.
- Then single combined objective function is created by multiplying each normalized objective by its corresponding weight.
- Combined objective function is minimized while meeting all supply and demand requirements.

- The procedure is repeated with different sets of weights to study how changes in priorities affect the final solution.

$$minZ = w_1Z_1 + w_2Z_2 + w_3Z_3 + ... + w_kZ_k$$

$$\sum_{n=1}^{k} w_n = 1, \quad w_1, w_2, ..., w_k \geq 0$$

6.1 Mathematical Formulation

Normalization is essential to bring all objectives to a common, dimensionless scale using min-max normalization.

$$Z_k^{norm} = \frac{Z_k - Z_k^{min}}{Z_k^{max} - Z_k^{min}}$$

Combined Objective Function:

$$Minimize\ Z = w_1Z_1 + w_2Z_2 + w_3Z_3$$

$$\text{Minimize}\, Z = w_1 \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}x_{ij} + w_2 \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}x_{ij} + w_3 \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}x_{ij}$$

Test multiple weight combinations (w_1, w_2, w_3) to analyze Trade-offs.

- **Case 1: Cost Priority**

  Higher weight is assigned to transportation cost:

$$\text{Minimize}\ Z = 0.6 \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}x_{ij} + 0.2 \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}x_{ij} + 0.2 \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}x_{ij}$$

- **Case 2: Time Priority**

  Higher weight is assigned to transportation time:

$$\text{Minimize}\ Z = 0.2 \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}x_{ij} + 0.6 \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}x_{ij} + 0.2 \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}x_{ij}$$

- **Case 3: Carbon Emission Priority**

  Higher weight is assigned to carbon emissions:

$$\text{Minimize}\ Z = 0.2 \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}x_{ij} + 0.2 \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}x_{ij} + 0.6 \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}x_{ij}$$

7 Goal Programming Method

Goal programming is used when specific target values are desired for each objective rather than simply minimizing or maximizing them [3].

- Target values (goals) are first defined for each objective.
- For each goal, deviation variables are introduced to measure how much the actual result deviates from the target.
- Priority is assigned to each deviation based on the importance of the corresponding goal.
- The model's objective function will be minimizing these deviations, especially unwanted deviations.
- Then solved the model to find the result that best satisfies all objectives simultaneously.

7.1 Mathematical Formulation

Set target value for cost, time, and carbon emission (G_1, G_2, G_3). Define deviation variable, For each goal, two deviation variables are introduced:

- One for overachievement
- One for underachievement

Deviation Variables: Deviation variable represent how much achieved value is deviated from the target value of each objective.

- $d_1^+, d_1^- \rightarrow$ Cost Deviation
- $d_2^+, d_2^- \rightarrow$ Time Deviation
- $d_3^+, d_3^- \rightarrow$ Carbon Emission Deviation

Goal Equations: Goal equations represent the desired target levels of each objective. They are formed by equating the objective function to a specified target value and include deviation variables to measure underachievement or overachievement of the goals.

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}x_{ij} + d_1^- - d_1^+ = G_1$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}x_{ij} + d_2^- - d_2^+ = G_2$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}x_{ij} + d_3^- - d_3^+ = G_3$$

Objective Function:

$$MinZ = [P_1(d_1^+), P_2(d_2^+), P_3(d_3^+)]$$

- **Case 1: Cost Priority**
  First rank is given to transportation cost:
  Minimize d_1^+
- **Case 2: Time Priority**
  First rank is given to transportation time:
  Minimize d_2^+ keeping d_1^+ at its optimal value
- **Case 3: Carbon Emission Priority**
  First rank is given to carbon emission:
  Minimize d_3^+ keeping d_1^+ and d_2^+ at its optimal value

8 Results

In this study, the computational analysis was done using "Excel Solver and Python" software. Excel solver was applied in creating and solving the optimization models within a well structured environment. On the other hand, python software was applied via the "pulp" library, which is commonly used for "Linear Programming" models. This allowed efficient implementation and computation of mathematical models. The advantages of the "pulp" library was that it facilitated comparative analysis of different methods.

8.1 Results of Weighted Sum Method

- **Case 1:** $w_1 = 0.6, w_2 = 0.2, w_3 = 0.2$
  $x_{11}=40\ \ x_{21}=20\ \ x_{22}=30\ \ x_{32}=20\ \ x_{33}=40\ \ x_{43}=30$

Total Cost	Time	Carbon Emission
102000 Rs.	34 Hours	4220 Kg CO_2

- **Case 2:** $w_1 = 0.2, w_2 = 0.6, w_3 = 0.2$
  $x_{11}=40\ \ x_{13}=0\ \ x_{22}=50\ \ x_{33}=60\ \ x_{41}=20\ \ x_{43}=10$

Total Cost	Time	Carbon Emission
103000 Rs.	30 Hours	4280 Kg CO_2

- **Case 3:** $w_1 = 0.2, w_2 = 0.2, w_3 = 0.6$
  $x_{11} = 40 \;\; x_{21} = 20 \;\; x_{22} = 30 \, x_{32} = 20 \;\; x_{33} = 40 \;\; x_{43} = 30$

Total Cost	Time	Carbon Emission
102000 Rs.	34 Hours	4220 Kg CO_2

8.2 Results of Goal Programming Method

Cost target = 105000 Rs., Time target = 35 Hours, Carbon emission target = 4500 kg CO_2

- **Case 1: First rank $\rightarrow$ Cost**
  $x_{11} = 10 \;\; x_{12} = 30 \;\; x_{21} = 50 \;\; x_{32} = 20 \;\; x_{33} = 40 \;\; x_{43} = 30$

Total Cost	Time	Carbon Emission
105000 Rs.	37 Hours	4340 Kg CO_2

- **Case 2: First rank $\rightarrow$ Time**
  $x_{11} = 40 \, x_{13} = 0 \;\; x_{22} = 50 \;\; x_{33} = 60 \;\; x_{41} = 20 \;\; x_{43} = 10$

Total Cost	Time	Carbon Emission
103000 Rs.	30 Hours	4280 Kg CO_2

- **Case 3: First rank $\rightarrow$ Carbon Emission**
  $x_{12} = 40 \;\; x_{21} = 50 \;\; x_{32} = 10 \;\; x_{33} = 57.5 \;\; x_{41} = 10 \;\; x_{43} = 12.5$

Total Cost	Time	Carbon Emission
105375 Rs.	39 Hours	4350 Kg CO_2

9 Comparative Analysis

A comparative analysis has been conducted to determine the strengths and limitations of the Weighted Sum Method and Goal Programming Method to solve the "Multi-Objective Transportation Problem". Comparison has been made considering crucial parameters like dealing with trade-offs, stability of solution, effectiveness of each method, efficiency in achieving desirable results, and variability of optimal solutions. Through such comparisons, it is possible to identify the way in which each approach reacts to changes in weights and targets, and how well they deal with multiple conflicting objectives. A comparative analysis offers an idea about the advantages and disadvantages associated with each approach, helps in selecting appropriate approaches for practical transportation problems.

- **Trade-off Between Objectives:** Regarding the issue of handling the trade-offs, the Weighted Sum Method makes provision for a trade-off between cost, time and carbon emission based on weights. it has been noted that where time takes higher weight, total time decreases to 30 hours whereas there is an increase in cost and carbon emission. However, In other cases, such results are also found, signifying that there is not much of a trade-off. On the other hand, Goal Programming Method takes care of trade-offs based on the order of priorities.
- **Stability of the Solution:** In terms of stability of the solution, the Weighted Sum Method appears to have fairly consistent results since in two cases out of the three yields the same results as cost = 102000 Rs., time = 34 hours, carbon emission = 4220 kg CO_2. The slight variations in the results do not seem to alter the solutions much. In contrast, the Goal Programming Method has varying results due to changing priorities in different cases. This gives different results in all three cases, thus the Goal Programming method is not stable like Weighted Sum Method. However, this variation shows that goal programming is more flexible and practical.
- **Effectiveness of Each Method:** In regards of effectiveness, the Weighted Sum Method is effective for all objectives that need to be consider simultaneously and used to find a balance solution. This enables a decision-maker to determine compromise solution between all objectives. However, Goal Programming Method is more

suitable for dealing with realistic conditions, wherein achieving specific objectives is necessary. Goal programming aims to reduce the gap between the expected and the actual values.

- **Efficiency in Achieving Desired Results:** In terms of efficiency in achieving desired results, the Weighted Sum Method considers all objectives simultaneously. It gives the optimum result in the balancing of various objectives but cannot give optimum results to individual objectives. On the other hand, Goal Programming Method is more efficient in the realization of desirable results. This is because this approach takes into consideration specific targets that have been predetermined.
- **Significant Differences in Optimal Solutions:** In terms of optimal solution, the results show that the Weighted Sum Method yields almost the same solution in Case 1 and Case 3, showing very small variation in the optimal results. In contrast, Goal Programming Method gives different solution based on the priority or the objectives in all three cases.

10 Conclusion

In this research, the main goal was to solve the "Multi-Objective Transportation Problem" and comparing using the Weighted Sum Method and Goal Programming Method, based on three objectives namely transportation cost, transportation time and carbon emissions. From the results obtained through the comparison of these methods, one can draw the conclusion that both methods are able to solve a multi-objective problem but in a different manner.

The solutions obtained with the use of the Weighted Sum Method are stable consistent in Case 1 and Case 3. At the same time, they vary slightly when changing the Weight coefficients. The use of this method does not allow taking into consideration changes in the priority order of objectives by a decision-maker. Solutions provided with Goal Programming depend upon priority levels of goods assigned to particular objectives. This method is more flexible and more suitable for cases where certain objectives have to be accomplished. It makes it possible to handle tradeoffs better and come up with solutions that better suit the decision maker.

As seen from the comparative analysis, Goal Programming is much better as reaching the desired target as well as trade-offs in a practical way, provided clear priorities are known. While the Weighted Sum Method becomes effective in situations when all objective functions need to viewed as being of equal importance. From the results, the research reveals that the selection of a certain optimization technique depends on the specific needs of the decision maker and on the kind of problem they addressing. If all the objectives are equally important, then the use of the Weighted Sum Method may help find a balance between them. But where in real life some objectives prevail over others in the problem under consideration, the Goal Programming approach works much better.

The outcomes of this research provide valuable insight into the performance of these techniques under various scenarios. The information may assist decision-makers in selecting the appropriate optimization technique according to their needs. Consequently, better transportation planning will be achieved.

11 Limitations and Future Scope of Research

- This research is based on secondary data that is collected from existing source. Future study can be included real-time data set to solve transportation problem and to improve transportation planning.
- In this research work, a limited dataset containing a limited number of supply points and demand points has been used. In the future research, the proposed model can be developed further by considering more supply points and more demand points.
- In this research, Weighted Sum and Goal Programming methods are used for comparative analysis. In the future advanced optimization algorithms such as "Genetic Algorithm, Fuzzy Algorithm, Evolutionary Algorithm " can be used.
- This research work being done includes cost, time and carbon emission as its key objective. In the future, more objectives may be considered. These might include issues such as quality of service, risk, reliability, and customer satisfaction.
- In real-life transportation systems, several parameters are uncertain and subject to change with time, which include fluctuation of demand, changes in the cost, and the influence of traffic or weather conditions on delivery time. these uncertainties can be incorporated into future work.
- In future, the proposed model will be tested on additional benchmark data sets. This will provide more evidence concerning the efficiency of the model and increase the credibility of the results.

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Conflict of Interest Statement

The author declares there are no conflicts of interest, financial or otherwise, that may have affected the conduct, results or publication of this study.

Ethical Declaration

The proposed research does not include any human subjects, animals, or experiments that need ethical approval. All data and sources utilized for conducting the research have been gathered in accordance with relevant academic, and ethical norms.

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