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Supply chain integrated inventory model with present value and dependent crashing cost is polynomial

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ABSTRACT

Due to today's highly competitive environment, both reducing lead time and the associated inventory cost are critically important issues in supply chain. And, the consideration of time value effect is lacked in most previous researches. However, the effect of inflation is too critical to ignore. Therefore, we develop an integrated inventory model with crashing cost which was determined by the length of lead time is polynomial to recover the real inventory problems. The objective of this research is to minimize present value of the joint expected total cost over infinite time horizon. Then, we provide a solution algorithm to determine the optimal order quantity, the length of lead time and the number of lots which are delivered from the vendor to the buyer in the solution procedure. Numerical example is provided here to illustrate the solution procedure.

1. Introduction

Two of the most important time-based advantages are quickly satisfying the customer demands and reducing total cost effectively. The vendor and the buyer find their own optimal economic-lot-size, respectively, in traditional inventory management systems. As a result, the traditional inventory management system may not result in an optimal policy for whole supply chain. Therefore, an integrated inventory approach may help to determine the optimal order quantity and shipment policy.

Wikner [1] indicated that crashing cannot be classified as a lead-time reduction as a long-term strategic time compression program. However, small lot size, postponement and various customized items are often applied as a JIT strategy to confront the fierce competition. The short life cycle is observably common in current situation, and we suppose that will be a basic assumption in this research [1]. We consider that the type of crashing is appropriately applied with agile systems in most short-term management decisions.

The market nowadays is fiercely competitive; the length of lead time directly affects the customer service level, inventory investment in safety stock, and the competitive abilities of a business. Hence, the objective of this research is to find out an optimal inventory strategy that can minimize the present value of the joint expected total cost over infinite time horizon.

2. Literature review

2.1. Integrated inventory model

Goyal [2] first advocated a notion of an integrated inventory model for a single supplier–single customer problem. He concluded that the optimal order time interval and production cycle time which can be obtained by supposing that the supplier's production cycle time is an integer multiple of the customer's order time interval. Banerjee [3] generated Goyal's joint economic lot-size model [2] by assuming that a vendor has a finite production rate and produces to order for a buyer on a lot-for-lot basis. Later, Goyal [4] extended Banerjee's model [3] by relaxing the lot-for-lot policy and supposed that

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the vendor's economic production quantity should be an integer multiple of the buyer's purchase quantity that provided a lower joint total relevant cost. A review of related literature was proved by Goyal and Gupta [5].

Based on the equal sized shipments to the buyer, Lu [6] presented a heuristic approach for the one-vendor multi-buyer integrated inventory case. He relaxed the assumption of Goyal [4] about completing a batch before starting shipments and investigated a model that allows shipments to occur during production. Hill [7] considered a more general class of policy for determining successive shipments sizes to the buyer. The results were obtained by Hill [7], which provided a lower total cost as compared with Lu [6] and Goyal [8]. Pan and Yang [9] presented an integrated vendor–buyer inventory model with controllable lead time in a JIT environment. They considered that lead time is an important element which directly affects the customer service level, safety stock and competitiveness in any inventory control system. Their results were shown that their modeling could provide a lower total cost and shorter lead time contrasted with the model of Banerjee [3] and Goyal [4]. Shi and Su [10] suggested an integrated inventory model from the retailer's perspective only, and thus ignored the fact that the manufacturer might have no incentive to accept returns. Hill and Omar [11] contemplated a "vendor" which supplies a product to a 'buyer' in a supply chain.

2.2. Lead time

The assumption in most inventory models is that lead time is constant or a random variable, which is not a controllable subject. Actually, lead time can be reduced by an additional crashing cost, so as to improve customer service level, and reduce inventory in safety stocks; in other words, it is controllable. Over the last few decades, there has been a wealth of research considering with variable lead time. In fact, Tersine [12] proposed that the crashing of lead time usually consists of the following components: order preparation, order transit, supplier lead time, delivery time and set-up time. In recent years, how to shorten lead time is one of the key factors to the success of JIT production.

Liao and Shyu [13] presented a probabilistic inventory model in which the lead time is a decision variable. Additionally, it is assumed that the demand follows normal distribution and the lead time consists of n components has a different cost for lead-time reduction. Later, Ben-Daya and Raouf [14] extended Liao and Shyu's [13] model by considering both the lead time and the order quantity as decision variables. Ouyang, Yeh and Wu [15] extended Ben-Daya and Raouf's [14] model by adding the stock-out cost and assumed that the shortages are allowed. Ouyang, Chen and Chang [16] further investigated the impact of ordering cost reduction on the modified continuous review inventory systems, which involve variable lead time with a mixture of backorders and lost sales; and Chang assumed that the lead time demand follows as a normal distribution. [16].

In many practical situations, lead time could be shortened by paying an additional crashing cost. Pan, Lo and Hsiao [17] considered a continuous review inventory system in which the shortage is allowed and the total amount of stock-out is a combination of backorder and lost sale. Subsequently, Pan and Hsiao [18] investigated another integrated inventory system in which both lead time and backordering are negotiable. Srinivas and Rao [19] developed an inventory model where the replenishment lead time is assumed to be dependent. These articles focus on shortening the lead time as mush as possible, so as to lower the total cost.

2.3. Time value modeling

Most inventory systems do not consider time value effects. The impacts of economic cycles such as inflation or deflation cause variation in the purchasing power of money. Therefore, time value is an indispensable element (Yang et al., [20]). A recent surge of research on time value of money has given more flexible policies for decision makers in real production situation. In Ding and Grubbström's [21] article, an approach in terms of a present value principle taking all payments into consideration is applied in order to derive the optimal solution. By applying the present value measure, the opportunity cost for the initial inventory build-up is incorporated automatically. Wee and Law [22] applied the discounted cash flows (DCF) approach for problem analysis. In their article, a heuristic approach is presented to derive the near optimal replenishment and pricing policy that tries to maximize the total net present-value profit. Then, Yang et al. [20] provided a mixed inventory model, in which the distribution of lead time demand is normal, to consider the time value. Recently, Dey, Mondal and Maiti [23] have extended the idea of Kar [24] for a deteriorating item with time dependent demand (which is increasing at decreasing rate) and interval valued lead time over finite time horizon. Inflation rate and time value of money are taken into account.

3. Notations and assumptions

The following notations and assumptions are used throughout the integrated vendor–buyer inventory model.
Notations:
D: average demand per year,
P: production rate, and $P > D$,
Q: order quantity of the purchaser,
A: purchaser's ordering cost per order,
S: vendor's set-up cost per set-up,
L: length of lead time,
C_V: unit production cost paid by the vendor,