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Inventory management with variable lead-time dependent procurement cost☆

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Abstract

A reduction in the inventory replenishment lead-time allows reducing safety stock requirements and improving customer service. However, it might be accompanied by increased procurement costs because of premium charges imposed by suppliers, or higher transportation costs. This paper studies a single-stage variable lead-time inventory system with lead-time dependent procurement cost. Selection of the lead-time value represents finding the trade-off between benefits of lead-time reduction and increase in the procurement cost. A model for joint optimization of inventory and procurement costs is developed. Numerical studies are conducted to identify conditions under which lead-time reduction is favorable compared to procuring at the lowest cost.

Keywords: Inventory control; Variable lead-time; Sensitivity analysis

1. Introduction

1.1. Problem area

Demand uncertainty coupled with inventory replenishment lead-time creates the inventory carrying risk. Lead-time reduction and application of risk reducing inventory management policies have been shown to improve efficiency in managing inventory. Tersine and Hummingbird [1], Jayaram et al. [2] and Disney and Towill [3] have demonstrated the positive impact of physical lead-time reduction. The lead-time reduction allows using more accurate demand information in making inventory replenishment decisions, which in turn reduces safety stock requirements and improves the customer service level. However, the lead-time reduction may be associated with some additional risks and costs [4]. For instance, a shorter lead-time may lead to higher purchasing costs and unavailability of supplies due to the limited supplier capacity. Burnetas and Gilbert [5] provide examples from travel industry, where late orders are charged a premium price. They also mention premium transportation charges for short lead-time orders as a source of increasing purchasing costs in other industries. Cachon [6] has discussed examples from the retail industry. Retailers placing late orders are not eligible for discounts and face the possibility of insufficient supplies because suppliers give priority to early orders. Das and Abdel-Malek [7] report that suppliers accept short lead-time orders at a higher unit price because of

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their disruptive impact on suppliers' operations. These observations lead to the problem of finding the trade-off between lead-time reduction and additional procurement costs. The trade-off between purchasing cost and delivery lead-time from the manufacturing point is discussed by Elhafsi [8] and Slotnick and Sobel [9] among others. These authors show that manufacturers are interested in providing flexible pricing in response to more attractive delivery time conditions.

1.2. Literature review

Ouyang and Wu [10] and Lan et al. [11] consider a continuous review re-order point policy with variable lead-time. Costs associated with lead-time reduction are represented by the lead-time crashing cost, which is independent of the order size. They consider the random demand. The above-mentioned papers focus on computation of the optimal policies. Hariga and Ben-Daya [12] propose similar variable lead-time periodic review and base stock policies. Similarly, lead-time crashing has been investigated in two stage systems involving buyer and supplier [13]. The integrated inventory model with controllable lead-time is used in demonstrating that the buyer–suppliers system as a whole benefits from the lead-time reduction while gains for individual partners are not distributed uniformly.

Burnetas and Gilbert [5] have analyzed the trade-off between higher procurement costs against the benefit of making ordering decisions using better demand related information. The authors develop an optimal ordering policy for a short life-cycle product. The procurement cost increases along the product life cycle, while a parameter of the demand process (modeled as a Bernoulli process) is continuously updated as more accurate information becomes available. The authors demonstrate that ordering pattern depends upon characteristics of the procurement cost function.

There have been numerous investigations on early commitment policies, which are closely related to variable lead-time inventory policies in the supply chain environment (e.g., [6,14]). Under these policies, a supplier offers a discount, if an internal supply chain customer places orders in advance. The customer increases its inventory carrying risk by committing early (i.e. using the longer lead-time) or loses an opportunity to procure at the lower cost. The primary objective of early commitment policies is finding a discount level optimizing the supply chain performance.

Early commitment policies under evolving forecasting accuracy are investigated by Ferguson [15]. He analyzes negotiation of an exchange price between a supplier and a manufacturer depending upon the supply chain power structure and the frame of commitment. Information about the external demand has two levels of accuracy (not necessarily no information and completely accurate information). This level of accuracy depends upon a choice between using either early commitment or delayed commitment. In the case of balance of power in the supply chain and, if accuracy of demand information improves quickly, the delayed commitment is preferable. However, if improvement of forecasting accuracy is small, the early commitment is preferable. The author also provides an excellent summary of literature related to early commitment. His main observations are that existing models usually consider short planning horizons, two levels of information accuracy or two procurement cost levels.

Buyer–supplier interactions are also analyzed using dual sourcing models (for instance, [16–18]), where the buyer allocates orders between suppliers with different characteristics including lead-time. The dual sourcing models are directed towards minimizing risk of suppliers' non-performance while this paper focuses on setting the supply lead-time in the long-term collaboration framework.

1.3. Contribution

In this paper, a single stage, long horizon, reorder point inventory system is studied; wherein the procurement cost increases with decreasing lead-time. An instance of such inventory problems is routine procurement of a product for which there are multiple modes of transportation at different cost levels. The objective of this paper is to find the lead-time value representing the trade-off between benefits of lead-time reduction and increase in the procurement cost. The lead-time reduction is expected to reduce the inventory cost because of more accurate demand information and lower safety stock requirements. Yet, it increases the procurement cost because the supplier sets a higher price for short lead-time orders, limited supplies force to seek more costly alternative products or a more expensive shipping mode is used to ensure the shorter lead-time. In order to describe this trade-off, a model for joint optimization of inventory and procurement costs with respect to the lead-time is developed. It is based on the traditional continuous review re-order point model. Demand is modeled as an autoregressive process. This model differs from the traditional model by inclusion of the lead-time dependent procurement cost. A procurement cost function is used to describe the dependence of the procurement cost upon the lead-time.