



A multi-echelon supply chain model for reworkable items in multiple-markets with supply disruption

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ABSTRACT

The objective of this paper is to develop a multi-echelon supply chain model for multiple-markets with different selling seasons. Here, two suppliers are involved to supply the raw materials to the manufacturer where the main supplier may face supply disruption after a random time and the secondary supplier is perfectly reliable but more expensive than the main supplier. In this article, the manufacturer produces a random proportion of defective items which are reworked after regular production and are sold in a lot to another market just after completion of rework. The retailer sells the finished products in different markets according to seasons. Finally, an integrated expected cost per unit product of the chain is minimized analytically by considering the lot-size ordered as a decision variable. An appropriate numerical example is also provided to justify the proposed model.

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1. Introduction

Almost all industrial products face multi-echelon supply chain model. It occurs when an item moves through more than one stage before arrival at the final customers. A large amount of researches on multi-echelon inventory control has appeared in the literature during the last decades. Clark and Scarf (1960) were the first to study the two-echelon inventory model. They proved the optimality of a base stock policy for the pure serial inventory system and developed an efficient decomposing method to compute the optimal base stock ordering policy. Tzafestas and Kapsiotis (1994) applied a simulation method to develop a deterministic mathematical programming approach to optimize a supply chain. Goyal (1995) incorporated a policy where size of successive shipments from manufacturer to customer within a production cycle increased by a factor equal to the ratio of production rate and the demand rate. Diks and de Kok (1998) determined a cost optimal replenishment policy for a divergent multi-echelon inventory system under periodic review order-up-to-policy. Gyana and Bhaba (1999) considered an optimal multi-ordering policy for procurement of raw materials. In their model, single manufacturing system was developed to minimize the total inventory cost for both raw materials and finished products. Yang and Wee (2000) investigated an integrated deteriorating inventory model for both buyers and vendors. They showed that the integrated approach results in an impressive cost-reduction compared with an independent decision by the buyer. Iida (2001) also studied a dynamic multi-echelon inventory model with non-stationary

products. Khouja (2003) assumed three coordination mechanisms between the members of the supply chain and showed that some coordination mechanisms lead to significant reduction in total cost. Cardenas-Barron (2007) extended the model of Khouja (2003) by algebraic method, considering n-stage multi-customer supply chain inventory system. Some researchers (Yang and Wee (2002), Rau et al. (2003), Ouyang et al. (2009) and Chung et al. (2000)) introduced the model with deteriorating raw materials under the premise that the manufacturer sells his products in one market. Leung (2009) developed an extension of the work of Khouja (2003), incorporating the integer multipliers mechanism. He individually derived the optimal solution for the cases of three-stage and four-stage model, using the perfect squares method. Leung (2010) extended the previous model of Leung (2009) by considering with/without lot streaming and with/without complete backorders under the integer-multiplier coordination mechanism and he derived the optimal solution of the three- and four-stage model. Li et al. (2010) discussed the sourcing strategy of a retailer and the pricing strategies of two suppliers in a supply chain under an environment of supply disruption. He et al. (2010) studied a production-inventory model for deteriorating items with multiple-market demand, where each market has a different selling season and a different constant demand rate. Sarkar et al. (2011) introduced an imperfect economic manufacturing quantity model for time-dependent (quadratic) demand pattern with inflation and time value of money. Sana (2011b) developed an imperfect production system with allowable shortages due to regular preventive maintenance for products sold with free minimal repair warranty. Das Roy et al. (2011b) developed a deterministic inventory model with the exponential partial backlogging of the unsatisfied demand and shipment of the batches of imperfect quality items. Pal et al. (2011) studied an EPQ model in an imperfect production

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system where defective items are reworked after the regular production process. They also considered that the reliability of the machinery system may be controlled by using new technologies. Many researchers such as Sarkar (2011a, 2011b, 2012a, 2012b, 2012c), Sarkar et al. (2010a, 2010b), Das Roy et al. (2011a, 2011c), Sana (2010), Sana et al. (2007), Sana and Chaudhuri, 2010 worked on imperfect production inventory system. Recently, Sana (2011a) introduced an integrated production-inventory model of perfect and imperfect quality products in a three-layer supply chain where supplier, manufacturer and retailer are the members of the chain.

In our model (Fig. 1), we formulate a multi-echelon supply chain model in which suppliers (main and secondary), manufacturer and retailer are the members of the chain. In the chain, main supplier may face supply disruption due to the unavailability of the products, labour and transportation problems, etc. Then, manufacturer is compelled to order raw materials from the secondary supplier at a more expensive cost to continue production process. Manufacturer produces perfect and imperfect (defective) items during the regular production-run time where a random percent of total products is imperfect quality. These defective items are reworked after regular production and are sold in another market in a lot after completion of rework. The demand of end customers varies with different selling seasons. There are some products which are not favorable for the whole year in a particular place. The demand of those products varies according to the places and seasons. In a particular season, selling of those products is profitable for a fixed place. If the retailer sells the products at that place, he must spend idle time excluding that season. However, if he sells those products at different places according to the proper season, the profit of the chain will be more. Finally, an integrated cost

function per unit item of the members of the chain is minimized by trading off setup costs, inventory costs, production costs and reworked costs of the chain.

The rest of the paper is organized as follows: Section 2 provides fundamental assumptions and notation, Section 3 formulates the model, numerical example is illustrated in Section 4, and Section 5 concludes the paper.

2. Fundamental assumptions and notation

2.1. Assumptions

The following assumptions are made to develop the model:

- (i) Model is developed for single item.
- (ii) There are two suppliers, the main supplier may face supply disruption after a random time due to unavailability of raw materials in the market, labour and transportation problem, etc. Then, the secondary supplier, perfectly reliable but more expensive than the main supplier, is selected for supply of raw materials.
- (iii) Production rate of the manufacturer is constant and is greater than demand rate of retailer to avoid shortage.
- (iv) Production rate of defective items is random and no scrap items are produced during regular production time.
- (v) In each production run, reworking starts just after the end of regular production process and produced items are not as perfect as the original quantity.
- (vi) Reworked products are sold to another market in a lot after completion of rework.

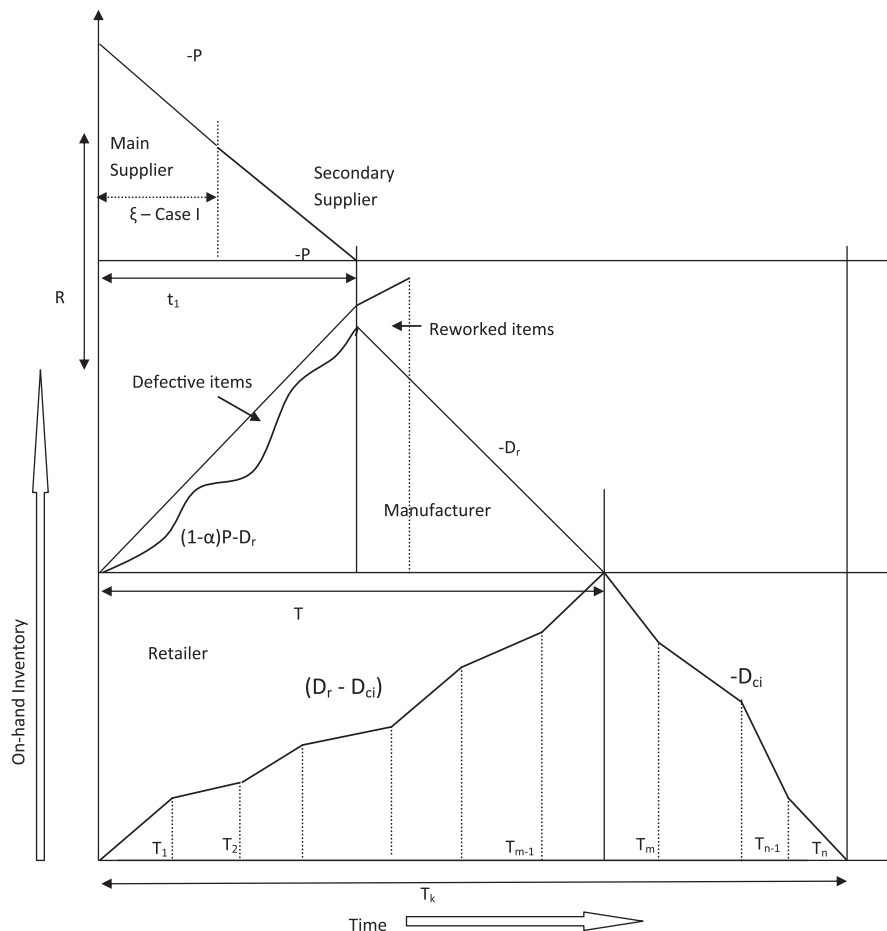


Fig. 1. Logistic diagram of the model.

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