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Solving Multistage Transportation Problems: Minimizing Costs and Optimizing Transshipment Strategies

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Abstract: ***The transportation problem is a special type of linear programming problem where the objective is to minimize the cost of distributing a product from a number of sources or origins to number of destinations. The process of shipping products or containers to one location as an intermediate and then to another is known as transshipment. Transloading the practice of switching modes of transportation during a trip is one such explanation. Another reason is to combine small shipments, dividing the large shipments to the other end. A significant portion of international transshipment occurs in regions designated to the customers, avoiding the requirement for the customer's inspection or fees, which would otherwise be a significant barrier to effective transportation problems, are those in which transshipment is permitted. It may not pass via intermediary nodes, perhaps requiring a change in the method of transit. In this paper a simple multistage transportation problem is solved using the lingo software.***

Keywords: Transportation, shipments, origins, destinations, lingo

1. Introduction

The transportation problem is a unique type of linear programming problem focused on minimizing the cost of distributing products from multiple sources to various destinations. Due to its specific structure, the standard simplex method isn't ideal for solving it. Instead, specialized solution methods are required. In a transportation problem, the origin refers to the location where shipments are sent out, while the destination represents the location where these shipments are delivered. The unit transportation cost is defined as the expense incurred in moving a single unit of goods from a specific origin to a specific destination. As a distribution - focused problem, the primary objective of the transportation problem is to determine the most efficient way to allocate and transfer goods from multiple supply points to multiple demand points, either minimizing transportation costs or maximizing overall profit. When there are only a few origins and destinations, making decisions about the distribution of goods is relatively straightforward. However, as the number of origins and destinations increases, the complexity of the decision - making process grows significantly, transforming it into a challenging linear programming problem. Transportation problems can be categorized into various groups depending on their primary objective and the relationship between supply at the origins and demand at the destinations. These objectives might focus on minimizing transportation costs, maximizing profit, or optimizing other factors such as delivery time or resource utilization. Additionally, the classification considers whether the supply from origins matches the demand at destinations (balanced problem) or if there are discrepancies, such as excess supply or unmet demand (unbalanced problem). These distinctions are critical in determining the appropriate approach to solve the problem efficiently. Transportation problems aimed at reducing the cost of shipping goods are referred to as minimizing problems. " Alternatively, when the focus is on increasing the profitability of shipping goods, these problems are known as "maximizing problems. A transportation problem is considered balanced when the total supply of goods available at all origins matches the total demand for goods at all destinations. This means that the quantity of goods to be shipped is perfectly aligned with the requirements at the receiving locations. On the other hand, if the total supply and total demand differ—such as when there is either excess supply or insufficient supply to meet demand—the transportation problem is classified as unbalanced. Addressing unbalanced problems often involves introducing adjustments, such as dummy origins or destinations, to facilitate their resolution. It is important to highlight that transportation methods are sometimes applied to solve problems that do not involve the physical movement of goods. In this paper a simple multistage transportation problem has solved using lingo software.

2. Review of Relevant Literature

A. Uthairatanakij et al. (2005). determine the nature of the processes leading to chilling injury in nectarines and how the gaseous composition of the storage atmosphere effects the development of low temperature disorders, levels of ACC and conjugated ACC were measured in fruit of the CV. Donghua Wang and Xue Liang (2009) developed optimization model and bring forward some valuable ideas, so as to improve the special structure of transportation model and accelerate the process of resources distribution. Anand Jayakumar A et al. (2013) developed a mathematical model for aggregate planning tailored to a pump manufacturing company. Anand Jayakumar (2014) reviewed mathematical models related to supply chain network design. Anand Jayakumar A et al (2015) optimized a p - median problem using Python, while Anand Jayakumar A and Krishnaraj C proposed the implementation of quality circles. Additionally, Jayakumar A et al. (2015) created a mathematical model for supply chain network design and worked on enhancing productivity in a stitching section. Jayakumar A et al. (2016) developed another mathematical model focused on aggregate planning. Evans - Obinna et al. (2016) highlight that quantitative techniques provide a scientific method for managerial decision - making. Their study demonstrated that applying quantitative methods in management can assist organizations in resolving complex problems efficiently, accurately, and cost - effectively. Anand Jayakumar A et al. (2017) optimized a fixed charge problem using Python. In the same year, they proposed a mixed strategy for aggregate planning. Anand Jayakumar A et al. (2019) developed another model specifically for aggregate planning. Anand Jayakumar A and Krishnaraj C (2021) developed a mathematical model for optimizing supply chain networks using the gravity location method. Krishnaraj C et al. (2021) developed a solution for a supply chain network optimization model. Sourav Miha (2021) created a transportation model designed to establish a shipping schedule that minimizes overall shipping costs while adhering to supply and demand constraints. The model operates under the assumption that shipping costs are directly proportional to the quantity of units transported along a specific route. Xiaolong Jiao et al. (2021) developed a cold chain transportation model aimed at preserving the freshness of fruits and vegetables within a low - temperature cold storage environment. The model is structured around the topology of the cold chain transportation network. By establishing assumptions for the fresh - keeping cold chain transportation system, the objective model is divided into three components: the cost of vehicle fuel consumption, the cost of refrigeration during cold chain transportation, and the total cost of fruit and vegetable loss. Sahani et al. (2024) introduced the transportation issue model, one of the earliest linear programming models applied in real - world scenarios. This model has garnered attention from experts due to its innovative table operations approach. To enhance the unique framework of the transportation model and accelerate the resource distribution process, this study aimed to refine optimization techniques and provide valuable insights through a critical and constructive analysis.

3. The Modeling Framework

Consider the transportation problem of a single commodity through a multi stage process. The items can be transported from factories to intermediate warehouses and then to retailers. In a two - stage transportation problem, transport all the materials to warehouses from which they are transported to retailers. Consider a multi - stage transportation problem as follows:

Consider a multi - stage transportation problem as follows:

X_{JK} = Quantity supplied from factory J to warehouse K

C_{JK} = Unit transportaion cost from factory J to warehouse K

Y_{KL} = Quantity transported from warehouse K to retailer L

C_{KL} = Unit transportion cost from warehouse K to retailer L

b_L = Quantity required by reatiler K

a_J = Quanity avilable in the factory J

The objective is to

Minimize $\sum_J \sum_K X_{JK}\, C_{JK}\ \sum_K \sum_L X_{KL}\, C_{KL}$

S. t

$\sum_K X_{JK} \le a_J$ Where j= 1, 2, 3……. m

$\sum_J X_{JK} \ge \sum_L Y_{KL,}$ Where K= 1, 2 …. n

$\sum_K X_{JK} \ge b_L$, Where L=1, 2…p.

$X_{JK}, Y_{KL} \ge 0$

A multi transportation problem with three factories $F_1, F_2\ and F_3$, three warehouses $W_1, W_2, and\ W_3$, and three retailers $R_1, R_2, and\ R_3$. The supplies in the factories150, 90, and 70 and the demands at the three retailers are 160, 90, and 60. The warehouses have infinite capacity. The transportation cost is given in table no.1

Table 1: Data set of Transportation Model

S. No	Sources to Destination	Cost
1	F_1 to W_1	10
2	F_1 to W_2	7
3	F_2 to W_1	6
4	F_2 to W_2	9
5	F_3 to W_1	5
6	F_3 to W_2	8
7	W_1 to R_1	7
8	W_1 to R_2	6
9	W_1 to R_3	9
10	W_1 to R_1	12
11	W_2 to R_2	10
12	$W_2$to R_3	7
13	W_3 to R_1	6
14	W_3 to R_2	5
15	W_3 to R_3	4

4. Result and Discussion

By optimizing the objective function subject to list constrained the result is shown in table 2.

Table 2: Optimum Results of Transportation Model

S. No	Source	Destination	Quantity
1	1	2	90
2	1	3	60
3	2	1	90
4	3	1	70
5	1	2	160
6	2	3	90
7	3	3	60

From table 2, it is observed that the highest optimum quantity is required for first number of warehouse and for second number of destination, whereas the lowest optimum quantity is required for third number of source and for third number of destination respectively according to demand. The total transportation cost is Rs.3250, which has been obtained after 3 iterations.

5. Conclusion

Optimizing the Simple Transportation Model is essential for reducing costs and improving efficiency in the distribution of goods across supply chains. Beyond cost savings, this model supports better decision - making by uncovering bottlenecks, streamlining logistics, and ensuring effective resource utilization. The above is the quantity transported from the source to destination. The highest optimum quantity is required for first number of warehouse and for second number of destination, whereas the lowest optimum quantity is required for third number of source and for third number of destination according to the demand. The total transportation cost is Rs.3250, which has been obtained after

3 iterations. Furthermore, advanced methods such as sensitivity analysis can enhance the solution by assessing the impact of changes in factors like supply, demand, or transportation costs. In today's fast - paced world, where sustainability and cost - effectiveness are paramount, optimizing transportation models has become more critical than ever.

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