A Coordinated Supply Chain Model for Imperfect Items under Power Function Lead Time Crashing Cost and Investment with a Service Level Constraint

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ABSTRACT

This paper presents a coordinated vendor-buyer supply chain model in two stages with imperfect quality items, lead time and ordering cost reduction, and service level constraint. It is assumed that each arrival lot received by the buyer contains a percentage of imperfect quality items which follows a uniform distribution. A 100% screening process for detecting the defective items is conducted. Lead time crashing cost and investment for ordering cost reduction follow power function distribution. The shortage during the lead time is permitted and backordered partially for the buyer. However, the level of shortage is limited by service level constraint policy. The optimal order quantity, reorder point, lead time, ordering cost, and the number of delivery are determined by the Lagrange method such that joint total cost of the system is minimized and the service level constraint is satisfied. An iterative procedure is developed to determine the optimal solution and a numerical example is presented to illustrate the result of the proposed model.

KEYWORDS
Crashing Cost, Imperfect Items, Investment, Power Function, Supply Chain Model

INTRODUCTION

The coordinated vendor-buyer model on supply chain system received a lot of attention in recent years. As global markets became more competitive, critical information needs to be shared along the supply chain in order to satisfy customer demands. Close cooperation between the vendor and the buyer is necessary to find a more profitable joint production and inventory policy such that the joint total relevant cost for all stages could be optimized. Therefore, in today’s competitive business world, supply chain coordination is a key component for enhancing its responsiveness and profitability. Goyal (1976) first introduced the idea of optimizing the joint total cost in a single-vendor, single-buyer model. In this model, the demand for the item was assumed followed a uniform distribution and shortages were not permitted. Banerjee (1986) developed the Goyal’s (1976) model by assuming that a vendor has a finite production rate and considered a lot-for-lot policy. Goyal (1988) extended Banerjee’s (1986) model by relaxing the lot-for-lot policy to generalize the problem. A review of

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related literature was done by Goyal and Gupta (1989). Later, other related vendor-buyer coordination problems are investigated by academicians and practitioners, for example in Hill (1999), Goyal and Nebebe (2000), Wu et al. (2007), Mahdavi et al. (2008), Zavanella and Zanoni (2009), Hou et al. (2009), Nam et al. (2010), and Glock (2011). Further, a comprehensive review of vendor-buyer coordination problem which is referred to as the joint economic lot sizing (JELS) was done by Glock (2012a). Many earlier studies dealing with the coordinated (integrated) inventory-production model assumed that the production processes are perfect. Several researchers have demonstrated that defective items may occur caused by deterioration on production process. For example, Lin and Srivastava (2015) developed a two-warehouse inventory model with quantity discounts and imperfect production process. Yadav et al. (2015) studied EOQ (economic order quantity) model for imperfect items under the effect of inflation and learning with selling price dependent demand. Later, Lai et al. (2015) proposed two integrated optimization models of two-echelon for imperfect production system under quality competition environment.

Lead time is one of essential factors in any inventory management system. Lead time is the time between placing of an order and the receipt of goods ordered. It is generally composed of many controllable components such as order preparation, order transit, supplier lead time, delivery time, and setup time (see Glock, 2012b). In fact, under practical situations, lead time can be reduced at an added crashing cost. For example, the production process can be restructured to reduce setup time and production equipment can be modified to speed up the production process (see Glock, 2012a). According to Hsu and Lee (2009), crashing cost could be expenditure on equipment improvement, order expedite, special shipping and handling, or information technology. Reducing the lead time leads to various advantages such as reduced loss due to stock-out, reduced safety stock levels, and improve the customer level in order to select the most cost effective inventory model. Many researchers have developed inventory models incorporating lead time as negotiable. Liao and Shyu (1991) first considered lead time as a unique decision variable on an inventory model. Ben-Daya and Raouf (1994) extended Liao and Shyu’s (1991) model by including both order quantity and lead time as decision variables. Several papers (e.g., Moon and Choi, 1998; Ouyang et al., 1999; and Ouyang and Chuang, 2000) then generalized Ben-Daya and Raouf’s (1994) model by considering reorder point as another decision variable. Later, several authors (e.g., Ho, 2009; Glock, 2012b; Hoque, 2013) have presented various integrated vendor-buyer production-inventory models with controllable lead time. In the recent year, Vijayashree and Uthayakumar (2014) developed a vendor-purchaser integrated inventory model with the lead time and setup reduction. Mandal and Giri (2015) presented a single-vendor multi-buyer integrated inventory model with controllable lead time and quality improvement through reduction in defective items. Most of the above literatures considering controllable lead time assumed that lead time can be decomposed into several components with minimum and normal duration on each component. It is further assumed that each of these components can be crashed by paying some extra amount of money, each having a different piecewise linear crashing cost function for lead time reduction. However, it is very difficult to separate the lead time into components due to the increasing complexity of real life inventory situations. It needs a complete knowledge and concrete information regarding the components. Thus, Ma and Qiu (2012) developed a continuous review inventory model with power function lead time crashing cost. Moon et al. (2014) described the lead time crashing cost by adopted negative exponential function and proposed min-max distribution free continuous-review model. Besides, Vijayashree and Uthayakumar (2015) proposed two-echelon supply chain inventory model with controllable lead time. In the proposed model, the lead-time-dependent cost was also assumed to be a nonlinear function in the length of lead time.

In modern production management, ordering cost reduction is one of keys to business success. Many studies have focused on the benefit from ordering cost reduction in the inventory system. The ordering cost reduction can be attained by capital investment, such as procedural change, worker training and specialized equipment acquisition. It has been a trend by reducing ordering cost, the competitive edge in business can be increased. The impact of capital investment in reducing ordering
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