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A Closed Loop Supply Chain System with Flexible Manufacturing and Reverse Logistics Operation under Shortages for Deteriorating Items

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Abstract

We presented a closed loop structure with remanufacturing for decaying items. The model is considered for single item with two different quality standards. A mount of product is collected from the user. After collection process, a ratio of the collected items is to be remanufactured. Furthermore, a salvaged option is considered within the structure in study. In practices, remanufactured items are perceived by some customers to be of lower quality than newly produced items hence sold in a secondary market at a lower price. Due to this assumption shortage is occurring and the excess demand is completely backlogged. To make the study realistic, we consider production and remanufacturing rate as demand and stock dependent. We establish a mathematical model to determine the optimal replenishment cycle. As a result, in this article, Illustrative examples and sensitivity analysis is presented to describe the situation.

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Keywords: Production; Remanufacturing; Reverse logistics; Shortages; Flexible manufacturing/remanufacturing; Waste disposal; Deterioration

1. Introduction

Reverse and closed-loop supply chains have recently gained attention in the literature due to recognition of the important role served environmentally and financially. Given current economical and environmental concerns, it is of great importance to develop efficient Closed-loop supply chains which integrate a reverse flow into the traditional

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forward chain in order to take back re-process and re-sell product returns, either in the original primary market or in another secondary market. The text provides a unique pioneering work on strategic planning of reverse and closed-loop supply chains in this new and rapidly growing area. Schrady [1] was the earliest author to propose a deterministic model with infinite production rates for production and remanufacturing. He analyzed the problem in the traditional economic order quality (EOQ) model for repairable items. Nahmias and Rivera [2] considered the model of Schrady [1] for the case of finite repair rate and limited storage in the repair and production shops. Koh et al. [3] generalized the model of Nahmias and Rivera [2] by assuming a limited repair capacity. Dobos and Richter [4 and 5] explore a reverse logistics inventory system with non instantaneous production and remanufacturing rate to the case of multiple remanufacturing and production cycle. Dobos and Richter [6] explored their previous model by assuming that the quality of collected used items is not always suitable for further recycling. A closed-loop supply chain for the returned items is developed by Savaskan et al. [7] assuming the returned rate depends on collection investment. Dekker et al. [8] proposed a quantitative model for closed loop supply chain. He analyzed that the amount of returns is highly uncertain and this uncertainty greatly affect the collection and inventory decisions. Later on, other researchers have developed models that relax some of the assumptions made so far. Examples of these works, including, but not limited to, are those of, Konstantaras and Skouri [9], El Saadany and Jaber [10], Alamri [11], Chung and Wee [12], Singh and Saxena [13], Yang et al., [14] and Singh et al. [15] have investigated their model with the reverse flow of material, using the different assumption.

In several large organisations it is possible to remanufacture the used products as good as those of new products, such as metals, timbers and paper; but in most of the cases customers do not consider newly manufactured and remanufactured items as being interchangeable, such as mobile phones, suppliers procure used mobile phones and end-of-lease mobile phones from user and then resell them in a developing market where the technology is acceptable. King et al. [16] defined the term repair as the correction of specified faults in a product, where the quality of repaired products is inferior to those of remanufactured. Jaber & El Saadany [17] investigated a disposal model with lost sale, assuming that demand for manufactured items is different from that for remanufactured (repaired) ones. Konstantaras et al. [18] investigated a closed loop supply chain with inspection and sorting of returned items assuming that remanufactured and newly purchased items are sold in a primary market, while the refurbished units are sold in secondary market. In a subsequent paper, Hasanov et al. [19] extended the work of Jaber & El Saadany [17] by assuming that unfulfilled demands for remanufacturing and production items are either fully or partially backordered. A comparison among these models is given in Table 1.

The product can be produced more efficiently by a modern flexible production process that substantially reduces the production set-up time. In practice demand and inventory level may influence production. A supply chain model for flexible manufacturing with variable holding cost was developed by Singh et al. [20]. In general, almost all products deteriorate over time. Some items have a significant rate of deterioration, which cannot be ignored in the decision making process model. The earliest approach to illustrate the optimal policies for deteriorating items was made by Ghare and Schrader [21] who derived a revised form of the economic order quantity (EOQ) model assuming exponential decay. Covert and Philip [22] developed an EOQ model with Weibull distribution deterioration.

Table 1: Similarities and differences in assumptions among Jaber & El Saadany [17], Konstantaras et al. [18], Hasanov et al. [19] and this paper

Assumptions	*product case*	*Demand*	*Production*	*remanufacturing*	*Deterioration*	*Spare*	*backlogging*
Jaber & El Saadany [17]	Single product with two different qualities	Constant	Infinite	Infinite	No	Waste disposal	Lost sale
Konstantaras, et al. [18]	Single product with two different qualities	Constant	No	Constant	No	No wastage	Not allowed
Hasanov et al. [19]	Single product with two different qualities	Constant	Infinite	Infinite	No	Waste disposal	Fully and partially backlogging
This paper	Single product with two different qualities	Constant	Demand and stock dependent	Demand and stock dependent	Yes	Salvaged	Fully backlogging

The surveys and classifications of inventory models can provide useful information for decision makers who want to