Applied Mathematical Modelling 36 (2012) 6011–6030

Contents lists available at SciVerse ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Integrated markdown pricing and aggregate production planning in a two echelon supply chain: A hybrid fuzzy multiple objective approach

R. Ghasemy Yaghin [a], S.A. Torabi [b,*], S.M.T. Fatemi Ghomi [a]

[a] *Department of Industrial Engineering, Amirkabir University of Technology, 424 Hafez Avenue, Tehran, Iran*
[b] *Department of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran*

ARTICLE INFO

Article history:
Received 20 April 2010
Received in revised form 9 January 2012
Accepted 17 January 2012
Available online 30 January 2012

Keywords:
Fuzzy mathematical programming
Short life cycle products
Markdown pricing
Retailing
Production planning

ABSTRACT

Given high variability of demands for short life cycle products, a retailer has to decide about the products' prices and order quantities from a manufacturer. In the meantime, the manufacturer has to determine an aggregate production plan involving for example, production, inventory and work force levels in a multi period, multi product environment. Due to imprecise and fuzzy nature of products' parameters such as unit production and replenishment costs, a hybrid fuzzy multi-objective programming model including both quantative and qualitative constraints and objectives is proposed to determine the optimalprice markdown policy and aggregate production planning in a two echelon supply chain. The model aims to maximize the total profit of manufacturer, the total profit of retailer and improving service aspects of retailing simultaneously. After applying appropriate strategies to defuzzify the original model, the equivalent multi-objective crisp model is then solved by a fuzzy goal programming method. An illustrative example is also provided to show the applicability and usefulness of the proposed model and solution method.

1. Introduction

Many firms focus on pricing alone as a tool to improve profit. However, for manufacturing industries, coordination of price decisions with other aspects of the supply chain such as production and distribution is not only useful, but also essential. The coordination of these decisions needs an integrated approach to optimize the whole system rather than individual elements, improving both the efficiency of the firm and its supply chain. This integration of pricing, production and distribution decisions in retail or even manufacturing environments is still in its early stages in many companies, but it has the potential to radically improve supply chain efficiencies in the same way as revenue management has changed for example, the airline, hotel and car rental companies' businesses dramatically [1].

With high variability of demand levels for short life cycle products, the manufacturer should have a plan indicating the production, inventory, and work force levels. In the manufacturing echelon, aggregate production planning (APP) is a medium range capacity planning that typically encompasses a time horizon from 3 to 18 months. During the process of APP, the planners make decisions regarding overall production levels for each product category to meet the fluctuating and typically uncertain demands in the near future and also regarding other issues such as hiring, laying off, overtime, backorder, subcontracting and inventory levels [2].

* Corresponding author. Tel.: +98 2188021067; fax: +98 2188013102.
E-mail address: satorabi@ut.ac.ir (S.A. Torabi).

0307-904X/$ - see front matter
doi:10.1016/j.apm.2012.01.029

In the retailing echelon, both pricing and inventory decisions need to be made. Pricing decisions are used to control the demand side, while inventory replenishment decisions are used to control the supply side. The central problem is to optimally coordinate the demand and supply decisions. Moreover, in the manufacturing echelon, manufacturer works on optimizing the production plan with APP approaches that highly rely on demand forcasts. Nevertheless, the uncertainty and variability characteristics of short life cycle products make the estimation of their demands extremely difficult. For short life cycle products, the retailer should make dynamic pricing and ordering decisions according to the dynamically changing market demands, in order to obtain maximum cumulative profit from the product during its lifecycle.

Retailers of style and short life cycle products often use *markdown pricing* to clear excess inventory before the end of life cycle. The major reasons for using the markdown pricing, which is a type of dynamic pricing, could be attributed to the (1) restricted time of products' use for example overcoats, (2) fashionability for example video games, (3) deterioration for example day-old breads and (4) obsolescence such as electronic goods. In fact, retailers could change the demand levels by employing the markdown pricing strategy. The retailer may also take into account a possible trade-off between price reduction and advertising expenditure as both contribute to demand increases.

In a two echelon supply chain, ordering and pricing policies for the retailer and aggregate production plan for the manufacturer are the most important decisions. These activities are often conducted either individually or sequentially with poor overall performance for the whole supply chain resulting to extra inventory and other deficiencies. Therefore, to reach a better situation, integration of ordering, pricing, production and distribution decisions in an integrated retail and manufacturing environment is of particular interest. Moreover, in the real life, most of the input data and related parameters are not known with certainty because of incompleteness and/or unavailability of required data over amid-term planning horizon [3,4]. In addition, often the decision maker (DM) cannot fit with certainty some probability distribution for uncertain parameters. Therefore, the decisions made on the basis of stochastic models may lead to inappropriate results in practice. However, such fuzziness in the critical data cannot be represented in a deterministic or stochastic formulation and therefore the corresponding optimal results may not serve the real purpose of modeling.

The aim of this paper is to propose an integrated ordering, markdown pricing and production planning model in a two echelon supply chain consisting of a manufacturer and a retailer over a given multiple period horizon in a fuzzy environment. The three objective functions, i.e., the total profit of manufacturer, the total profit of retailer and a qualitative objective including the service-oriented aspects of retailing with regard to a number of qualitative and quantitative constraints are jointly considered for short life cycle products. Notably, in a multi-product, multi-objective context, objectives' goals, resource capacities, unit costs and other parameters are often assumed to be crisp and defined with certainty while they are normally vague and imprecise in nature. Accordingly, this paper presents a fuzzy multi objective programming method to capture this inherent fuzziness in the critical data and objectives' goals.

The paper is organized as follows. Section 2 reviews the relevant literature followed by the problem formulation at Section 3. Section 4 provides a possibilistic programming model for the problem. In Section 5, a hybrid fuzzy goal programming model is proposed and the resulting equivalent crisp model is solved with different goal priorities in Section 6. Finally, Section 7 concludes this paper.

2. Literature review

There are two different research streams in our work, i.e., dynamic pricing especially markdown policy and aggregate production planning. Therefore, at below we briefly review the most relevant works in each area.

2.1. Dynamic pricing

Several researchers have studied the dynamic pricing for short life cycle products over a finite planning horizon. Elmaghraby and Keskinocak [5] provide a state of the art overview on dynamic pricing in the presence of inventory considerations. Markdown pricing as a kind of dynamic pricing has been analyzed by some researchers [6–11] via various approaches such as system dynamics, stochastic dynamic programming, and empirical study. Mantrala and Rao [12] found that the choice of an optimal markdown strategy significantly influences profitability in the area of fashion goods. Nair and Closs [13] studied coordinating price markdown policies with supply chain policies associated with operational decisions using the computer simulation on retail performance of short life cycle products. For joint

Table 1
A classification of some techniques used in MPP.

Analytical approaches	Instance source	Experimental approaches	Instance source
Stochastic dynamic programming	Mantrala and Rao [12]	Simulation	Nair and Closs [13]
Non-linear programming	Urban and Baker [15]	Empirical study	Heching et al. [9]
Theory of games	Elmaghraby et al. [11]	System dynamics	Reiner and Natter [10]