Pareto Optimal Solution Selection for a Multi-Site Supply Chain Planning Problem Using the VIKOR and TOPSIS Methods

Houssem Felfel, Mechanics, Modeling and Production Laboratory, National Engineering School of Sfax (ENIS), University of Sfax, Sfax, Tunisia
Omar Ayadi, Mechanics, Modeling and Production Laboratory, National Engineering School of Sfax (ENIS), University of Sfax, Sfax, Tunisia
Faouzi Masmoudi, Mechanics, Modeling and Production Laboratory, National Engineering School of Sfax (ENIS), University of Sfax, Sfax, Tunisia

ABSTRACT

In this paper, a multi-objective, multi-product, multi-period production and transportation planning problem in the context of a multi-site supply chain is proposed. The developed model attempts simultaneously to maximize the profit and to maximize the product quality level. The objective of this paper is to provide the decision maker with a front of Pareto optimal solutions and to help him to select the best Pareto solution. To do so, the epsilon-constraint method is adopted to generate the set of Pareto optimal solutions. Then, the technique for order preference by similarity to ideal solution (TOSIS) is used to choose the best compromise solution. The multi-criteria optimization and compromise solution (VIKOR), a commonly used method in multiple criteria analysis, is applied in order to evaluate the selected solutions using TOPSIS method. This paper offers a numerical example to illustrate the solution approach and to compare the obtained results using TOSIS and VIKOR methods.

KEYWORDS

Multi-Objective Optimization, Multi-Site Supply Chain Planning, Pareto Optimal Solutions, TOPSIS, VIKOR

1. INTRODUCTION

In the face of today’s highly competitive and global markets, manufacturing enterprises no longer operate as independent entities, but rather as multi-site supply chain. Thus, these enterprises are required to develop an integrated multi-site planning approach that takes into account the coordination between the different entities of the supply chain. Since the manufacturing sites are situated in different places, the planners need to define the amounts of products to be produced at each site as well the flow of products from one site to another.

The supply chain planning problem can be classified following the time horizon into three major categories: strategic, tactical, and operational (Fox et al. 2000). The strategic level concerns the design and the structure of the supply chain over a long time horizon that could last more than five years. The operational level is related to short term decisions lasting from few days to a few weeks. It deals with issues such as lot sizing, scheduling, and sequencing. The tactical planning model is between these two extremes including procurement, production, storage and distribution decisions. The focus of this work addressed the tactical level of the supply chain planning.

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The profit and the cost represent the most used objectives for supply chain performance. The majority of the works in the literature focus on the maximization of the profit or the minimization of the cost as a single objective. One can refer to Moon et al. (2002), Gnoni et al. (2003), Leung et al. (2006), Lin and Chen (2006), Shah and Ierapetritou (2012), Lin et al. (2011) and Felfel et al. (2015b). Besides, the product quality level represents another important performance metric of the supply chain in a highly competitive market environment. This objective is rarely treated in the literature on supply chain planning problems. It is worthwhile noting that profit and product quality conflict with each other. In fact, the best product quality corresponds usually to a higher cost, which means a less profit.

Several multi-objective optimization problems and solution approaches have been proposed in the literature on multi-site supply chain. Leung et al. (2007) developed a robust optimization model to deal with a multi-site production problem under uncertainty for a multinational lingerie company located in Hong Kong. The proposed model attempted simultaneously to minimize the total cost as well as the variance of the total cost. The proposed model was solved as a single objective model using LINDO software. Torabi and Hassini (2009) dealt with a multi-site multi-echelon supply chain production planning model integrating procurement and distribution plans.

The authors considered four objective functions simultaneously, which are the minimization of the cost, the minimization of the late deliveries, the minimization of the volume of defective products and the maximization of the value of purchasing. A novel fuzzy approach was proposed to solve the developed multi-objective model and to find an efficient compromise solution. Mirzapour Al-e-Hashem et al. (2011) proposed a multi-site, multi-product, multi-period aggregate production planning problem. A novel robust multi-objective mixed integer nonlinear programming model was developed considering two conflicting objectives simultaneously. The first objective function consists on the minimization of the total losses of the supply chain and the second consists on the maximization of the customer satisfaction level. The proposed multi-objective model was solved then as a single-objective model by means of the LP-metrics method.

In a multi-objective optimization problem, the objective functions are usually conflictual and there exists no solution that satisfies all the objectives simultaneously. Therefore, the solution of the multi-objective optimization problem is a set of non-dominated solutions called front of Pareto optimal solutions. This front of Pareto represents the trade-off between the different objective functions rather than a single solution. Thus, the mission of the decision maker is to generate the front of Pareto optimal solutions and then to select the best alternative. Most of the works literature on supply chain optimization problem focused on generating the set of Pareto and do not look for the selection of a compromise solution (Guillen et al., 2005; Azaron et al., 2008; Franca et al., 2010; Fahimnia et al., 2013; Guo et al., 2013; Felfel et al., 2014). Felfel et al. (2015a) dealt with a multi-objective, multi-product, multi-site supply chain planning problem. The authors considered two objectives which aimed to minimize of the total cost and to maximize of the product quality level. A lexicographic minimax method was used to find a fair Pareto optimal solution that satisfies equitably the considered objectives. The main critic of this work is that adopted lexicographic minimax method does not help to select a Pareto solution from the set of Pareto but rather to generate a fair solution. Despite plenty of research regarding multi-objective supply chain optimization problem appeared recently, to the best of the authors’ knowledge, there is no prior work that focused on the selection of the best compromise solution from the set of Pareto.

Multi-criteria decision making (MCDM) is related to the choice of the best solution from a set of alternatives in the presence of multiple conflicting criteria (Vinodh and Vimal, 2012). Many methods were developed for MCDM (Vincie, 1992) such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), ELimination and Choice Expressing REALity method (ELECTRE), Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE), Multicriteria Optimization and Compromise Solution (VIKOR), Technique for Ordering Preference by Similarity to Ideal Solution (TOPSIS), etc. The TOPSIS method proposed by Hwang and Yoon (1981) focuses on the selection of a solution having the farthest distance from the negative-ideal solution and the
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