Decision Support Systems 54 (2012) 133–141

Contents lists available at SciVerse ScienceDirect

Decision Support Systems

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

A pragmatic stochastic decision model for supporting goods trans-shipments in a supply chain environment

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ARTICLE INFO

Article history:
Received 15 June 2011
Received in revised form 27 March 2012
Accepted 29 April 2012
Available online 7 May 2012

Keywords:
Lateral trans-shipments
Stochastic demand
Wholesaler operations
Inventory replenishment

ABSTRACT

This paper develops a set of decision rules to assist wholesalers to decide whether it is more cost effective to trans-ship urgent outstanding retailer orders from other wholesalers, very fast but at a higher purchase cost, or to order from their suppliers. By considering the uncertainty in demand, it models the total cost encountered by wholesalers, including purchasing, backordering and holding costs in the inventory replenishment process. Unlike previous models that are complex, highly mathematical and difficult to apply, this model provides a pragmatic and less complex method adoptable by ordinary logistics managers and requires input data that are accessible from the previous transaction records of an organization. The application of the proposed decision rules are illustrated considering different scenarios of wholesaler–supplier combinations.

1. Introduction

Ever increasing market competition forces wholesalers to be ever cost conscious and responsive to the changing needs of the market. A consequence is that wholesalers maintain a low inventory for the purpose of buffering in order to minimize the possible costs. However, the criticality of losing the sales due to stock outages with consequent possible lost profit and decreased customer satisfaction are no less important. To manage these potentials, wholesalers adopt a mix of urgent order lateral trans-shipments from other wholesalers at a higher cost, while at the same time backordering from their usual suppliers to meet the continuing stochastic retailer demands — this produces flexibility in the inventory system. Rules that assist wholesalers' decision making processes have practical importance for inventory management.

Supply chain management concepts that streamline the flow of goods have been the focus of research for a considerable time. Previous research into wholesaler inventory management has presented complex criteria drawn from diverse information sources that are problematic to adopt in real-world practice. There remains a need for simpler and more readily applicable rules for lateral trans-shipment decisions. In a multi-location setting under a continuous review (R,Q) ordering policy Axsäter [3] considers a decision rule for determining how many units should be trans-shipped, depending on the complete state of the system. The decision is optimal and can be repeatedly used as a heuristic. He puts a significant focus on future cost difference for a certain initial state and the highly mathematical analysis and probability assumptions may not be easily understood by ordinary managers. The models proposed by Evers [9] and Minner et al. [18] consider the case of lost sales rather than backordering under (R,Q) policies. Olsson [21] has considered an optimal (R,Q) ordering policy under complete pooling but due to the problem complexities the optimal solution is restricted to systems with only two locations. Chiu and Huang [6] considered a system with more than two echelons. However, they then restricted focus to a single location of each echelon. Our study considering a multi-location setting, develops decision rules for reactive lateral trans-shipments of urgent demands that cannot be satisfied from the stock on hand. The decision rules for determining whether it is more cost effective to trans-ship urgent orders or to backorder all outstanding orders from suppliers, the size of trans-shipment, the favorite wholesaler and the favorite supplier. Our approach handles the cost difference issue raised above using an alternative approach mainly based on predicted holding and backorder costs in different time periods. We find that the total cost function against the number of units trans-shipped has a linear relationship and presents a close estimation reflecting the cost variations, in real case, it is not a completely linear relation though. This new approach does not undervalue previous scholarly work, it builds on it by proposing a more pragmatic decision model for supply chain environment in wholesaler system. The model can be applied to a real context with multiple wholesalers, and multiple suppliers with variable lead times. It is less complex in calculations and the data requirement that can be fulfilled with previous transaction records data of the organization enables adoption of this model by an ordinary manager. The proposed approach is validated through the illustration of a practical application of the model in different scenarios.

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doi:10.1016/j.dss.2012.04.012

The next section reviews the relevant literature, Section 3 then goes on to describe and develop the proposed mathematical model for total costs, including purchasing costs, backordering costs and holding costs that are encountered in inventory replenishment by wholesalers and develops the decision rules for trans-shipments. Section 4 shows how these decision rules could be applied in practice and implications for management. Section 5 concludes with a discussion of the effectiveness and limitations of the decision model, with suggestions for further research.

2. Literature review

Thomas and Griffin [25] reviewed the literature addressing coordinated planning between two or more stages of the supply chain, placing particular emphasis on models that would lend themselves to a total supply chain model. Even if a given supply chain network is under a single ownership and centralized control, the integrative view of supply chain management obligates its managers to solve multiple stage inventory problems of a scale for which researchers have yet to identify consistently efficient solution procedures [7,8]. While Köchel et al. [13] stressed the importance of organizing shipments of resource units between the nodes of the logistics network; Weber [26] provided complementarity and substitutability in the shipment related problem. Burton and Banerjee [5] examined the cost effects of two lateral trans-shipment approaches in a two-echelon supply chain network and discovered that a lateral shipment approach was considerably superior to a policy of no such shipments, albeit at the expense of increased transportation activity. Minner and Silver [17] evaluated two simple extreme trans-shipment strategies and developed an analytical approach for estimating the approximate total expected costs. The majority of research papers that deal with goods replenishment issues assume a decision rule is applied when asking for a shipment from other wholesalers [7,14,19].

In organizations, high quality information that is accurate, timely, complete, and consistent and supported by the appropriate analytic tools is critical for managerial decision making [16]. For example, information technology has a significant role to play and appropriate evaluation and decision tools need to be provided for decisions on efficient product development. Taking into account the trend of customer demands and supply of goods for production purpose, Xu et al. [27] proposed a decision model to support product design and indicated the importance of a reliable forecast related to future demands in determining the design criteria. The data repositories, data warehousing and enterprise resource planning implementations improve the potential of decision support capabilities and decision support benefits [11]. In an enterprise value chain that comprises suppliers and customers, integrated information systems are required among the partners in order to deal with the market demand in a responsive way. The importance of a responsive decision model is that it is able to forecast the expected cost of the goods covering inventory and backorder cost [22]. Kimbrough, Wu and Zhong [12] investigated the deployment of artificial agents to manage the flow of goods across the supply chain, minimizing bull-whip effect which can be detrimental to the efficiency in performance of the whole logistics systems. However, it is mainly based on deterministic demand and fixed lead-time and the stochastic phenomenon has been less considered. Reliable information sharing and information quality play an important role in securing performance and achieving total lowest cost in the entire network [15]. Efficient and real-time information sharing can enhance the development of a responsive decision support model and decision models based on mathematical calculations have the potential to support managers in making critical decisions. This paper considered the impact of uncertainty in logistics systems and develops a decision support model for wholesale inventory managers in making lateral trans-shipment decisions in a pragmatically easy method.

Archibald et al. [1] proposed using a stochastic dynamic program to optimize the decision of whether to laterally trans-ship. A simulation with a heuristics approach was evaluated by Tagaras and Cohen [24]. According to Axsäter [2], when a wholesaler cannot supply goods to a retailer, lateral trans-shipment can take place and he proposed a method for optimizing the control policy of inventory replenishment. His model developed decision rules for lateral trans-shipments, aiming to evolve an integrated approach for supporting decisions regarding trans-shipment of goods. The underlying concept of the proposed decision rule by Axsäter ([3]: 1174) is difficult to visualize and adopt practically.

Numerical investigations for small networks show that the rule substantially outperforms the no pooling and complete pooling policies. We have looked at other similar models such as those models considered by Evers [9] and Minner et al. [19] but they examine the case of lost sales. Evers [9] restricts his analysis to two locations only and Minner et al. [19] propose a more flexible heuristic for a multi-location setting, but assume that demand has to be satisfied only just before the new replenishment order arrives. For (R,Q) ordering policies it is often difficult to optimize both ordering parameters and the trans-shipment policy. Also, the method is found to be conservative in its results. Considering an optimal (R,Q) ordering policy under complete pooling Olsson [21] analyzed the steady state nature of the system by assuming that the lead time for an order to arrive is exponentially distributed. However, due to the problem complexities the optimal solution is restricted to systems with only two locations. Chiu and Huang [6] considers a system with more than two echelons but they then restrict focus to a single location of each echelon and assume that unmet demand can be satisfied through trans-shipments if required. Grahovac and Chakravarty [10] propose the base stock level for the replenishments and created the K threshold for triggering trans-shipment requests. When the inventory level of a retailer drops below K, they first try to receive an emergency order with a shorter lead time from the upper echelon, and only use a lateral trans-shipment if this is not possible. However, evaluation of this K threshold approach shows that it is not that reliable and depends largely on whether they are identical and non-identical retailers.

In summary, the extant literature has to some extent dealt with inventory replenishment policies and decisions for wholesaler operations, however, there are limitations that hinder the application of most of them. Consequently, wholesaler inventory managers still use ad hoc methods to make decisions and there is still a need for a practical decision support system to support effective and informed decisions. This paper studies the sourcing decisions of a wholesaler in fulfilling retailer demand and provides a pragmatic approach deriving simple decision rules that are conveniently adoptable by wholesaler inventory management.

3. Model development

When a wholesaler maintains a limited inventory in order to be cost competitive, it constantly needs to externally source to fulfill retailer demand and avoid inventory shortage. We consider a context where there are a finite number of wholesalers operating autonomously in a local region. Following Axsäter [4], we assume that the retailer demand from these wholesalers follows a Compound Poisson distribution. The wholesalers usually replenish their stocks from suppliers, requiring a lead time in order to supply the goods. They may also opt to purchase laterally from other wholesalers in the same cost center which, for the purpose of the model, we assume, due to their close proximity, will provide an instant supply of goods. Such transactions among wholesalers are called lateral trans-shipments and they are more expensive than the usual supplier's prices.

We assume that all wholesalers apply a periodic review policy described by Rosenshine and Obee [23] to replenish from external