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Cost-time trade-off in bi-criteria multi-index bulk transportation problem: A numerical approach

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Abstract
In this study, a bi-criteria multi-index bulk transportation problem is explored. The bulk transportation problem refers to a logistics scenario where the demand of each destination must be met exclusively by one source, although a single source can cater to multiple destinations. This problem balances two critical criteria: cost and time, focusing on achieving an optimal trade-off between them. A numerical example is used to illustrate the methodology for deriving the cost-time trade-off pairs in the multi-index bulk transportation problem. The least-cost solution is identified first, along with its corresponding time. Once this optimal solution is obtained, subsequent efficient trade-off pairs are determined. These trade-offs reveal how small compromises in cost can potentially reduce transportation time or vice-versa. The approach emphasizes achieving efficient transportation planning by minimizing costs while ensuring reasonable delivery times. This type of problem has real-world applications in logistics and supply chain management, where it is critical to optimize operations by balancing multiple objectives. The study provides practical insights into multi-index systems, showing how systematic methods can yield a sequence of cost-effective and time-efficient solutions to support better decision-making.

Keywords: Bi-criteria, transportation problem, cost time trade off, multi index, decision making

Introduction

Mental health disorders are a growing public health concern in the United States. According to the National Institute of Mental Health (NIMH), over 21 million adults in the U.S. experienced a Transportation Problem is a special class of LPP where requirements are to be fulfilled by availabilities, by transporting from sources to destinations.

At first, concept of Transportation Problem, with objective of cost minimizing of Transportation has been developed by Hitchcock [1]. Then single objective Transportation Problem are discussed by several authors, named as, Balas [2], Bhatia *et al.* [3], Ganfinkel and Rao [4], Hammer [5], Seshan and Tikekar [6] and Sharma and Swarup [7], Hakim [8], Ahmed *et al.* [9] and Pramila and Uthra [10] using different approaches.

Bulk Transportation Problem has been taken into consideration. As Bulk Transportation Problem is something different type of Transportation Problem with some constraint that requirement is to be met from one source only. Maio and Roveda [11] introduced Bulk Transportation Problem in literature at first with the objective of minimsing the BTP. Then Srinivasan and Thompson [12] studied the BTP with branch and bound algorithm further. Later on Bhatia [13] discussed a note on the time minimising BTP.

When more than one type of products are supplied through different mode of Transportation Problem, thus Multi-Index Transportation Problem is considered, which was first introduced by Schell [14] and Galler and Dwyer [15] in literature. Then Haley [16], Junginer [17], Pandian and Anuradha [18] and Rautman *et al.* [19] explained MITP through different approaches. Purusothan and Murthy [20] brought the new algorithm to minimse cost of MIBTP i.e. Lexi-search algorithm. Then, Bi-criteria TP is introduced where TP includes of both cost and time as objectives. Bhatia [21], Glickman and Berger [22], Aneja and Nair [23] and Prakash *et al.* [24] studied Bi- criteria transportation problem and bi- criteria bulk transportation problem has been studied by Prakash and Ram [25], Prakash *et al.* [26]. Then BCMIBTP is not studied so far in literature.

Here, the efficient solution of cost-time will be yielded by solving the numerical problem.

Formulation

Let there be m sources, n destinations and 1 facility. The formulation of Bi-criteria multi-index bulk transportation problem is as follows:

$$\text{Min}\left(\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l} c_{ijk}\, y_{ijk} : y_{ijk} = 1,\ \max\{t_{ijk} : y_{ijk} = 1\}\right)$$

Subject to the constraints

$$\sum_{j=1}^{n}\sum_{k=1}^{l} b_j y_{ijk} \leq a_i$$

$$\sum_{i=1}^{m}\sum_{k=1}^{l} y_{ijk} = 1$$

$$y_{ijk} = 1 \text{ or } 0$$

Where,

c_{ijk} is bulk transportation cost from i_{th} source to j_{th} destination with facility k.

y_{ijk} is decision variable having value 0 or 1, value depends on whether the requirement of j_{th} destination is met or not from the source 'i' with facility 'k'.

t_{ijk} is the bulk transportation time from i_{th} source to j_{th} destination with facility 'k'.

a_i is the number of unit of product available at i_{th} source.

b_j is the number of units required at j_{th} destination.

Let C_1 and T_1 be the minimum cost with corresponding time of BCMIBTP. Let Y_1 be the solution that gives efficient cost-time trade-off pair $[C_1, T_1]$, and let C_2 and T_2 be another cost and time pair, this must satisfy C_2 ($>C_1$) and T_2 ($<T_1$). Then, the solution Y_2 giving solution $[C_2, T_2]$ is said to be subsequent solution if there exist no other solution Y providing [C, T] cost-time trade-off pair s.t. $C_1<C<C_2$ and $T_2<T<T_1$. Thus, we will get nest efficient pair as $[C_2, T_2]$ provided by Y_2. Proceeding the same way, the next efficient cost-time trade-off pair will be determined.

Proposed Algorithm

1. Cross off the cells (i,j) from the table for which availability a_i is less than the requirement b_j.
2. Determine the minimum cost for each mode of Bulk Transportation.
3. Select minimum cost of problem P_1, let C_{11} and T_{11} be the cost and time and Y_{11} be the solution providing C_{11} and T_{11} with facility k=1 for Bulk Transportation Problem and Y_{12} be the solution providing minimum cost C_{12} with corresponding time T_{12} for problem P_2.
4. Select minimum of cost associated with decision variable for each destination through facility k=1 and k=2. Let Y_1 be the solution obtained and let the cost and time C_1 and T_1. Let (C_1,T_1) be the first efficient time-cost trade-off pair of BCMIBTP.
5. To obtain the next pair, delete the cells whose time is greater than or equal to T_1 from P_1 and P_2 respectively. Repeat steps 2 to 3 for reduced problem. Thus (C_2,T_2) be the next efficient pair will be determined.
6. Repeat above steps until the reduced problem becomes feasible.

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