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Integrated vendor–buyer supply chain model with vendor's setup cost reduction

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ABSTRACT

This paper deals with an integrated vendor–buyer supply chain model. Two models are constructed based on the probability distribution of the lead time demand. The lead time demand follows a normal distribution in the first model. In the second model, we consider the distribution free approach for the lead time demand. For the second model, only mean and standard deviation are known. The aim of our model is to reduce the total system cost by considering the setup cost reduction of the vendor. Finally, some numerical examples are presented to illustrate the models.

1. Introduction

Supply chain management (SCM) is a collaboration among suppliers, manufacturers, retailers, and customers. The supply chain model is used to minimize the total cost or to maximize the total profit throughout the network under the condition that demands of each facilities have to be met. Thus, the integrated inventory control policy is a matter of concern (for instances [1–4]). Goyal [5] developed the first research work on the integrated vendor–buyer problem. Banerjee [6] extended Goyal's [5] model with an assumption on the number of lot size. Goyal [7] extended Banerjee's [6] model by assuming the manufacturing quantity of the vendor as an integer multiple of the buyer's ordering quantity. Huang [8] developed an integrated vendor–buyer model in an imperfect production process. Cárdenas-Barrón [9] made a correction on an inventory model based on concurrent pricing and lot sizing for make-to-order contract production. Cárdenas-Barrón et al. [10] used the arithmetic–geometric inequality to solve a vendor–buyer integrated inventory model with a closed form solution. Teng et al. [11] considered a vendor–buyer inventory model with a closed-form optimal solution.

Controlling the lead time plays an important role for any inventory model. Tersine [12] introduced the lead time as a partition of five components as the supplier's lead time, order preparation, order transit, delivery time, and the setup time. Liao and Shyu [13] considered the lead time as a unique decision variable in their inventory model. Ben-Daya and Raouf [14] explained both the ordering quantity and the lead time as decision variables without shortages. Ouyang et al. [15] extended Ben-Daya and Raouf's [14] model in view of shortages but they made a mistake which is corrected by Moon and Choi [16]. Hariga and Ben-Daya [17] developed some stochastic inventory models with variable lead time. Pan and Yang [18] considered the lead time as a controllable factor to obtain the joint total expected cost.

Scarf [19] first established the min–max distribution free approach for the newsvendor problem without any information about the distribution of the lead time demand except mean and standard deviation. Gallego and Moon [20] made Scarf's [19] ordering rule very easy. After Gallego and Moon's [20] proof, the distribution free approach becomes a very famous

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approach for solving inventory models without any specific distribution of the lead time demand except mean and standard deviation.

Moon and Gallego [21] found out some valuable applications of the distribution free approach for different types of inventory models. After this model, the distribution free approach has been applied by many researchers from the different sectors. Moon and Yun [22] considered the distribution free job control problem. Moon and Choi [23] explained the distribution free procedure for make-to-order (MTO), make-in-order (MIA), and composite policies. Ouyang et al. [24] developed an inventory model with the product's quality improvement and the vendor's setup cost reduction. Ouyang et al. [25] explained an integrated production inventory model with the controllable lead time and shortages including a long-term strategic supply chain between the buyer and the vendor. They simultaneously optimized the lead time, reorder point, number of lots delivered in one production cycle, and the ordering quantity. The setup cost for the vendor was treated to be fixed in that model.

Lin [26] proposed a min–max distribution free approach for the integrated inventory model with the defective goods and the probabilistic lead time demand. Using min–max distribution free approach Liao et al. [27] discussed a newsvendor model with the lost sales penalty and the balking policy. Lee et al. [28] developed an inventory model with the negative exponential backorder cost and the mixture of distribution for the lead time demand. Hsu and Lee [29] investigated a single-manufacturer multiple-retailer supply chain model with the distribution free approach. Jha and Shankar [30] considered a single-vendor single-buyer supply chain model with a service level constraint. Annadurai and Uthayakumar [31] developed a (T,R,L) inventory model with the controllable lead time and the lost sales reduction. Lin et al. [32] developed an integrated supplier–retailer inventory model with the defective items and the trade credit policy.

This paper is an extension of Ouyang et al.'s [25] model by adding an investment for the vendor's setup cost reduction. We optimize the lead time, number of lots delivered in one production cycle, ordering quantity, reorder point, and the vendor's setup cost. An algorithm is developed to optimize the joint total expected cost for the buyer and the vendor where the lead time demand follows the normal distribution. A distribution free approach is considered for the same model. Only mean and standard deviation of the distribution function are known. An algorithm is also implemented for the distribution free approach. Some numerical examples are given to illustrate our model.

2. Mathematical model

The following notation is used to develop the model:

- S setup cost of the vendor per setup (\$/setup) (decision variable)
- Q quantity ordered by the buyer (units) (decision variable)
- R reorder point of the buyer (units) (decision variable)
- L length of the lead time for the buyer (days) (decision variable)
- m number of lots delivered from the vendor to the buyer in one production cycle, a positive integer (units) (decision variable)
- D average demand per unit time of the buyer (units/year)
- A ordering cost of the buyer per order (\$/order)
- P production rate per unit time (units/year)
- S_0 initial setup cost of the vendor per setup (\$/setup)
- C_v unit production cost paid by the vendor (\$/unit)
- C_b unit purchase cost paid by the buyer (\$/unit), $C_b > C_v$
- r_v holding cost rate of the vendor per unit per unit time (\$/unit/unit time)
- r_b holding cost rate of the buyer per unit per unit time (\$/unit/unit time)
- π unit backlogging cost for the buyer (\$/unit)
- X lead time demand which has a cumulative distribution function (c.d.f) F with mean DL and standard deviation $\sigma\sqrt{L}$, where σ denotes the standard deviation of demand per unit time
- $E(\cdot)$ mathematical expectation
- x^+ maximum value of x and 0

The following assumptions are considered to develop our model:

1. An integrated vendor–buyer model is considered.
2. When the buyer orders a lot size Q, the vendor manufactures the lot mQ with finite production rate $P(P > D)$ at one setup but delivers the quantity Q over m times.
3. The buyer places an order when the level of inventory reaches to the reorder point R.
4. The reorder point is $R = DL + k\sigma\sqrt{L}$, where $DL =$ the expected demand during the lead time, $k\sigma\sqrt{L} =$ safety stock, and k = safety factor.
5. Shortages are allowed and fully backordered.