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An integrated production-inventory model with defective item dependent stochastic credit period

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ABSTRACT

In this paper an integrated production-inventory model has been developed for a defective item in a business of a buyer and a manufacturer. After production the manufacturer sells the packed products of the item to the buyer in some lots and then the buyer sells these products to the customer after checking them. There have chances to get the defectiveness of the products. So in this paper, it has been considered that the defective ratio of the item is random to be assumed as follows a beta distribution of first type. To compensate the losses due to defectiveness, the manufacturer offers a defective ratio dependent stochastic credit period to the buyer. Here also the lead time demand has been considered as a normal distribution and the lead time is composed of the cycle period and fixed delay time due to machinery set-up, waiting, transportation, etc. The integrated profit functions have been formulated for three cases which are illustrated numerically and solved by some proposed solution procedures. Finally a sensitivity analysis has been carried out with respect to some parameters.

1. Introduction

A number of academics and researchers have studied the supply chain management in inventory. In supply chain management, establishment of a long-term cooperative relationship between vendor/manufacturer and buyer/retailer is beneficial for the two parties with regard to costs/profits, tensionless stable sources of supply and smooth running of the business. Many studies have investigated integrated vendor–buyer models from the viewpoint of both the buyer and vendor to find the optimal economic order quantity to achieve the minimal total cost such as Banerjee (1986), Pan and Yang (2002), Chang, Ouyang, Wu, and Ho (2006), Chung (2011), Kaya, Kubalı, and Örmeci (2013) and Glock and Kim (2014). Goyal (1988) generalized Banerjee's (1986) model by relaxing the assumption of the lot-for-lot policy of the supplier and illustrated that the inventory cost can be reduced significantly if the supplier's economic production quantity is a positive integer multiple of the retailer's purchase quantity. Lu (1995) assumed that the supplier's production rate is greater than the demand rate and the delivery starts as soon as the quantity ordered by the retailer is produced and later on goods are delivered on a lot-for-lot basis. Goyal (1995) relaxed the lot-for-lot policy and assumed that if the demand is constant, shipment sizes will increase according to the ratio of production rate and demand rate. Goyal and Nebebe (2000) proposed the first shipment to be smaller and is followed by shipments of equal size. Ouyang, Wu, and Ho (2007) proposed an integrated inventory model with quality improvement and lead time reduction. Wee and Chung (2007) and Teng, Cardenas-Barron, and Lou (2011) worked on economic lot size of the integrated vendor–buyer system derived without derivatives. Recently, an integrated vendor–buyer model with set-up cost reduction was developed by Sarkar and Majumdar (2013). Then Das, Das, and Mondal (2014) worked on integrated production inventory model considering transportation and business cycles with a discrete trade credit.

When the assumption of deterministic demand is relaxed and demand is assumed as stochastic then lead time becomes an important issue and its control leads to several benefits. Kim and Benton (1995) considered the effect of lot size on lead time and safety stock. They incorporated a lead time lot size linear relation into a classical stochastic continuous review (Q,s) model. Then Hariga (1999) modified that Kim and Benton's model by rectifying the annual back-order cost and proposing another relation for the revised lot size. Ben-Daya and Hariga (2004) extended the assumption. Hsu, Wee, and Teng (2007) developed their model for deteriorating items with expiration date and supplier's uncertain lead time. Bera, Rong, Mahapatra, and Maiti (2009) considered a multi-item mixture inventory model involving random lead time

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and demand with budget constraint and surprise function. Jha and Shanker (2009) considered that buyer's lead time is controllable which can be shortened at an added cost in a two-echelon supply chain inventory model. Li, Xu, and Ye (2011) developed their supply chain model with controllable lead time. Then Yu, Tang, Fu, Pan, and Tang (2012) enriched a deteriorating repairable system with stochastic lead time. Rong and Maiti (2015) researched on an EOQ model with service level constraint under fuzzy-stochastic demand and variable lead-time.

For non-instantaneous deteriorating item deterioration does not occur prior to certain period of time. This characteristic can be usually observed in almost all food stuffs, fashionable items, electronics products, etc. Wu, Ouyang, and Yang (2006) introduced the phenomenon of non-instantaneous deterioration and established the optimal replenishment policy for non-instantaneous deteriorating item with stock-dependent demand and partial backlogging. For inventory problems, a number of studies considered the items produced as perfect in their models. However, imperfect items are produced due to non-ideal production processes. Wee, Yu, and Chen (2007) have investigated the effect of items with imperfect quality on the EOQ model. Integrated vendor-buyer models that consider defective items have also been presented. Huang (2004) developed an integrated vendor-buyer model with defective items which are treated as a single batch and returned to the vendor after a 100% screening process. Ouyang, Wu, and Ho (2006) developed an integrated vendor-buyer model with defective items represented as crisp and fuzzy cases respectively. Subsequently, Maihami and Kamalabadi (2012) and Shah, Soni, and Patel (2013) have studied the inventory models for non-instantaneous deteriorating items under variety of conditions. In real business world, there are so many products specially electrical and electronic goods such as ceiling fan, table fan, bulb, and television which are to be delivered in packed form from the manufacturer to the buyer (retailer). For such type of items, it can not be predicted by the manufacturer that which of the products are defective. When the buyer sells such item to end customer (the user), then the pack is opened in front of the customer and then the product is checked whether it is good or imperfect. If it is seen to be imperfect, then it is returned to the manufacturer in a lot at the end of that cycle. Obviously, each buyer intends to calculate how many products are appeared as defective out of total receiving items from the manufacturer. Here, the ratio of the numbers of imperfect products to the delivered products of an item in a lot is called as the "defective ratio". The increase of the defective ratio effects on the profits of both parties. So the investigation about this matter in the literature is very necessary.

Integrated vendor-buyer models with a trade-credit policy have recently drawn increasing attention. When establishing a long-term cooperative relationship between the vendor and buyer, the application of trade-credit policy can have advantages for both parties. For the vendor, the policy can usually encourage the buyer to increase the size of their order, while the buyer can gain income from interest. The vendor and buyer could agree to share profits from the integration. Such a model has been developed by Chakravarty and Martin (1988) according to the coefficient of negotiation. Abad and Jaggi (2003) developed a seller-buyer model with a permissible delay in payments under non-cooperative and cooperative relationships. In an inventory control problem, Jaber (2007) considered lot sizing with permissible delay in payments and entropy cost. Sheen and Tsao (2007) presented a vendor-buyer model with trade credit and quantity discounts for freight cost to maximize the channel cooperation's profit. Yang and Wee (2006) considered integrated vendor-buyer models with a permissible delay in payments under the assumption that the vendor replenished the integer multiplication of the buyer's order quantity. Krichen, Laabidi, and Abdelaziz (2011) worked on single supplier multiple cooperative retailer's inventory model with quantity discount and permissible delay in payments. An integrated supply chain model has been enriched by with procurement cost dependent variable trade credit by Das, Das, and Mondal (2013). Again, the manufacturer is offering a credit period to the buyer according to his/ her marketing policy. For packed item stated above, the manufacturer knows that there is some possibility for existence of imperfectness of items at the time of selling from the buyer. Henceforth, the buyer is not able to pay the dues to the manufacturer after over the credit period for the imperfectness of manufacturing. Noticing this event, the manufacturer intends to offer the defective ratio dependent credit period. Again, since the defective ratio is not predictable by the manufacturer, so it must be in stochastic nature. Therefore, the defective ratio dependent credit period should be stochastic. Till now, no one studies such type of credit period. So, the investigation about this matter is very necessary in the literature.

In this paper we consider an integrated production inventory problem for single manufacturer and single buyer. To fulfil the buyer's order the manufacturer produces the item and sells in some cycles with lot size quantity. We assume that the buyer's lead time demand is stochastic and follows normal distribution. The lead time is considered as a linear expression of the cycle length and a fixed delay due to machinery set-up, waiting and transportation, etc. It is unpredictable to the manufacturer that which of the packed products are defective. Here it is assumed that the defective ratio (θ) of the buyer's collected item is random and follows first type beta distribution. The manufacturer offers a credit period which is a linearly increasing function of θ but bounded to the buyer. So the proposed work on such type of stochastic credit period in an integrated production-inventory problem has a new contribution to the literature. The model is developed for the three cases depending on the position of the credit period with respect to the cycle length and selling period of non-defective products in each cycle. The solution procedures for solving the model in three cases are suggested. The effect on the objective functions and the variables for different values of the distribution parameters are explored.

2. Integrated production inventory model

It is an integrated production inventory model for a manufacturer and a buyer of a randomly defective produced item.

2.1. Notations

To formulate the proposed model the following notations have been used.

D	customer's demand rate per unit time
P	manufacturer's production rate per unit time
A	ordering cost of the buyer for each order of size nQ
B	manufacturer's set-up cost per set-up
S	buyer's safety stock
Q	buyer's required quantity of the finished products in each shipments
W	amount of quantity produced in a production-run by the manufacturer
n	number of lots delivered from the manufacturer to the buyer (decision variable)
f	unit of raw-material used to produce single unit of the item
u	manufacturer's raw-material purchase cost per unit
c	buyer's procurement cost per unit
s	unit selling price of the produced item by the manufacturer
h_m	unit holding cost rate of the manufacturer