An Approach for a Multi-Objective Capacitated Transportation Problem

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Nurdan Kara
National Defence University, Turkey

Hale Gonce Köçken
https://orcid.org/0000-0003-1121-7099
Yildiz Technical University, Turkey

INTRODUCTION

The classical transportation problem (TP) is a special type of linear programming (LP) problem. In this problem, a homogeneous product is to be transported from several sources to several destinations in such a way that the total transportation cost is minimum, or profit is maximum. In this problem, while sources can be defined as suppliers, production centers, factories, etc., demands may be customers, warehouses, sinks, etc. Moreover, this problem may have equality or inequality type of constraints. In real-life problems, the constraints of TPs are not generally in equal form. In some cases, the decision-maker may have specified a supply amount that must be provided from a particular source. Then, the corresponding supply constraint will be "greater than or equal to" form. Similarly, when the amount of resources owned by any supplier is limited (i.e. has an upper limit), then the corresponding supply constraint will be "less than or equal to" form. These different types of inequalities may also appear in any demand constraint. Therefore, TP with mixed constraints arises.

Moreover, when the total demand equals the total supply, the TP is referred to be a balanced transportation problem. If a TP has a total supply that is strictly less than the total demand, then the problem has no feasible solution. In this situation, it is sometimes desirable to allow the possibility of leaving some demand unmet. In such a case, we can balance a transportation problem by creating a dummy supply point that has a supply amount equal to the unmet demand and associating it with a penalty.

Furthermore, a STP with two or more fractional objective functions is called as a multi-objective fractional STP. In this problem, maximum profitability - profit/cost or profit/time – as a criterion function is maximized subject to supply, demand, and conveyance constraints.

The transportation problem, in its simplest form, deals with the physical transfer of some goods from sources to destinations but also has different applications in many different fields. Many subproblems that can be defined especially in the field of logistics are based on the logic of transportation problems. From a more general point of view, there are many transportation problems in the field of the supply chain, which includes the movement of the product or service from the supplier to the customer and is defined as the whole systems of organizations, people, technology, and activities. Some of these are the transportation of raw materials to be sent from suppliers to the factories, the transportation of goods to warehouses or distribution centers, the delivery of the products to customers, and transferring used products to recycling centers.

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In today's world of globalization, we are faced with the transportation of more products and the diversity in the ways of transportation of the product. To meet this need, we had to define the solid transportation problem (STP) which is one of the important research topics from both theoretical and practical aspects. STP is a special type of the traditional transportation problem in which three-dimensional properties (supply, demand, convenience) are taken into account in the objective and constraint set instead of source and destination. The necessity of considering this special type of transportation problem arises when heterogeneous conveyances are available for the shipment of products. The STP is also applied in public distribution systems. In many industrial problems, a homogeneous product is delivered from a source to a destination by means of different modes of transport called conveyances, such as trucks, cargo flights, goods trains, ships, etc. These conveyances are taken as the third dimension. An STP may be transformed into a traditional TP by considering only a single type of conveyance.

It is generally aimed to minimize only the transportation cost in all these transportation problems, namely the classical two-dimensional transport problem or the three-dimensional STP. However, it is very rare to consider only cost in real-life problems. Therefore, it is required to consider the optimization of several objectives such as minimization of transportation time, packing cost of goods, maximizing the total profit, the security level of transportation, etc. In addition to these objectives, environmental objective functions, such as the minimization of carbon emissions from related transportation processes can also be taken into account within the scope of green, closed loop, or sustainable supply chain management. All these situations lead to considering multi-objective versions of TP or STP. Thus, Multi-objective TP (MTP) and Multi-objective STP (MSTP) can be modeled more realistically. Although the optimal solution concept is utilized in single-objective problems, Pareto-optimal solutions emerge in multi-objective problems. Since the total number of these non-dominated solutions is usually very large, the preferences of the decision-makers are taken into account with methods such as weighting, interactive approaches, scalarization procedures, etc. In this way, the most suitable solutions are tried to be chosen to present the decision-makers among many Pareto-optimal solutions.

One of the most important research topics for solid transportation problems is the use of fuzzy set theory. This theory was first introduced by Zadeh. In several applications, the required data for real-life problems can be imprecise. Therefore, an adaptation of fuzzy set theory in the solution method increases the flexibility and effectiveness of the proposed approaches. This theory has been used for the development of the applications of solid transportation. Most research investigates multi-objective solid transportation problems under the fuzzy environment in two cases: (1) the costs, the supplies, the demands, and conveyances capacities are fuzzy numbers (2) All parameters are crisp while the fuzzy programming approach is used.

The classical TP, which has supply and demand constraints, deals with transporting a single commodity. However, additional indices such as commodities and modes of transport should be considered, and this necessity led to the multi-index TP. Moreover, fixed costs in establishing the production process can be added to TP models, so fixed charge TPs occur. Similar to MSTP, criteria other than cost (such as time, profit, etc.) led to the multi-index, multi-objective fixed charge TPs.

Although the linear membership function is widely utilized in many real-world decision-making problems, the usage of the non-linear membership function can provide a more realistic conclusion than the linear ones in some practical applications. That is, the non-linear membership function is much more versatile than linear types and can generate better results for objective functions' satisfactory levels. Therefore, the decision-maker can opt for the membership function, which is presenting a better solution for the objectives being a higher priority.

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