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A production model for deteriorating items with stochastic preventive maintenance time and rework process with FIFO rule

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ABSTRACT

Due to unreliable production facility and stochastic preventive maintenance, deriving an optimal production inventory decision in practice is very complicated. In this paper, we develop a production model for deteriorating items with stochastic preventive maintenance time and rework using the first in first out (FIFO) rule. From our literature search, no study has been done on the above problem. The problem is solved using a simple search procedure; this makes it more practical for use by industries. Two case examples using uniform and exponential distribution preventive maintenance time are applied. Examples and sensitivity analysis are conducted for each case. The results show that rework and preventive maintenance time have significant affected the total cost and the optimal production time. This provides helpful managerial insights to help management in making smart decisions.

1. Introduction

Due to rapid globalization in the last decade, many manufacturers face tight competition in the market place. Nowadays, consumers know where to find goods with cheaper price, better quality and faster delivery. Rework is a popular strategy by many companies to reduce their production cost and to maintain high product quality. From our literature search, no research has considered simultaneously the deteriorating inventory, stochastic preventive time (due to unforeseen circumstances such as finding the unplanned parts that need to be replaced), lost sales possibility and the first in first out (FIFO) rule. In real-life, most manufacturers try to reduce lost sales due to shortage. However, due to the stochastic nature of the model, shortages may occur. By considering lost sales cost in our modeling, we penalize the undesired effect of shortage. By optimizing the model, we seek to find the tradeoff between too much or too little inventory. Shortage should be kept as low as possible especially if the shortage cost is high. However, if the shortage cost is so large that it approaches infinity (for example, shortage of blood for emergency transfusion will result in human death, a very high cost indeed!), then blood in hospital should never be running out. The condition is also application for critical parts in industry where the shortage is extremely costly. Due to the characteristic of our model, it will optimize to no shortage model when shortage cost is very high. Therefore, considering lost sale during shortage gives us wider options in our replenishment decisions, thus a more general solution.

Schrady [1] was one of the earliest researchers in production models who considered rework processes. Chung and Hou [2] considered imperfect process, rework and shortages in their EPQ model. Teunter [3] developed an optimal production and rework lot-size quantity models for two lot sizing policies. Recently, Widyadana and Wee [4] simplified the solution methods by introducing an algebraic approach. Buscher and Lindner [5] developed an EPQ model which addresses lot size of production, rework and shipment. Chiu et al. [6] developed EPQ models which addressed random breakdown of production machines and rework. A similar model considering service level constraints with rework was developed by Chiu et al. [7]. Liu et al. [8] analyzed the number of production and rework setups used in one cycle; as well as their sequence and optimal production quantity in each setup. Cardenas-Barron [9] developed an EPQ model with rework by using a planned backorder. Sana [10] proposed an extended production inventory model with rework by considering variable product reliability factors, variable unit production costs and a dynamic production rate. The effect of scrap, rework and stochastic machine breakdown under an abort/resume (AR) policy was considered by Chiu [11]. Similar research has been conducted by Chiu et al. [12]. However none of the above research considered deteriorating items in their models.

Deteriorating items are items that lose their utility with time due to decay, damage or spoilage. Some examples of deteriorating items are found in semiconductor, pharmaceutical, chemical and foods. The rework process is commonly applied to products that have a

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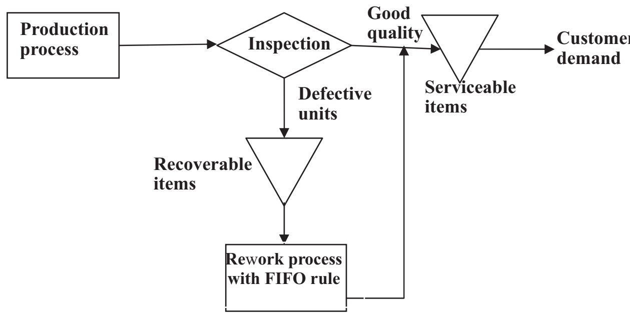

Fig. 1. Production system with rework.

deteriorating characteristic, however few researchers give attention to this area. Flapper and Teunter [13] introduced a logistic planning model with a deteriorating recoverable product and Inderfuth et al. [14] also devised a similar model. Inderfuth et al. [15] developed a production inventory model with rework and defectives items which began to deteriorate while waiting for rework. An EPQ model for deteriorating time with random machine breakdowns and fixed repair time was developed by Lin and Gong [16]. Wee et al. [17] developed an inventory deteriorating model with imperfect quality and assumed that the poor quality items are not recoverable. Later Chang and Ho [18] derived the closed-form solution to solve Wee's model. Some intensive research for deteriorating inventory models which addresses remanufacturing have been done by Wee and Chung [19], Yang et al. [20] and Chung and Wee [21]. Unlike most of the researchers who assumed deterioration only occurred in recoverable items, we consider deterioration occurs for both the serviceable and the recoverable items. To make it more practical, our model also considers the stochastic preventive maintenance time.

Salameh and Jaber [22] were one of the first authors who considered lot-sizing problems with regular maintenance interruptions. Abboud et al. [23] developed an economic lot sizing model by considering machine unavailability due to preventive maintenance and shortage. Later the model was extended by Chung et al. [24] who considered deteriorating items with stochastic machine unavailability time and shortage. Sheu and Chen [25] developed an EPQ model taking into account the level of preventive maintenance for an imperfect production system. They assumed that the constant renewal of the production system will reduce the preventive maintenance level. Production-inventory models for a deteriorating production process and deteriorating items were developed by Alfares et al. [26]. They also considered some realistic aspects in their model such as varying demand, varying production rate, inspection and maintenance. Gharbi et al. [27] developed a production inventory model by considering preventive maintenance, machine failure and backorders. Backordering occurs if demands during repair time exceed the total inventory. Tsou and Chen [28] shown that preventive maintenance has an effect on the production system. Chakraborty et al. [29] developed production inventory models by considering deteriorating production process, random breakdown machine and preventive maintenance. The effect of perfect and imperfect preventive maintenance time in an EPQ model was introduced by Liao et al. [30]. Karamatsoukis and Kyriakidis [31] developed a production-inventory model with a predetermined buffer, idle periods, and preventive maintenance. The effect of stochastic maintenance and corrective time in an EPQ model for deteriorating items are considered by Widyadana and Wee [32]. Berthaut et al. [33] analyzed production inventory control policy by simultaneously considered corrective cost, maintenance cost, holding cost and backlog cost. Wee and Widyadana [34] assumed rework using the last in first out (LIFO) rule. Lev and Weiss [35] developed optimal inventory policy for both finite and infinite horizon models with changes in any or all costs. Yang et al. [36] considered products risks due to rapid technological innovation Wee and Wang [37], assumed an EPQ model with partial backordering and phase-dependent backordering rate. All of the above researchers have developed procedures for computing their respective optimal policies.

From the authors' literature search, there is no model that considers stochastic preventive maintenance time, deteriorating items and rework process using the first in first out (FIFO) rule simultaneously. In this paper, a lot sizing model for deteriorated items with rework and stochastic maintenance time is developed. Both the serviceable and the recoverable items are assumed to deteriorate. The rework production system is shown in Fig. 1. In this system, items are produced before inspection. Good quality items are sold to the customer immediately and defective items are kept for rework. We assume all recoverable items can be reworked to an "as new" condition. We maintained the machine at the end of the production time; and the maintenance time is assumed stochastic. When there is no serviceable inventory, the rework process starts as long as there is available machine. Shortages will occur when the demand is greater than the existing stock during machine maintenance time, and shortage items are assumed to be lost sales. Two different preventive maintenance time distributions, the uniform distribution and the exponential distribution, are considered. This paper is divided into four sections. Section 1 is the literature review and the motivation for the study. The model development is explained in Section 2. Section 3 shows a numerical example and the sensitivity analysis of the study. Finally, conclusion and future research are given in Section 4.

2. Model development

The assumptions:

1. The good quality rate and rework rate must be greater than the demand rate.
2. The stringent preventive maintenance results in negligible machine breakdown during production and rework period.
3. Production, rework and demand rate are constant.
4. Deteriorating rate is constant.
5. There is no repair or replacement for deteriorated items.
6. Defective items are generated during the production and the rework period. The defective items appear during the rework process are rejected.
7. All shortages are lost.