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Models of Joint Economic Lot-sizing Problem with Time-based Temporary Price Discounts

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ABSTRACT

In this research we develop mathematical models of Joint Economic Lot-sizing Problem (JELP) in a situation when a supplier offers time-based temporary price discounts to a buyer during a sale period. To respond this, the buyer places a special order with higher quantity. In literature, it has been assumed that the buyer tends to place the special order at the end of the sale period. We relax this assumption by considering the time when the buyer places the special order during the sale period, i.e., the sooner the special order took place, the higher discount received. In our proposed models called Joint Economic Lot-sizing Problem with Time-based Temporary Price Discounts (JELPTPD) we devide the sale period into k phases. The buyer must place the special order in one of these phases. The highest discount will be given when the special order is placed at the first phase while the lowest one will be given when it is placed at the *k*th phase. There are two cases discussed. The first case is when the sale period is uniformly divided while the second case is when the sale period is proportionally divided following some rules. Our numerical experiments showed the behavior of the buyer to respond the temporary price discount offers. In major experiments, the buyer shifted the decision on placing the special order in the earlier phases instead of the end of the sale period.

1. Introduction

Nowadays's fast-moving economy create new technologies, faster production cycle as well as more demanding customers. This business environment has forced companies to increase the competiveness, not only through integrating various functions and increasing the operational efficiency within their internal organization but also making collaboration and coordination with their customers and suppliers. Some iniative strategies have been made to achieve this purpose. One of them is to manage efficient inventories across the supply chain through better coordination between the supplier and the buyer. Both parties need to seek Economic Order Quantity (EOQ) based on their integrated total cost function, rather than each party's individual cost functions.

In literature, such a problem is generally called Joint Economic Lot-sizing Problem (JELP). This problem have been discussed intensively in the literature from Goyal (1977) to the recent papers such as Zhou and Wang (2007). Recently, Ben-Daya et al. (2008) made a comprehensive review on JELP. These authors elaborated some extensions to the original JELP model such as setup cost reduction, variable production cost, quality and process failure issues, stochastic demand, consideration of a lead time between buyer and supplier, multiple buyers case, transportation cost and capacity and three-layer systems.

In a different perspective some papers in the literature discussed about EOQ with temporary price discounts (EOQTPD). In this problem, suppliers offer temporary discounts in the price charged to the buyer during a period of trade promotion so called sale period. The objective is to increase cash flow and decrease inventories of items during a cycle time. In order to take benefits of the discounted price, the buyer must order a higher quantity. The buyer then responds by ordering a special (higher) quantity at this sale period. Because the sale period might not coincide with usual replenishment time, it will increase holding and ordering costs. As a consequence, the discounted price obtained by the buyer must be higher than these costs of this additional quantity. Similar to JELP, this collaborative strategy can be a good medium for efficacy inventory coordination between both parties. It will result in lowering inventory costs, improving asset utilization, and reducing effects on order variability.

Intensive discussions on EOQTPD have been available in the literature in the last decade. Some of them are Abad (2003, 2006) and Sarker and Kindi (2006). Abad (2003) explored two cases on EOQTPD in terms of retailing business; the case of when the discount is only applicable to only units resold during the sale period and the case of when the discount is applicable to all units

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purchased during the sale period. In the latter case, which will be the focus of this paper, the buyer (in this case it is a retailer) usually purchase a large lot not only for reselling at the sale period but also for forward buying purposes. Some portion of the lot purchased will be carried forward for selling to consumers at the regular price after the sale period ends. The retailer is free to purchase in larger lot size during the sale period. Due to the inventory costs burdened, the retailer (buyer) tends to buy larger lot size at the end of the sale period. This phenomenon have also been discussed in the other two EOQTPD papers.

In this paper, we enhance the case of EOQTPD, where the supplier offers temporary price discounts to buyer which depends on the time making ordered during the sale period, i.e., the sooner the order took place, the higher the discount. It is noted that, similar to the problem in Abad (2003), we also consider the situation of this case is in retailing business, where the buyer is a retailer.

In our proposed model, we devide the sale period into k phases, as shown in Fig. 1. In each phase, the supplier offers different discount values. The objective is to entice the buyer to place orders as soon as possible, not until the end of the sale period. The highest price discount will be given if the buyer will place the special order a the first phase, while the lowest discount will be given if the special order placed at the kth phase.

We will discuss the proposed model in the framework of JELP. We will explore the model from both side views. We name the proposed model JELP with Time-based Temporary Price Discounts (JELPTPD). To our best knowledge, such a discussion have not yet been explored either in the JELP literature or in the EOQTPD literature.

In this paper, we propose two cases of JELPTPD. In case 1, we assume that sale period is divided into k phases uniformly. Thus the duration of each phase is identical. In case 2 the sale period is divided proportionally into k phases following some rules (i.e. geometric series). The first phase has the shortest duration while the kth phase has the longest duration. Using these two cases, we aim to analyze the behavior of the problem through some numerical experiments.

The organization of this paper is as follow. In Section 2, we review some papers related to JELP and EOQTPD. After describing the formulation of the reference models, we formulate the models of JELPTPD of each case in Section 3. In this chapter we also discuss the algorithms used. Section 4, we conduct numerical experiments as well as a sensitivity analysis in order to elaborate the behavior of the model. We finally make a conclusion of this research in Section 5.

2. Literature review

The initial work of JELP was done by Goyal (1977). Some assumptions were used such as infinite production rate and lot-for-lot policy shipments. The author also assumed that each production sent to the buyer is indivisible. This implies that all production lot should be completed before starting shipment. Actually, the term of JELP was firstly introduced in Banerjee (1986). In this paper, the author modified the model of Goyal (1977) through relaxing the assumption of infinite production rate. He combined the Economic Order Quantity (EOQ) model of the supplier and buyer. He also showed that this JELP model has minimum cost considering both the buyer and the supplier. The conclusion was obtained after making a comparison between the solutions of the independent model and those of the joint model. Goyal (1988) extended Banerjee's JELP model by relaxing the lot-for-lot assumption because it is impractical in real life. The author developed a model that the supplier can possibily supply in a multiple integer of the buyer's order quantity.

Moreover, Huang (2002) considered an integrated vendor-buyer cooperative inventory model for items with imperfect quality under equal-shipment policy. Pujawan and Kingsman (2002) developed a model that considers a situation where there are multiple deliveries for one order. In this case, an order could be splitted into a number of production runs. Some authors proposed geometric increasing shipment policies rather than equal-shipment sizes such as Goyal (2000) where the growing factor equals to the ratio of production rate to the demand rate.

Furthermore, some papers attempted to relax assumptions used in the previous literature. Lu (1995) relaxed the assumption of completing production lot before starting shipments while Hill (1999) relaxed any shipment policy assumptions. In this latter paper, the author suggested an exact iterative algorithm to find the optimal solution. Hill and Omar (2006) and Zhou and Wang (2007) modeled JELP by relaxing assumptions regarding holding costs. There have been many extensions of the basic JELP. Recently, Ben-Daya et al. (2008) made a comprehensive review on JELP and its extensions. The authors concluded that the extension the JELP had been conducted in two main ways: the first is to relaxing assumptions which are no realistic such as deterministic and constant demand and perfect product quality and the second is to extend the JELP to deal with more complex problems such as multi buyers and more than two echelon supply chains. Table 1 shows the position of the proposed model among previous papers discussed here.

3. Model formulation

3.1. Notations

We use notations troughout this paper as follows:

D	annual demand rate (units/year)
i	holding cost fraction
δ_n	temporary price discount during the nth phase ($/unit), where $n=1, 2, \ldots, k$
A	ordering cost ($/order)
C_p	production cost ($/unit)
C	purchasing cost ($/unit)
k	number of phases over the sale period
Q	regular economic order quantity (units/cycle)
Qs_n	special order quantity on discount placed in the nth phase (units/order)
q_n	remnant on-hand inventory on discount in the nth phase (units)
T	cycle time for EOQ
T_s	cycle time for special order quantity
T_{sale}	sale period

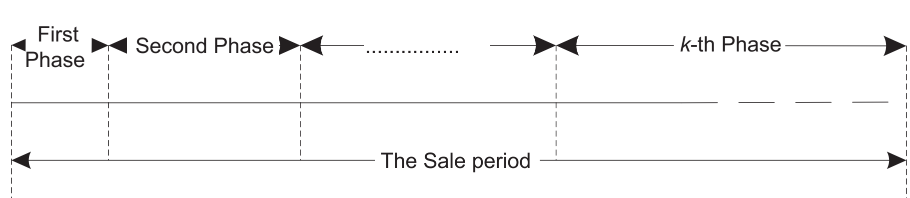

Fig. 1. The sale period devided into k-phases.