Real World Application of Transportation Problem: A Case Study Approach

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***Abstract*—The transportation problem is a foundational concept in linear programming broadly used in supply chain logistics supply chain management, and operations research to determine the most efficient allocation of resources from multiple sources to various destinations while minimizing transportation costs. We have various paths to from source to destination but in transportation method we find a path which has minimum transportation cost and less time consuming. A user decides the path which has most effective and more efficient. This review paper provides a detailed examination of the transportation problem, beginning with its mathematical formulation and classical solution methods, including the North West Corner Rule, Least Cost Method, and Vogel's Approximation Method. The paper delves into modern optimization strategies such as LP solvers, heuristic algorithms, and artificial intelligence techniques that increase both the efficiency and flexibility of the model. Additionally, the paper highlights practical applications across industries, evaluates the structural strengths and limitations of existing models, and summarizes key findings from past research.**

***Index Terms*—Transportation Problem, Linear Programming, Stepping Stone Method, Modified Distribution Method, Optimization Techniques, Northwest Corner Rule, Least Cost Method, Vogel's Approximation Method, Artificial Intelligence.**

I. INTRODUCTION

Transportation has been a fundamental aspect of human civilization, facilitating the movement of goods and resources across distances through various modes such as roadways, railways, waterways, airways, and pipelines. As societies have advanced, the complexity of transportation systems has grown, necessitating the development of effective management techniques to ensure efficient and cost-effective distribution.

Historical records, such as those from the Song Dynasty in China, highlight early applications of transportation strategies. For instance, Minister Ding Wei's innovative use of canals to transport construction materials and scientist Shen Kuo's contributions to military supply logistics demonstrate the roots of transportation planning and resource allocation. These examples illustrate the enduring relevance of transportation as both a logistical challenge and a strategic necessity.

With the advancement of mathematical modeling and operations research, the transportation problem emerged as a structured approach to address the optimal allocation of resources from multiple origins to various destinations at minimal cost. This model led to the development of a specialized modified distribution method, which proved to be more intuitive and computationally efficient than the Simplex method commonly used in linear programming. Due to its practical utility and adaptable structure, the transportation model has become a cornerstone in supply chain management, logistics, and industrial planning.

This review paper aims to provide a comprehensive overview of the transportation problem model, discussing its historical development, classical and modern solution techniques, and its broad range of applications. It also explores current challenges and outlines potential directions for future research in optimizing transportation and resource distribution systems.

II. CONCEPT OF TRANSPORTATION PROBLEM

A. LITERATURE REVIEW

The transportation problem has been an integral component of human social and economic activity for centuries. Its importance is underlined by the variety of transport modes—road, rail, maritime, air, and pipeline—that play a crucial role in connecting producers to markets. Historical examples, such as those from the Song Dynasty in China, highlight early efforts in logistics and distribution management, showcasing the roots of optimization in transport-related decision-making.

The transportation problem (TP) is a foundational area in Operations Research (OR), with wide-ranging applications in logistics, supply chain management, inventory control, communication networks, scheduling, and personnel allocation. Its primary objective is to determine a cost-effective shipping schedule that satisfies both supply and demand constraints, thereby reducing transportation costs and improving operational efficiency.

B. CONCEPTUAL STUDY

The transportation problem is a method used to figure out the best and cheapest way to move goods from several starting points (like factories or warehouses) to several ending points (like stores or customers).

It's an important part of Operations Research, which helps in planning and decision-making. The main goal is to decide how much to send from each source to each destination so that the total cost of transportation is as low as possible.

C. Explanation of Relevant Concepts

Model: Model is a way to represent a real-world problem using math or logic. It helps us understand complex situations, test different choices, and find the best or nearly best solution. The transportation problem is one such model—it simplifies the complex connections in real-life systems by turning them into numbers or easy-to-understand forms.

Mathematical Model: A mathematical model is a way to represent real-life situations using math—like equations, graphs, pictures, or diagrams—to help us understand how something works.

Transportation Problem Model: The transportation problem is a type of linear programming used to find the cheapest way to move goods from several sources (such as factories) to several destinations (such as warehouses), while making sure that supply at each source and demand at each destination are fully met.

Linear programming provides strong tools to understand and solve such problems. It can break down complex situations and make them easier to understand using numbers and visual methods (like charts and tables). With special table-based steps, the transportation problem can be solved in a logical and step-by-step way.efficiency.

D. Different Methods For Finding The Initial Basic Feasible Solution of A Transportation Problem

1) North-West Corner Rule (NWCR)

Steps:

- Start from the top-left (north-west) cell of the cost matrix.
- Allocate as much as possible to that cell (minimum of supply and demand).
- Adjust supply and demand; move right if demand is satisfied, or down if supply is exhausted.

Advantages:

- Very simple and fast.

Disadvantages:

- Ignores costs, often leads to high total transportation cost.

2) Least Cost Method (LCM) / Matrix Minima Method

Steps:

- Find the cell with the lowest transportation cost.
- Allocate as much as possible to that cell.
- Adjust supply and demand and cross out rows or columns as they get exhausted.
- Repeat with the next least cost cell.

Advantages:

- Considers cost, often better than NWCR.

Disadvantages:

- Slightly more complex; may still not be optimal.

3) Vogel's Approximation Method (VAM)

Steps:

- For every row and column, calculate the penalty by finding the difference between the two smallest cost values.
- Identify the row or column that has the highest penalty.
- In that row or column, allocate the maximum possible amount to the cell with the lowest cost.
- Update the supply and demand values, remove any row or column that is fulfilled, and then repeat the process by recalculating penalties.

Advantages:

1. Usually gives the best initial feasible solution.

Disadvantages:

2. Slightly time-consuming to compute penalties.

Table 1: Comparison of NWCR, Least Cost and VAM Methods

Method	Speed	Cost Consideration	Typical Quality of Initial Solution
North-West Corner	Fast	No	Poor
Least Cost	Medium	Yes	Better
Vogel's Approximation	Slow	Yes (via penalties)	Best among the three

E. Diffrence Between Transportation Problem and Other L.P. Models

1) **Structure:** Transportation Problem has a special tabular structure with rows (sources) and columns (destinations) while Other L.P. Models have no fixed structure; constraints and variables can vary widely.

2) **Objective:** Transportation Problem always aims to minimize transportation cost whereas other L.P. Models: Can aim to maximize profit or minimize cost.

3) **Constraints:** Transportation Problem has supply and demand constraints only but on the other hand L.P. Models Can have any type of linear constraints (e.g., labor, materials, and budgets).

4) **Solution Methods:** Transportation Problem using special methods like Northwest Corner, Vogel's Approximation, and MODI whereas Other L.P. Models uses general methods like Simplex or Graphical methods.

So, the goal of the problem and the rules or limits that must be followed are given below.

$$P_{max}(C_{min}) = C_1 Y_1 + C_2 Y_2 + \ldots\ldots\ldots\ldots + C_n Y_n$$

Subject to:

$$A_{11} Y_1 + A_{12} Y_2 + \ldots\ldots\ldots\ldots + A_{1n} Y_n \le B_1$$
$$A_{21} Y_1 + A_{22} Y_2 + \ldots\ldots\ldots\ldots + A_{2n} Y_n \le B_2$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$A_{m1} Y_1 + A_{m2} Y_2 + \ldots\ldots\ldots\ldots + A_{mn} Y_n \le B_n$$

$$\text{and } Y_1, Y_2, \ldots\ldots\ldots, Y_n \ge 0$$

III. Present Study of Transportation Problem

After World War II, the transportation problem became more important because the UK had shortages of goods and needed better ways to move and manage them. In April 1948, the first group for Operations Research (OR) experts, called the Operational Research Club, was started in Britain. Later in 1957, the UK and USA together created the first international OR group, called the International Federation of Operations Research Societies. Since then, many studies have been done on transportation problems. In 1962, Professor Guan Meigu from Shandong Normal University introduced the Chinese Postman Problem, which is a special type of route planning problem in Operations Research.

IV. Solution of Transportation Problem

1. Combine Data in One Table: Instead of separating production, marketing, and cost data, present them together in one unified table. This makes table operations faster and more convenient.

2. Integrate Figures and Tables: During calculations using the potential method, keep the figures (like dual values) and tables (with allocations and costs) side by side. This helps users perform and verify calculations more easily.
   We generally used the formula Cij = ui + vj

3. Use Vogel's Approximations Method More Effectively: Apply Vogel's Approximation Method during the setup of the initial basic feasible solution. It can lead to better starting points and improve overall efficiency of the solution process.

To check the solution will be optimal or not we use m + n – 1 = No. of Allocations.

V. CASE STUDY

Supposedly, there are three Jute Industries A, B, C and each production is 0.6, 0.1, 0.1 billion kilograms. There are four Jute markets P, Q, R and S With the sales of 0.7, 0.5, 0.3, 0.2 billion kilograms. The production-marketing balance and transportation price table is presented below (seeing Table 2 and Table 3) to solve the transportation problem and realize the optimum distribution with minimum cost.

Table 2: Production-marketing Balance Table

Market → Factory ↓	**P**	**Q**	**R**	**S**	**Production**
A					6
B					1
C					10
Sales	7	5	3	2	

Table 3: Transportation Price Table

Market → Factory ↓	**P**	**Q**	**R**	**S**	**Production**
A	2	3	12	7	6
B	1	0	6	1	1
C	5	8	15	9	10
Sales	7	5	3	2	

Solution: Combine the two tables above into a new one: production-marketing balance and transportation price table, seeing Table 4.

We use Vogel's Approximation Method to solve the given problem.

Table 4: Production-Marketing Balance and Transportation-price Table

Market → Factory ↓	**P**	**Q**	**R**	**S**	**Production**	**Penalty**
A	2	3	12	7	6	1
B	1	0	6	$1_{(1)}$	1	1
C	5	8	15	9	10	3
Sales	7	5	3	2	**17**	
Penalty	1	3	5	6 ↑		

We remove factory row B because its production is fulfilled by the given sales. In the same manner we solve this problem step by step until all production and sales is not allocated.

Table 5: Determination of Initial Basic Feasible Solution

Market → Factory ↓	**P**	**Q**	**R**	**S**	**Production**	
A	$2_{(1)}$	$3_{(5)}$	12	7	6	$u_1 = -3$
B	1	0	6	$1_{(1)}$	1	$u_2 = -8$
C	$5_{(6)}$	8	$15_{(3)}$	$9_{(1)}$	10	$u_3 = 0$
Sales	7	5	3	2	**17**	
	$v_1 = 5$	$v_2 = 6$	$v_3 = 15$	$v_4 = 9$		

Calculated with Penalty Method: Make u3=0

v1+u1=2 then u1=-3
v2+u1=3 v2=6
v2+u4=1 u2=-8
u3+v1=5 v1=5
v4+u3=9 v4=9
v3+u3=15 v3=15

Calculate the check number λij = cij - (ui - vj).

For example, λ13 = c13 - (u1 + v3) = 12 - (15 - 3) = 0, and so on (seeing in Table 5). Then check all numbers λij are be greater than equal to zero.

VI. Applications of Transportation Problem

1. **Supply Chain and Logistics Management:** Enables efficient allocation of goods from factories to warehouses, retailers, or end-users. Reduces transportation costs while ensuring timely deliveries. Widely applied across manufacturing, agriculture, and retail sectors for distribution planning.

2. **Production and Inventory Control:** Aligns production outputs with market demand through optimal routing. Supports Just-in-Time (JIT) systems by minimizing inventory levels and maximizing responsiveness.

3. **Military and Defense Logistics:** Plays a crucial role in planning supply chains for military operations. Transportation - allocate limited logistics resources (e.g., food, weapons, and medical supplies) effectively—historically evident in the Song Dynasty examples.

4. **Infrastructure and Public Sector Planning:** Assists governments in developing cost-effective transport infrastructure. Used in public resource allocation such as food distribution, disaster relief, and rural outreach programs.

5. **Industrial Planning:** Aids in redistributing raw materials and finished goods between factories, departments, or warehouses. Encourages interdepartmental cooperation and efficient resource usage.

6. **Communication and Network Flow Problems:** Applied to problems with similar structure, such as telecom bandwidth allocation, internet traffic routing, and data flow optimization.

7. **E-Commerce and Online Delivery Systems:** Optimizes routes for last-mile deliveries in e-commerce platforms like Amazon, Flipkart, etc. Integrates with AI and heuristic algorithms for real-time logistics optimization.

8. **Agricultural Product Distribution:** Ensures efficient movement of agricultural goods (e.g., grains, jute) from farms to markets. Reduces waste and cost, particularly beneficial in developing economies.

9. **Environmental Applications:** Supports green logistics by selecting routes and modes of transport that lower carbon emission. Aids in sustainable transport planning and environmental impact reduction.

10. **Healthcare and Emergency Response:** Optimizes medical supply chains during pandemics, natural disasters, or crisis events. Ensures fast and cost-effective distribution of vaccines, oxygen cylinders, and relief materials.

VII. Future Scope

1. **Use of Artificial Intelligence (AI) and Machine Learning (ML):** AI and ML can make transportation systems smarter by helping them:
   - Make better decisions when things change (like prices or demand).
   - Choose the best routes in real time for delivery trucks.
   - Predict future demand so companies can plan ahead.

2. **Real-Time and Flexible Models:** Older transportation models don’t change once the plan is made. But in real life, situations change quickly.

   New models are being developed that:
   - Can change routes or supply plans instantly if something goes wrong (like a truck breaking down).
   - Adjust prices or delivery based on changing conditions. These models are especially useful for online shopping and emergency services.

3. **Eco-Friendly and Green Transport Models:** As climate change becomes more serious, transportation systems need to be more eco-friendly.

   Future models will try to:
   - Reduce pollution and fuel use.
   - Choose greener transport options (like trains over trucks).
   - Balance cost, time, and environmental impact using smart methods.

4. **Multiple Transport Modes and Goals:** Real transport systems often use more than one method—like truck, train, and ship together. Also, companies care about more than just cost—they want speed, safety, and reliability too.

   Future research will:
   - Work on models that include many transport types.
   - Use advanced methods (like genetic algorithms) to find the best balance of cost, time, and safety.

5. **Blockchain and Smart Contracts:** Blockchain can help track goods and make the system more secure and transparent.

   Smart contracts can:
   - Automatically carry out transport decisions when certain rules are met. In the future, transport models could work with blockchain to make systems safer and more automated

6. **Handling Emergencies and Disruptions** Events like pandemics or wars can cause big problems for transportation.

   Future models should:
   - Be strong enough to handle sudden changes or shortages.
   - Help plan backup options when normal routes aren't available.

7. **Solutions for Developing Countries:** In developing countries, infrastructure is often weak and data is limited.

   Future solutions should be:
   - Simple, low-cost, and work with less data.
   - Available on mobile phones or light software to help farmers, small businesses, and local governments.

8. **Hybrid Models and Interdisciplinary Applications:** Transportation problems are not isolated to logistics; they intersect with:
   - Healthcare (e.g., vaccine delivery),
   - Telecommunications (e.g., bandwidth allocation),
   - Energy distribution (e.g., electricity grid flows),
   - Urban planning (e.g., traffic control systems).

VIII. Conclusion

When we classify and organize problems based on their characteristics in a scientific way, it becomes easier to understand and solve them. History shows this works—Darwin discovered evolution by studying how animals are grouped, and Mendeleev predicted new elements by arranging them in the periodic table.

In short, organizing problems properly makes them easier to deal with.

The transportation problem is not just about technology, but also about management. It uses a clear set of concepts and methods to explain and solve real-world transport and distribution problems.

The theory behind it comes from real-life experience and research. Over time, this practical experience helped create a standard method (or paradigm) that can be used to solve resource allocation and optimization problems effectively.

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