The Impacts of the Number of Suppliers on Inventory Management in a Make-to-order Manufacturer

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We consider a supply chain consisting of a make-to-order manufacturer and \(N\) component suppliers and study the impacts of the number of suppliers on component inventory management. The manufacturer has full information and continuously observes the state of both component inventory level and customer backorders. Based on this information, the manufacturer determines whether or not to place a component purchasing order to a supplier among \(N\) suppliers even though some orders are in process by other suppliers. The goal of this paper is to numerically identify the manufacturer’s purchasing policy which minimizes the total supply chain cost and the best choice of \(N\). Our model contributes to the current literature in that the problem of simultaneously considering multiple outstanding orders and incorporating order setup cost into the model has not been covered yet. From numerical experiment, we investigate how much the policy with \(N\) suppliers can contribute to reducing the supply cost compared to the policy with a single supplier.

**Keyword:** multiple suppliers, multiple outstanding orders, make-to-order, supply chain management, setup cost, purchasing

1. Introduction

In this paper, we consider a supply chain consisting of a customized end item manufacturer and \(N\) component suppliers. The manufacturer faces customer orders from the market with the option to accept or reject and processes accepted customer orders using a single type of component. The manufacturer has full information and continuously observes the state of both component inventory level and customer backorder level, and the number of purchasing orders which are in process by suppliers. Based on this information, the manufacturer determines whether or not to place a purchasing order to a supplier that is not processing the manufacturer’s purchasing order. In the context of inventory control, there can be multiple outstanding orders, since there are \(N\) suppliers. The goal of this paper is to identify the manufacturer’s purchasing policy which minimizes the supply chain cost (consisting of customer order rejection, customer backorder, order setup, and component inventory holding), to find the best choice of \(N\), and to examine the beneficial effects of having \(N\)

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suppliers rather than a single supplier.

The model presented in this paper has the operating feature similar to a make-to-order inventory-production (MTOPI) system in the literature. MTOPI system is concerned with a supply chain that is made up of a production facility and a raw material supplier. The production facility manufactures products on a make-to-order basis to meet customer demands using raw materials purchased from a supplier. Since the production facility carries no finished goods inventory, thus, inventory control is necessary only for raw materials replenishment. The unique aspect of MTOPI system compared to other inventory systems is that there is a delay between the arrival of a demand and the time raw materials are actually needed to produce a product for that demand. This is a result of explicitly modeling the production process as a queue. Consequently, inventory control in the production facility will depend on both the inventory level and the number of customer backorders, instead of just the inventory level (or inventory position) as in classical inventory control models (He et al., 2002).

He and Jewkes (2000) studied order-up-to-purchasing policies when inventory is empty, and showed that the order size is the economic order quantity. In He and Jewkes (2000), lead time is not considered. He et al. (2002) considered a system with Poisson arrivals and exponential lead times, and studied a policy with varying order quantity according to the backorder level when the inventory becomes empty. The papers of jointly considering admission control and purchasing policy are very limited in the MTOPI literature. Berman and Kim (1999) characterized an optimal purchasing policy when admission control on customer order is based on a threshold and lead time is zero. Kim (2005) extended to the case with an exponential lead time and identified an optimal purchasing policy as a dynamic reorder point which is a function of the size of customer backorders. However, all MTOPI references in the above assume that at most one purchasing order is outstanding.

Since customer order can be rejected and inventory is reviewed continuously, our model has some features similar to classical continuous review inventory models with lost sales. However, references in this stream have the constraint that at most one replenishment order may be outstanding at any time is almost universally applied. Archibald (1981) presented optimal and approximate solution procedures for an \((s, S)\) model with compound Poisson demand and a fixed lead time. Buchanan and Love (1985) derived a solution procedure for the \((r, Q)\) model with Poisson demand and an Erlang-distributed lead time. Beckmann and Srinivasan (1987) analysed the Poisson demand \((s, S)\) model with exponential lead time as a queueing model. Mohabbi and Posner (1998) considered the behaviour of \((r, Q)\) policies for compound Poisson demand models with Erlang or hyper-exponential lead time distributions. Hill and Johansen (2006) explored the behaviour of optimal inventory control policies under both continuous and periodic review.

In classical periodic review inventory models with lost sales, some references analyzed the case that more than one order may be outstanding at anytime. Morton (1971), Nahmias (1979) and, Van Donselaar et al. (1996) developed myopic heuristic solution procedures under a fixed lead time which is an integral number of review periods and a negligible set-up cost. When demand is discrete, Johansen (2001) explores optimal and near optimal base stock policies with negligible set-up costs and constant lead times.

In the context of already-published work in this area, the contribution of this paper can be established in the following two essential aspects. First, compared to MTOPI models and classical continuous review inventory models with lost sales, we study the issue of inventory management with multiple outstanding orders rather than at most single outstanding order. Under the mechanism of multiple outstanding orders, there exist multiple reorder points which depend on both the inventory level and the customer backorder level. In contrast, classical continuous review inventory models with lost sales have a single reorder point depending on just the inventory level. Second, we explicitly incorporate purchasing setup cost into the model and examine its impact on the optimal purchasing policy. Even though some classical periodic review inventory models with lost sales consider multiple outstanding orders, the setup cost is not included into the models.

The rest of the paper is organized as follows. We present a problem description in the next section. In Section 3, we provide a formulation of our model. Section 4 presents a numerical procedure that finds the optimal cost and characterizes the optimal purchasing policy based on numerical investigation. Section 5 discusses the results of numerical experiment and the last section states conclusions.