An Integrated Production-Supply System with Uncertain Demand, Nonlinear Lead Time and Allowable Shortages

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ABSTRACT

A supply chain consisting of a single-supplier and a single-buyer is modeled and compared in two different modes: non-coordinated and coordinated. The model is established based on the fact that the demand is uncertain and shortages are considered as lost sales. The buyer's order lead time is a nonlinear function of the buyer's order size and the number of shipments from the supplier. Quantity discount offers are used as a tool to achieve the coordination between both parties. In non-coordinated mode the total annual profits of both parties are maximized using partial derivative and a lower and an upper bound are obtained for the supplier's wholesale price. For the coordinated mode total annual profit of the whole supply chain system is maximized using partial derivatives and coordination may increase the total annual profit of the whole system is mathematically proved. In order to encourage the both parties to coordinate, a fair profit-sharing method is proposed based on the total costs that each party incurs. The supplier's wholesale price is evaluated such that coordination seems appealing and profitable for both parties.

Keywords: Allowable Shortages, Production-Supply System, Supplier-Buyer Coordination, Supply Chain, Uncertain Demand Nonlinear Variable Lead Time

INTRODUCTION

In today’s competitive market, companies are realizing that efficient inventory management across the entire supply chain can be achieved through high coordination and cooperation among the parties of a supply chain. Recent advances in information technology allow all the parties to communicate much faster and cheaper than before. This facilitates the coordination efficiently and effectively. It is only through high coordination that the parties
of a supply chain can make joint decisions to increase their profits.

When the Japanese first introduced the Just-in-Time (JIT) production system, researchers got interested in the idea of coordination. If the supplier and the buyer mutually cooperate, they can develop long-term relationships, solve problems together, make joint decisions, and find a way to share the savings. The advantages of the coordinated inventory models include lead time reduction, technology sharing, lower costs, lower inventory levels and improved quality and customer service. Banerjee (1986) proposes a single-vendor single-buyer deterministic inventory model where he assumes a lot-for-lot policy. Goyal (1988) develops a model in which Banerjee’s lot-for-lot assumption is relaxed. Since then lots of papers have been written in this area all showing that the integration of the parties results in lower costs and higher overall profits.

Finding a proper mechanism to coordinate is one of the main hassles of a supply chain manager. Quantity discount offers can be mentioned as one way to do so. The supplier can offer discounts to the buyer in either all-unit or incremental form. Weng (1995a) shows that if the supplier has complete knowledge of the buyer’s information, the optimal policy in benefiting both the supplier and buyer is independent from the type of quantity discounts. Therefore, the supplier should be more concerned with finding an optimal discount-price rather than selecting the type of quantity discount. Monahan (1986) studies a deterministic non-coordinated single-supplier model with infinite production rate and lot-for-lot assumption. He shows that the supplier can increase his profit by offering an all-unit discount to a buyer. As the managers got acquainted with the idea of coordination in 1990s, they were more eager to utilize quantity discounts as a tool to achieve coordination. Weng (1995b) develops a single-supplier single-buyer supply chain where demand is a deterministic function of the selling price. The main focus of his paper is to find a method to divide the increased profit resulted from coordination between both parties.


Whenever demand is probabilistic, the role of lead times becomes even more critical (Yang & Pan, 2004). When the lead time is shorter the buyer’s safety stock level in inventory is lower which in turn results in lower inventory levels, less spoilage of the perishable product, and less storage space, but more susceptible to shortage. In most of the previous studies the lead time is assumed to be constant for the sake of simplification.

Kim and Benton (1995) assume a linear relationship between the lead time and lot size. Later, Hariga (1999) improves Kim and Benton’s model such that it is more appropriate for the JIT environment with smaller lot sizes. Ben-Daya and Hariga (2004) propose an integrated single-vendor single-buyer model where the demand is uncertain and they assume that the lead time is a linear function of the order size. Also, they incorporate the effect of nonproductive time by adding a fixed value to the lead time. Li and Liu (2005) develop a single-supplier single-buyer supply chain where the demand is probabilistic and lead time is constant. In their paper, they prove that when the parties are coordinated the overall profit is larger than the time that the parties are operating individually. They also propose a method to share the savings.

This paper is a direct extension of Li and Liu (2005) such that the constant lead time assumption is relaxed by considering a variable
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