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Order assignment considering buyer, third-party logistics provider, and suppliers

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ABSTRACT

This paper presents a fuzzy multiple-objective mixed-integer programming model that tackles some different features of order assignment problems by considering vague aspects of such decision-making problems, the model reflects realities encountered in practice. In particular, the model considers three main parties of the supply chain: the purchasing organisation, suppliers, and third-party logistics providers (3PL) and in doing so, considers the three main aspects of order assignment, namely purchasing, holding, and ordering. By applying the theory of fuzzy sets, and through some operations on objective function and constraints, this research achieves a mixed-integer programming model with less complexity and more performance in a group of order assignment problems.

1. Introduction

The first intention of this paper is to model and analyse the order assignment problem with a wider view by considering buyer, supplier, and 3PL parties. This modelling reflects the multiple-objective nature of the problem by including the contribution of each party to total cost and overall performance of the supply chain. The second intention is to model existing uncertainties in decision criteria of the order assignment problem. Finally, the paper tries to develop a solution for the multiple-objective decision-making problem under uncertainty.

Competitive price, on time delivery, flexibility, innovation, pro-activity, quality, and high serviceability are key operations objectives demanded by today's fast changing markets. To meet those objectives, clusters of suppliers, retailers, and logistics providers shape supply chains and compete with each other rather than single companies or brands (Christopher, 2000). To be competitive, a supply chain should be based on qualified associates, such as manufacturers, suppliers, distributors, wholesalers, retailers, and so on. In the supply chain, at the upstream or supply side, it is mainly the responsibility of the purchasing or procurement organisation or department to create a reliable, competitive supply base. In that respect, managing suppliers and assigning the right product to the right suppliers is of great importance.

This study concentrates on the order assignment problem where multiple-product orders are to be allocated to different suppliers and a 3PL. The selection of the right supplier and the assignment of the right quantity are tackled in the modelling process developed by this paper. The ordering, holding inventory and purchasing costs are considered in three main engaged parties—the buyer company, the 3PL, and the suppliers. The research avoids single perspective approaches, which looks at the order assignment problem only from the viewpoint of the buyer or supplier. On the other hand, the contributions of different parties are taken into account, and are aggregated in a broader model. Taking numerous perspectives into consideration leads to a multiple-objective type of decision making. To deal with real-life practical issues of the order assignment problems in the supply chain management, this study considers some aspects of uncertainties in the associated decision-making process. The uncertainties are discussed in setting the objective function level. Fuzzy systems in mathematical programming are employed to find a solution for the developed model. To have a better understanding of different aspects of the study, the next section provides a review of the literature on order assignment and related bodies of knowledge.

2. Literature review

Management of orders across the supply chain has been tackled recently from different perspectives. Order assignment has been studied in a wide range of research areas including order distribution (Chan et al., 2004, Chan and Chung, 2004a), order allocation (Kawtummachai and Van Hop, 2005), assignment problem (Chan and Chung, 2005), order fulfilment (Chan et al., 2006), order lot sizing (Lioa and Rittscher, 2007), multiple-supplier inventory

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management (Minner, 2003), supplier selection (Humphreys et al., 2003b; Chan and Chan, 2004; Chan et al., 2007), supplier evaluation (Jain et al., 2004), agent-based system (Abid et al., 2004), and capacity planning (Sawik, 2009). The literature addresses order assignment largely as a coherent part of the supplier selection process (see for example Degraeve and Roodhooft, 1999; Ghodsypour and O'Brien, 2001; Lioa and Rittscher, 2007). To tackle supplier selection in general, and order assignment problems in particular, several methods have been developed. Cost-oriented models are one of the main approaches to evaluation and selection of suppliers. These models, which are known as 'total cost of ownership' (TCO), try to quantify the cost of assigning orders to each supplier and find the minimum cost accordingly (Ellram, 1995; Degraeve and Roodhooft, 1999; Ferrin and Plank, 2002). Although the TCO models provide an enhanced perspective to the order assignment problems, they need to be supported by advanced accounting methods such as activity based costing or ABC (Ellram, 1995). Weighting system is another approach to evaluate and select suppliers, which typically rates and ranks suppliers according to weighted attributes (Narasimhan, 1983; Nydick and Hill, 1992; Barbarosoglu and Yazgac, 1997; Dulmin and Mininno, 2003). One of the gaps in the literature is studying the role of 3PLs in order assignment problems. Expanding 3PLs' activities in supply chains (Marasco, 2008) needs further studies on their performance and considering their functions and preferences in order assignment problems. Order assignment (and supplier selection in general) has been recognised as a multiple criteria decision-making problem (see for example Weber et al., 1991; Wilson, 1994). There are numerous studies which employ mathematical modelling and programming for order assignment and supplier selection problems. These include different approaches such as multi-attribute decision making (MADM) (Chan, 2003) and multi-objective decision making (MODM) (Chen et al., 2006), goal programming (Karpak et al., 1999), and data envelopment analysis (Weber and Desai, 1996).

Considering the complexity of majority of the above-mentioned models, heuristics and evolutionary methods such as artificial intelligence (AI) and expert systems (Kwong et al., 2002; Humphreys et al., 2003a), neural networks (Choy et al., 2003), genetic algorithms (Chan and Chung, 2004a and b; Chan et al., 2005a and b), Simulation approach (Chan et al., 2001), and game theory (Belenson and Kapur, 1973) have been considered to find solutions for order assignment problems. Order assignment and supplier selection problems could be categorised into two groups: single-product and multiple-product (Degraeve et al., 2000). While single product models try to simplify the order assignment problem (e.g. Chen and Chen, 2006), multiple-product models try to consider existing realities and interdependencies between products and multiple-supplier in order assignment problems. Determining the overall optimum in multi-objective programming models is usually complicated. Each objective can independently be optimised at a special point in the solution space. In such cases, one may determine a non-inferior (non-dominated) solution.

There are various methods proposed for solving multiple-objective models. In some methods, such as compromise programming, a multi-objective model is converted to a single objective one, by compromising the goals, based on their distance from ideal or non-ideal points (Zeleny, 1982). However, determining the priority of the goals by the decision makers is not often a simple task. Many researchers have used other methods such as weighting methods, constraint methods, and multiple-objective simplex method (Hwang and Masud, 1979). However, these methods usually contain high dimensionality and very high computational complexity (Deb, 2001). As a result, they can only be applied to small size problems.

Most of the above-mentioned methods usually use exact information and a complicated procedure to produce a crisp solution. In real world cases, decision makers might want to reach some aspiration levels that might not lead to a crisp optimal solution in part because the constraints and numbers might be vague, uncertain, and imprecise. Fuzzy sets and systems have been recognised as suitable tools for handling these uncertainties in supplier selection problems (Dhingra and Moskowitz, 1991; Humphreys et al., 2006). Zimmermann (1996) has developed an evolutionary procedure to handle multiple-objective mathematical programming with fuzzy objectives and constraints. It has widely been used in recent years to tackle supplier selection problems (Chen and Tzeng, 2000; Kumar et al., 2006; Amid et al., 2006; Famuyiwa et al., 2008).

Some of the recent literature on order assignment and supplier selection only considers a single-product/multiple-supplier situation (Rosenblatt et al., 1998; Chang, 2006). There are also some studies on multiple-product problems, where they do not consider multiple-supplier situations (Haksever and Moussourakis, 2005; Mondal and Maiti, 2002). Other researches such as Ghodsypour and O'Brien (2001) investigate total cost of logistics in supplier selection process with multiple-product and multiple-supplier. However, the problem simply considered the customer side of the relationship, and all costs are taken into account from the viewpoint of the buyer. As Lioa and Rittscher (2007) discuss, supplier selection and order assignment decisions should be made together. Consistent with Lioa and Rittscher's idea, this study endeavours to focus on the order assignment problem involving three key parties in the supply chain; suppliers, customer, and 3PL. There are few studies that examine the role of 3PL in order assignment problems. Lioa and Rittscher (2007) develop a multi-objective model to integrate the choice of suppliers, product assignment, and carrier company. They work on a crisp model with exact objective function.

This paper addresses multiple dimensions of the order assignment problem. The role and participation of the third-party logistics provider (3PL) in total purchasing and logistics cost is highlighted. Moreover, existing uncertainties and vagueness coupled with decision-making process in the order assignment are considered in this study. The rest of this paper is organised as follows. The next section describes the problem addressed by this research. Objectives are clarified and research method is explained. It also describes the structure of the problem. Section 4 presents the model for multiple-product–multiple-supplier order assignment. Operations on the model and the solution of the model are explained in Section 5. In Section 6, some numerical examples for the model are provided. Finally, Section 7 contains discussion and future studies.

3. Problem description

Based upon the nature of the case study in this research, each of the three parties—buyer, supplier, and 3PL, deals with one aspect of cost of order assignment. All products from suppliers to buyer flow through 3PL. 3PL does not collect the product from the supplier's site until they are required by the buyer's production lines. In that respect, the suppliers hold inventories of their final product, between the time they are ordered by the buyer and are collected by the 3PL. Shipment of orders is planned through a lot sizing system for all products and suppliers. In view of that, suppliers deal with inventory costs, 3PL deals with fixed logistics costs for each order cost, and the buyer deals with purchasing cost (see Fig. 1).

Based on the holding inventory costs, suppliers prefer smaller order quantities for higher value products. At the same time, 3PL prefers minimum number of orders and larger quantities to minimise its logistics costs and uses the capacity of its heavy transport vehicles as much as possible in each order. Finally, the buyer prefers to assign its orders to the supplier with lowest offered price. From this scenario, it is clear that objectives of these three