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Coordinated control of distribution supply chains in the presence of fuzzy customer demand

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Abstract

This paper considers a single product inventory control in a Distribution Supply Chain (DSC). The DSC operates in the presence of uncertainty in customer demands. The demands are described by imprecise linguistic expressions that are modelled by discrete fuzzy sets. Inventories at each facility within the DSC are replenished by applying periodic review policies with optimal order up-to-quantities. Fuzzy customer demands imply fuzziness in inventory positions at the end of review intervals and in incurred relevant costs per unit time interval. The determination of the minimum of defuzzified total cost of the DSC is a complex problem which is solved by applying decomposition; the original problem is decomposed into a number of simpler independent optimisation subproblems, where each retailer and the warehouse determine their optimum periodic reviews and order up-to-quantities. An iterative coordination mechanism is proposed for changing the review periods and order up-to-quantities for each retailer and the warehouse in such a way that all parties within the DSC are satisfied with respect to total incurred costs per unit time interval. Coordination is performed by introducing fuzzy constraints on review periods and fuzzy tolerances on retailers and warehouse costs in local optimisation subproblems.

Keywords: Fuzzy sets; Fuzzy two-level optimisation; Distribution supply chain; Inventory control; Uncertainty

1. Introduction

Over the past decade, supply chain (SC) management and control has become a strategic focus of leading manufacturing companies. This has been caused by rapid changes in environments in which the companies operate, characterised by high globalisation of markets and ever increasing customer demands for higher levels of service and quality. Research interests in SC management and control have been growing tremendously as well, leading to a wealth of literature devoted to SC problems (e.g., de Kok and Graves, 2003; Geunes et al.,

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2002). SC coordinated control, including all parts of SCs, such as buyer–vendor, production–distribution and inventory–distribution has been recognised as one of the key issues in SC problems (Thomas and Griffin, 1996).

A distribution supply chain (DSC) is a particular part of the SC, which has attracted considerable attention in the literature. Both academic researchers and industrial practitioners alike have expended much effort to manage the overall distribution system more efficiently through various coordination and cooperation strategies. The models for DSC coordination developed so far can be categorized into two main groups: (a) models that consider integrated DSCs in order to find joint optimal inventory policies that minimise the total cost of the DSC, and (b) models that propose some coordination mechanisms which help every member within a DSC to work together harmoniously.

One of the earliest models, developed by Schwarz (1973), considered a continuous review policy for a single-warehouse multi-retailer inventory system, and minimised the average system cost per unit time interval. Goyal (1977) suggested a joint economic lot size model with the objective being to minimise the total cost of a single supplier – single buyer system. Yang and Wee (2002) used a heuristic procedure to determine the optimal number of deliveries favoured by the buyers in such a way as to reduce the overall costs incurred by a single-vendor multi-buyer system. Lu (1995) developed a one-vendor multi-buyer integrated inventory model, where the vendor seeks to minimise total annual cost subject to the maximum costs which buyers are prepared to incur. Crowther (1964) proposed a quantity discount as a coordination mechanism and explained the rationale for offering quantity discounts. Monahan (1984) developed a coordination strategy in which discount is offered to buyers so as to induce them to order in the quantity that maximises the vendor's profit. In Viswanathan and Piplani (2001), the vendor specifies common replenishment periods and requires all buyers to replenish only at suggested time periods. As compensation, the vendor provides a price discount to entice the buyers to accept the common replenishment periods. A conclusion was made that the proposed coordination mechanism was beneficial only in the case when the order processing cost was larger than a given limit value.

In this paper, a single-warehouse, multi-retailer DSC is considered (see Fig. 1). It is supposed that customer demand is uncertain and is represented by discrete fuzzy sets. Retailers are supplied periodically from the warehouse and the warehouse is replenished periodically from an external source. All inventories in the DSC apply an order-up-to level replenishment policy. It is assumed that the DSC operates 'under one roof' in the sense that a single measure of performance of DSC control is defined; it is the total relevant cost per unit time interval, which includes order/set up cost, holding cost and shortage cost. The problem is to determine the review periods and order-up-to levels of all the inventories in the DSC which give a satisfactory small total cost of the DSC.

In the paper, the complex control problem of the DSC as a whole is decomposed into a number of simpler subproblems of controlling the retailers and the warehouse independently. The solutions obtained in such a way can be improved by coordination actions. An iterative coordination mechanism is developed which coordinates the retailers and the warehouse to get satisfactory control of the DSC as a whole. Coordination is

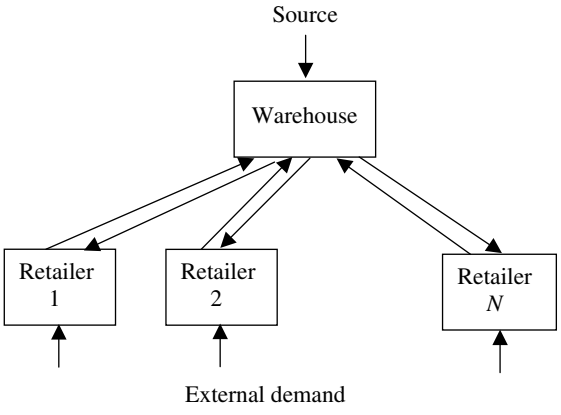

Fig. 1. One-warehouse, N-retailers DSC.