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A possibilistic multiple objective pricing and lot-sizing model with multiple demand classes

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Abstract

We address an inventory-marketing system to determine the production lot size, marketing expenditure and selling prices where a firm faces demand from two or more market segments in which the firm can set different prices. Considering pricing, marketing and lot-sizing decisions simultaneously, the model maximizes the profit and return on inventory investment under multiple time varying demand classes. The model is formulated as a fuzzy non-linear multi-objective one where some parameters are ill-known and modeled by fuzzy numbers. A hybrid possibilistic-flexible programming approach is proposed to handle imprecise data and soft constraints concurrently. After transforming the original model into an equivalent multi-objective crisp model, it is then converted to a classical mono-objective one by a fuzzy goal programming method. An efficient solution procedure using particle swarm optimization (PSO) is also provided to solve the resulting non-linear problem.

Keywords: Fuzzy mathematical programming; Lot-sizing; Market segmentation; Price differentiation; Fuzzy sets

1. Introduction

The integration/coordination of production and marketing decisions has been known to be crucial in practice for diminishing their conflicts and increasing a firm's profit by reducing opportunity losses incurred from separate or independent decision-making [1–6]. To do so, one important area is developing joint pricing and lot-sizing models (JPLM), where demands are assumed to be constant but price-dependent. As a result, item's price and economic lot size or economic order quantity (EOQ) are determined simultaneously to maximize a firm's total profit over a planning horizon.

In this regard, it is noteworthy to mention that marketing expenditures, which include the advertisement and promotion, directly affect the demand of an item. Marketing effort motivates sales and influences potential consumers with an immediate reason to buy [7].

Understanding and differentiating customers by their needs and responses to marketing mixes play a vital role in managing customer relationships. This can be achieved by market segmentation that has been applied in almost every

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marketing research area including both the consumer and the firm behaviors. One of the underlying principles of revenue management (RM) is to divide a single market into multiple sub-markets/segments and then set different prices in each sub-market. For instance, many firms differentiate customers by leading them to different channels, such as online versus retail store, where firms set one price in the retail channel but offer discounts to online purchasers. Market segmentation generally increases revenue and hence profit; however, different prices in various market segments stir some customers to switch between segments. For example, a customer might visit a retail store to "touch and feel" a product but goes home and buys it online at a lower price. As Phillips [8] mentioned, price differentiation is a powerful way for sellers to improve their profitability.

Traditionally, profit maximization or cost minimization has been considered in numerous papers as the objective function for designing and analyzing inventory-marketing models. In another relevant research stream, there are a number of studies on optimization of inventory systems under return on investment (ROI) maximization. Return on inventory investment (ROII) maximization has also been examined by Schroeder and Krishnan [9], Otake et al. [10], Otake and Min [11], Li et al. [12] and Wee et al. [13]. Despite these studies, there are few works focusing on the profit and ROII maximization simultaneously when modeling inventory systems [13].

More surprisingly, the application of fuzzy set theory in JPLM and channel pricing areas is more limited. It is often a difficult task to determine the exact values for the parameters of an inventory system, such as cost and demand parameters, which is the primary concern in the previous reports. Therefore, they are assumed to be imprecise, i.e., fuzzy in nature [14]. Most of the research developing inventory-marketing strategies formulate the market uncertainty (e.g., uncertain demands) by using probability distributions that need sufficient historical data. However, the stochastic models may not be the best choice whenever statistical data are insufficient and unreliable or even non-obtainable. In these situations, fuzzy set theory provides an alternative approach to deal with the epistemic uncertainty (i.e., lack of knowledge) in the inventory and marketing related parameters. Furthermore, a decision maker (DM) often has vague goals such as "This profit function should be larger than or equal to a certain value." For such cases, fuzzy set theory and flexible programming methods should be used [13].

Negligence of some issues such as inherent uncertainty in critical input data (i.e., market demands and unit costs) and imposing the decisions made at a managerial level as a hard constraint to an operational level without allowing any deviation; often result in poor efficiency of JPLMs in practice. In this regard, we formulate a novel JPLM and channel pricing model in a fuzzy environment. Therefore, the main purpose of this paper is to develop a fuzzy multi-objective integrated pricing and lot-sizing model to efficiently handle different demand classes in an inventory system under uncertainty. The two important objective functions, i.e., profit and return on inventory investment (ROII), are considered to find item's prices and economic production quantity. The proposed model integrates the marketing-inventory and price discrimination decisions into a single model while maximizing the total profit and ROII concurrently. As mentioned earlier, in an integrated inventory and marketing planning framework, objective functions' goals, unit costs, marketing parameters, etc., are often assumed to be crisp and defined with certainty. However, this rarely happens in practice where the goals and parameters are normally vague and imprecise. Therefore, this paper presents a fuzzy multi-objective programming method to capture this inherent fuzziness in the critical data and goals.

The rest of this paper is organized as follows. In the next section, the relevant literature is reviewed. Problem description, assumptions and formulation are presented in Section 3. Then, by applying efficient defuzzification strategies, the resultant crisp multi-objective model is dealt with fuzzy goal programming in Sections 4 and 5. In Section 6, a tailored particle swarm optimization is employed to solve the resultant non-linear problem followed by an illustrative example in Section 7. Finally, concluding remarks and some future research directions are given in Section 8.

2. Literature review

In inventory systems' modeling, besides the standard "inventory" decision variables, such as order quantity, the decision-maker must also decide on the selling price and some other market-related issues. In 1955, Whitin [15] incorporated the concepts of inventory theory and economic price theory. Since then, several researchers have considered joint pricing and lot-sizing models where demand depends on price or other factors over a planning horizon. For instance, Kim and Lee [6] have determined the optimal values of selling price and order quantity where demand is price-sensitive. The price and marketing expenditure-sensitive demands are also discussed by Lee and Kim [5], Lee [16], Esmaeili et al. [17,18], Esmaeili [19]. Abad [20] formulated a model where a supplier offers a discount to the retailers to obtain an optimal selling price and lot size for two classes of demand functions, iso-elastic and linear. For a deteriorating