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A manufacturing-oriented supply chain model for imperfect quality with inspection errors, stochastic demand under rework and shortages

Shilpi Pal [a], G.S. Mahapatra [b,*]

[a] Department of Mathematics, Indian Institute of Engineering Science and Technology, Shibpur, Howrah 711103, India
[b] Department of Mathematics, National Institute of Technology Puducherry, Karaikal 609609, India

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ABSTRACT

Supply chain model is very complex and it does not depend on only retailer or buyer-vendor. So we have developed a three layer supply chain production inventory model with a supplier, a manufacturer, and a retailer. Supplier produces raw material and sent it to manufacturer on continuous basis. But the manufacturer produces items which is not only of imperfect quality item but also have inspection error by classifying a non defective item as defective or classifying a defective item as non-defective during supplies to retailer. Thus the retailer received perfect and imperfect item. The retailer once again inspects the received items and detects the defective item. The retailer makes three different strategies to manage the defective items. Also the retailer have considered a price and stock dependent stochastic demand, where it has considered the effect of deterioration, shortages, backordered. In this paper we have optimized the integrated total cost with respect to production rate of manufacturer and the time when the item finished at retailer end. Numerical simulation is presented to provide important managerial insights and demonstrated the model numerically.

1. Introduction

Supply chain management (SCM) is a systematic progression in which an organization manages the flows of products, services, money, etc. The aim is to obtain maximum profit with minimum costing as well as fulfilling the customer's demand. Actually SCM includes the movement and storage of raw materials, work-in-process inventory, and finished goods i.e., from raw material to point of consumption. Since it is interconnected networks which helps in establishing long-term planning, thus the partnership between the supplier, manufacturer and retailer is advantageous for all the parties regarding costs, design, planning, execution, control. Thus researchers are working on supply chain activities with the objective of creating net value, building a competitive infrastructure, controlling worldwide administration, synchronizing supply with demand and measuring performance globally. Several researchers have shown that the buyer and the vendor can achieve their own minimal total cost, or increase their mutual benefit through strategic cooperation with each other. Initially it was observed by Goyal (1976) then the work has been extended by Banerjee (1986) by developing the joint economic lot sizing model for single buyer- single vendor. Cohen and Baghanan (1998) developed a integrated three supply chain segments with production, distribution, and inventory planning system, customer demand planning and supply, storage/location of the item. Wu and Ouyang (2003) considered the integrated single buyer and sing vendor inventory system with shortages. Agarwal, Chao, and Seshadri (2004) have developed a dynamic balancing of inventory model in supply chain management. Cheng and Wu (2006) worked on a multi-product, multi-criterion supply-demand network equilibrium model. Other researcher like Byrne, Heavey, Ryan, and Liston (2010) and Magableh and Mason (2009) worked on dynamic input and dynamic flow of the replenishment in the supply chain model. Lanzenauer and Pilz-Glombik (2002) obtained coordinating supply chain decisions by an optimization model. Kim, Jun, Baek, Smith, and Kim (2005) also worked on supply chain management system. Cardenas-Barron (2009) worked for single stage manufacturing system with rework and planned backordered. Chung (2011) extended the work of Cardenas-Barron (2009). Recently, Ben-Daya and Seliaman (2010) have developed an integrated production inventory model with raw material replenishment considerations in a three-layer supply chain. Pal, Sana, and Chaudhuri (2012) have developed a three-layer supply chain model with production-inventory model for re-workable items. Many researchers are working on two or three-echelon model like Jetly, Rossetti, and Handfield (2012), Park and Kim (2014), Wong,

* Corresponding author.
E-mail addresses: shilpi88pal@gmail.com (S. Pal), g_s_mahapatra@yahoo.com (G.S. Mahapatra).

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Kranenburg, Houtum, and Cattrysse (2007), Yildirmaz, Karabati, and Sayim (2009), Güller, Uygun, and Noche (2015), Yu (2010), Li, Wang, and Cheng (2010), Niu, Zhao, Castillo, and Joro (2012), Pal, Mahapatra, and Samanta (2016), etc. All of the above mentioned SCMs are considered with constant demand and production rates in a crisp environment.

Demand forecasting to control the stock is the main aim of inventory management. Demand may be at regular (like frequently used item which are demanded regularly) or irregular intervals (that is, slow-moving items which are demanded occasionally). Generally we consider demand in deterministic method which does not hold in reality. Li, Zhao, and Xie (2015) worked on inventory level dependent demand. So now a days researchers considered stochastic nature of sporadic demand. Stochastic models is more appropriate and promising for tackling the peculiarities of irregular demands forecasting and stock control. Browne and Paul (1991) concerned with the (r,q) inventory model, where demand accumulates continuously, but the demand rate at each instant is determined by an underlying stochastic process. Ben-Daya, Hassini, Hariga, and Al Durgama (2013) observed consignment and vendor management in single-vendor multiple buyers supply chains. Giri, Chakraborty, and Maiti (2015) worked on quality and pricing decisions for two layer supply chain under multi-manufacturer. Berling and Xie (2014) approximated an algorithms for optimal purchase inventory policy when purchase price and demand are stochastic.

Classical EPQ model assumes that all items produced are of perfect quality and are continuously produced to satisfy product's demand. However, in a real life production environment, some factors such as deterioration of production processes, wear and tear of machinery, imperfect quality of the components, etc., generates defective items which cannot be ignored in the production process. In most practical situations, defective items will be produced in each cycle of production. It is clear that there are many instances in which the produced imperfect quality items should be reworked or repaired with additional costs. Previous inventory models have mostly focused on developing cost-minimizing models with imperfect quality and have not considered the effect of imperfect inspection processes. Due to inspection error the total cost get effect since it includes few extra cost like discount cost (defective item sold at less price), return cost, etc. and hence it has practical importance. Salameh and Jaber (2000) and Hayek and Salameh (2001) model assumed that there items are imperfect quality item. El-Kassar (2009) worked on an optimal model with imperfect quality raw material needed for production. Many researchers have worked with rework of imperfect quality item like Yoo, Kim, and Park (2009), Sana (2011), Hsu and Hsu (2015), Eskandari and Hosseinzadeh (2013), etc. In this paper we proposes three layer supply chain model that incorporates both imperfect production quality and reworking.

In reality the production process is imperfect and produces a certain number of defective items with a known probability density function. A portion of defective items produced are not successfully screened out by the manufacturer during the production process and passed on to retailer, thereby causing defect sales returns and reverse logistics from retailer back to the manufacturer. Generally, a 100% screening process of the lot is conducted, at individual level of supply chain and the screening process may be defective. A considerable amount of research has been carried out to address the problems of imperfect quality EPQ models. But few researchers have addressed the important issues of handling sales return and/or various options of disposing of defects. Duffuaa and Khan (2005) focused on sensitivity analysis to investigate the statistical and economic impact of the several types of misclassification errors on the performance measures of the inspection plan. Yoo et al. (2009) proposed a profit-maximizing economic production quantity model that incorporated both imperfect production quality and two-way imperfect inspection. Rahim and Ben-Daya (2001) worked on joint deterministic production quantity model of an imperfect process with deteriorating products and with inspection schedule. Lin (2009) developed a production-inventory model for a simple supply chain system with defective items and inspection errors, where he assumed that both the Type I and Type II inspection errors are known constants. Khan, Jaber, and Maurice (2011) extended the work of Salameh and Jaber (2000) model by assuming that the inspection process was not error-free. Thus many researchers like Tsai and Wu (2012), Hsu and Hsu (2015), Hsu and Hsu (2013), etc. have considered the effect of imperfect inspection error.

Deterioration of the items are inevitable. In general, deterioration is defined by Wee (1993) as damage, spoilage, decay, obsolescence, evaporation, pilferage, etc. that result in decrease of usefulness of the original one. In recent trends, businessmen have shown an increasing awareness of controlling items from deterioration in inventory. It is appropriate to note that a product's lifetime ends when utility of the item reaches zero. For items such as steel, hardware, glassware and toys, the rate of deterioration is so low that there is less need for considering deteriorating items. But some items such as alcohol, gasoline, radioactive chemical, medicine and food items deteriorates remarkably overtime. Lee and Wu (2004) developed a note on EOQ model for items with mixtures of exponential distribution deterioration, shortages and time varying demand. Chung and Liao (2006) has worked on DCF (discounted cash flow) analysis for deteriorating items. Skouri, Papachristos, and Goyal (2008) proposed new credit period scheme under which the supplier offers to the buyer a fixed base level credit period in settling the account plus additional delay time, depending on the quantity order. Kang and Kim (2010) worked with compound Poisson demand. Chen and Chang (2010) observed the optimal ordering policies for deteriorating item. Pal, Mahapatra, and Samanta (2014) developed an inventory model for deteriorating items price and stock dependent demand. Chen and Chen (2004) worked on pricing and lot-sizing model with deterioration and shortages. Many researchers like Skouri, Konstantaras, Papachristos, and Ganas (2009), Pal, Mahapatra, and Samanta (2015), etc. developed an inventory models with ramp type demand rate, partial backlogging and Weibell's deterioration rate.

The purpose of this paper is to develop an economical order quantity model with imperfect quality and shortage backordering under inspection errors and deterioration was developed. Price discounts and return cost was included in order to throw light of Inventory in real life situations. In integrated supplier-manufacturer-retailer production-inventory model for items with imperfect quality and inspection errors the objective is to minimize the total joint annual costs incurred at individual layer as well as for integrated three layer. Practically all the production process has imperfection and produces a certain number of defective items with a known probability density function. The screening process is not perfect and the inspector may incorrectly classify a non defective item as defective, this phenomenon is as Type I inspection error; or incorrectly classify a defective item as non-defective, this fact is as Type II inspection error. Here the effect of selling less defective items on discount and returning high defective items to manufacturer for rework on inventory cost is observed. The rest of the paper is organized as follows: In Section 2, the notation and assumptions used in this paper are introduced. Also formulation of the model is done in this section. In Section 3, we develop a mathematical model and its cost components that integrates supplier, manufacturer and retailer annual cost and takes into consideration imperfect production process, inspection error and rework of the defective item. Section 4 provides the optimality condition of the model. Section 5, provides a numerical