Economic Modelling 29 (2012) 2016–2023

Contents lists available at SciVerse ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

A collaborating inventory model in a supply chain

Shib Sankar Sana *

Department of Mathematics, Bhangar Mahavidyalaya, University of Calcutta , Bhangar-743502, 24PGS(South), West Bengal, India

ARTICLE INFO

Article history:
Accepted 17 April 2012

Keywords:
Inventory
Supply chain
Imperfect
Production

ABSTRACT

The present article investigates an economic order quantity/ economic production quantity model in three-layer (manufacturer, vendor and retailer) supply chain management. In each stage, the products may undergo non-conforming quality items which have less value in the market. This model maximizes a collaborating expected profit function while production rate, order quantity, number of shipments with equal sizes are decision variables and unit production cost is a function of production rate. Numerical example is illustrated to test the model.

1. Introduction

Management Scientists, Researchers as well as Practitioners in manufacturing industries have emphasized to develop production-inventory control problems in supply chain management. A good management is trying always to coordinate the business process and activities of the channel members to improve overall performance of the chain. All steps from supply of raw materials to end customers can be included into a supply chain, involving raw materials supplier, manufacturer, vendor, retailer and finally customers. Better supply chain performance in terms of cost depends on the development and implementation of various strategies such as timely supply, quantity discount, buyback/return policies, quantity flexibility, commitment of purchase quantity, fill rate order size, etc. In competitive marketing environment, every company/ management keeps the brand image regarding quality issue with fair prices to capture the market. Consequently, the non-conforming quality (defective) products of each members of the chain are sold at second shop or buyback/return at less price to the market or predecessor member of the chain.

In traditional EPQ (economic production quantity) and EOQ (economic order quantity) model, all items are perfect quality(good). It is rational to all enterprises that all items are not perfect, a certain percent of the products are non-conforming quality. These non-conforming quality items may be reworked at a cost or sold at reduced price. For example, in marble, granite, tiles and glass industries; at manufacturer, a certain percent of produced items are defective regarding a particular size, design, etc. These defective items are not used in original purpose but these items are sold at less price for the other purpose such as land/road developing, small size of those items which have less market value. At vendor; a certain percent of good items, supplied from manufacturer to vendor may undergo into nonconforming quality due to transportation and preservation, which have less market value. Similarly, a certain percent of good items, supplied from vendor to retailer may undergo defective due to transportation and preservation, which have less market value at retailer. Generally, in collaborating system, the defective items are sent back at reduced price to the member where it was purchased.

This article considers the real-life businesses (building construction materials such as marbles, tiles, granite and glass, etc.) involving manufacturer, vendor and retailer as members of the chain. Manufacturer produces the nQ batch with variable production rate P while unit production cost is a convex function of the production rate. A certain percent of production rate is non-conforming quality products which are not sold by vendor, but it has a less market value. The vendor purchases Q lot size per order until the inventory level reaches to zero level and the lot size (q) per shipment is delivered to the retailers. The quantity q is delivered from vendor to retailer until the inventory level of retailer reaches at zero level. A certain percent of items of both the vendor and retailer are defective due to transportation and preservation system of them. In their agreement of business partners of the chain, it is mentioned that the defective items at each member to be sent back to the predecessor member at a price and all other price parameters would be fixed for a fixed period. Also, each has to purchase the amount of items at fixed price throughout the contract period as mentioned in the agreement. Finally, an integrated/collaborating expected average profit function is maximized to obtain optimal shipments, order sizes and production rate of the collaborating system.

The rest of the paper is organized as follows: Section 2 provides literature survey, Section 3 provides fundamental assumptions and

* Fax: +91 3218270460.
E-mail address: shib_sankar@yahoo.com.

0264-9993/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.econmod.2012.04.021

notation. Section 4 describes the formulation of the model. Numerical example is illustrated in Section 5. Section 6 concludes the paper. Section 7 provides references.

2. Literature survey

Many researchers have done noteworthy work in supply chain management. Among others researches, Lu (1995) obtained a heuristic solution for the single vendor and multiple buyer problem. Aderohunmu et al. (1995) showed the cost savings of both the vendor and buyer while they followed a cooperative batching policy and shared cost information along with other information in time. Banerjee and Kim (1995) investigated an integrated inventory model of the buyer, manufacturer and raw materials supplier in a JIT (just-in-time) environment. Goyal and Gunasekaran (1995) developed an integrated production-inventory-marketing model for determining the EPQ (economic production quantity) and EOQ(economic order quantity) for raw materials in a multi-stage production system. Thomas and Grifin (1996) observed that efficient supply chain management requires planning and coordination among the various channel members involving manufacturers, retailers and intermediaries if any. A well integrated supply chain requires coordinating the flows of materials and information between suppliers, manufacturers and customers (Narashiman and Carter, 1998).Clark and Clark (2000) developed a mixed-integer programming formulation for a multi-product lot-sizing problem with sequence-dependent setup times. Munson and Rosenblatt (2001) extended two level supply chain to a three level supply chain, considering a supplier, a manufacturer and a retailer while manufacturer was a dominant member of the chain. Cardenas-Barron (2007a) revisited the works related to algebraic modeling of inventory systems from 1995 to 2006. He also formulated and solved n-stage-multi-customer supply chain inventory model for finding the optimal equal cycle time and the optimal total annual cost. Ojha et al. (2007) considered a static deterministic model with imperfect production process while raw materials are received from a supplier, processed and delivered to the customers.Buscher et al. (2009) focused on six issues of the models developed in Ojha et al. (2007) and proposed some modifications of the model. Lin et al. (2009) developed a deteriorating inventory model while the products continuously decreases with price under a single-buyer–single supplier in a supply chain. They proposed a replenishment policy for the buyer asking for multiple shipments using a lot-splitting strategy and a production plan for the supplier with a single setup. Transchel et al. (2010) examined a multi-product production planning and scheduling problem with sequence-dependent setup cost and times. Sajadieh et al. (2010) investigated an integrated production-inventory model for two-stage supply chain (vendor–buyer) where the demand of customers at the buyer is stock-dependent. Sana (2011) presented an integrated production-inventory model for three layer(supplier, manufacturer, retailer) supply chain, assuming perfect and imperfect quality items. He considered the impact of business strategies such as optimal order size of raw materials, production rate and unit production cost and idle times in different sectors on collaborating marketing system. Taleizadeh et al. (2012) investigated an economic production quantity (EPQ) inventory model with rework process for a single stage production system in one machine with limited production capacity. In this direction, mention should be made of the works of Woo et al. (2001), Boyacci and Gallego (2002), Khouja (2003), Wang et al. (2007), Jalber et al. (2008), Huang and Ye (2010), Cárdenas-Barrón (2007b, 2008, 2009a), among others.

Manufacturing Scientists and Industrial Engineers have given more importance to FMS(flexible manufacturing system), EOQ(economic order quantity) and JIT(just-in-time)philosophy. Volume flexibility is a major component of FMS that helps to meet the market-demand at optimum level. Numerous attempts have been made to define and measure manufacturing flexibility. Silver (1990) discussed the effects of controllable production rates on the solution to the economic lot size scheduling problem. Gallego (1993) extended the economic lot size problem in which production rates could be slowed down from the maximum level. Khouja (1999) considered the economic lot scheduling problem with controllable production rates and imperfect quality in which yield rates decreased with increased production rates and lot sizes. Salameh and Jaber (2000) developed an EPQ/EOQ formula when total production/lot size is not perfect. In their model, defective items are sold as a single batch at the end of the total screening process. Cardenas-Barron (2000) revised the formula of Salameh and Jaber's (2000)model and showed that the error only affects the optimum value of the order size. Wu (2001) developed an EOQ model for linear demand and weibull deterioration with backlogging. Fung et al. (2001) developed a multi-item inventory systems with compound demand and service constraints considering coordinated periodic review and order-up-to-level policy.Chen and Lin (2002) developed a replenishment model for time discounting, inflation, time varying demand and normally distributed deterioration. Khanra and Chaudhuri (2003) developed an order-level-inventory model for time dependent quadratic demand of perishable items. Goyal and Cardenas-Barron (2002) extended Salameh and Jaber's (2000) model and proposed a practical approach to determine EPQ for items with imperfect quality. Goyal et al. (2003) developed the model of Goyal and Cardenas-Barron (2002), considering vendor–buyer integration. Huang (2004) investigated the model of Salameh and Jaber's (2000) in an integrated production and shipping context. Rahim and Tuffaha (2004) discussed an integrated model to determine the optimal initial settings of the process mean and the optimal production-run-time, assuming quadratic loss functions. Siajadi et al. (2005) investigated a joint optimization of production cycle of finished item and replenishment of raw materials to arrive at optimal level. Gallego et al. (2006) discussed an inventory management of a semiconductor production system that has characteristic of long manufacturing lead times, high demand uncertainty and short product life cycles.Ghosh and Chaudhuri (2006) investigated an economic order quantity model considering quadratic demand, time-proportional deterioration and shortages in all cycles. Tynjala and Eloranta (2007) investigated the effect of product variations and demand distributions on the optimal demand supply network setup. Smith et al. (2007) examined the benefit of optimizing price and order quantity jointly rather than the determination of economic order quantity and optimal price separately. Hassini (2008) developed a multi-period and multi-supplier selection problem with price discounting for a single product. Cardenas-Barron (2009b) formulated an EPQ model with planned backorders to determine the economic production quantity and the size of backorders for a single product which is manufactured in a single-stage production system that generates imperfect quality products and all defective products are reworked at the same cycle. Tahera et al. (2010) developed a model to obtain the optimum process means and production run for such a process with multiple quality characteristics. Sana (2010a) developed a production-inventory model to determine the optimal product reliability and production rate that achieved the biggest total integrated profit for an imperfect manufacturing process. Sana (2010b) investigated an EPL(economic production lotsize) model in an imperfect production system in which the production process may shift from an in-control state to an out-of-control state at any random time. At out-of-control state, the system produces non-conforming(defective) items which are reworked at a cost. Sarkar et al. (2010) obtained an optimal production lot size, safety stock and reliability parameter while the production facility is subject to random breakdown of the machinery system. Recently, Khanra et al. (2011) developed an EOQ model for deteriorating items with time dependent quadratic demand under permissible delay in payment. Cárdenas-Barrón (2011) obtained an optimal lot size and backorders level by algebraic method, considering both linear and fixed backorders costs.