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An economic production quantity model for deteriorating items with multiple production setups and rework

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ABSTRACT

Rework is one of the main issues in reverse logistic and green supply chain, since it can reduce production cost and environmental problem. Many researchers focus on developing rework model, but few of them developed model for deteriorating items. In this paper, we develop an economic production quantity (EPQ) model for deteriorating items with rework. In one cycle, production facility can produce items in m production setups and one rework setup, (m, 1) policy. An example and sensitivity analysis is shown to illustrate the model. The results show that the deteriorating rate affects the optimal cost per unit time, but the effect is not significant. The parameters that significantly affect the optimal total cost per unit time are the serviceable holding cost, the production setup cost and the demand rate.

1. Introduction

One competitive advantage in global competition market is producing high quality products. In order to produce high quality products, defective products eliminated through 100% screening. For an economic reason and environmental concerns, defective products are reworked to become serviceable items. Rework process is also one important issue in reverse logistics where used products are reworked to reduce waste and environment problems.

The earliest research that focused on rework and remanufacturing process was done by Schrady (1967). Since then, researches on rework have attracted many researchers. Khouja (2000) considered direct rework for economic lot sizing and delivery scheduling problem (ELDSP). Koh et al. (2002) developed production inventory models where supplier can fill the demand in two alternatives: either orders new products externally or recovers defective products through rework. Jamal et al. (2004) evaluated two rework policies. In the first policy, defective items are reworked in the same cycle; and in the second policy, rework is completed after N cycles. Cárdenas-Barrón (2009a) extended the model of Jamal et al. (2004) by developing an EPQ model for single product, imperfect quality, the same cycle rework and planned backorders. Chiu et al. (2004) developed an imperfect rework process EPQ model with repairable and scrap items. A model for two-stage manufacturing system with production and rework processes was developed by Buscher and Lindner (2007).Chiu et al. (2007a) developed an EPQ model with repairable defective items, scrap and stochastic machine breakdown. An EPQ model with rework process subject to backlogging and a service level constraint was developed by Chiu et al. (2007b) and Chiu (2007). Yoo et al., (2009) developed an EPQ model with imperfect production quality, imperfect inspection and rework. Similar research has been conducted by Jaber et al. (2009). They developed inventory models using the concept of entropy cost for perfect and imperfect quality items. Taleizadeh et al. (2010) developed production quantity model by considering random defective items, repair failure and service level constraints. Later, Taleizadeh et al. (2011) studied production inventory models of two joint systems with and without rework. Khan et al. (2011) review some research of EOQ model which incorporate imperfect items. Chung and Wee (2011) considered short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system. Yassine et al. (2012) analyzed shipment of imperfect quality items during a single production runs and over multiple production runs. Wee and Widyadana in press developed a single-vendor single-buyer inventory model with discrete delivery order, random machine unavailability and lost sales.

Some researches on rework also focus on production policy to minimize production and inventory costs. Dobos and Richter (2004) developed a production and recycling inventory model with n number of recycling lots and m number of production lots. Teunter (2004) developed EPQ models with rework in two

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policies. In the first policy, m number production lots are alternated with one recovery lot, $(m, 1)$ policy; in the other policy, one production lot is alternated with n recovery lots, $(1, n)$ policy. Later Widyadana and Wee (2010) introduced an algebraic approach to solve Teunter (2004) models efficiently and effectively. Mathematical models for the optimal EPQ, optimal production, rework frequency and their sequence are developed by Liu etal. (2009). They found that the $(m, 1)$ policy has a bigger chance to reach an optimal solution compare with $(1, 1)$, $(1, n)$ and (m, n) policy. Sarker et al., (2008) compared direct rework process and $(m, 1)$ rework policy in a multi-stage production system. Feng and Viswanathan (2011) proposed mathematical models for general multi manufacturing and remanufacturing setup policies. Hsueh (2011) investigated inventory control policies for manufacturing/remanufacturing during by considering different product life cycle phases. Wee et al. (2011) applied life cycle costing analysis to derive an optimal replenishment policy for a deteriorating green product.

Rework is common in semiconductor, pharmaceutical, chemical and food industries. The products are considered as deteriorating items because their utility is lost with time of storage due to price reduction, product useful life expiration, decay and spoilage. An optimal production quantity model for deteriorating item was introduced by Misra (1975). Wee (1993) considered an EPQ deteriorating inventory with partial back ordering, and Goyal and Gunasekaran (1995) introduced an EPQ model with marketing policies and deteriorating items. Later, Widyadana et al. (2011) introduced a simple method to solve a deteriorating item inventory problem. Consideration of deteriorating items in rework process was done by Flapper and Teunter (2004). They developed a logistic planning model with deteriorating recoverable product. Inderfuth et al. (2005) considered an EPQ model with rework and deteriorating recoverable products. Since the recoverable products deteriorate, it will increase rework time and rework cost per unit. A production planning of new and recovery defective items were developed by Inderfuth et al. (2006). They assumed defective items would deteriorate while waiting for rework. When the waiting time of the defective items exceeds the deterioration time limit, they cannot be recovered and should be disposed. Similar research with multiple products was conducted by Inderfuth et al. (2007). A more efficient methodology to solve the production inventory problem with rework was developed by Cárdenas-Barrón (2007, 2008 and 2009b). The preceding researches assumed serviceable items do not deteriorate. In our proposed study, we develop rework models for serviceable deteriorated items.

In our lot sizing model for deteriorated items with rework, both serviceable and recoverable items are deteriorating with time. The rework production system is shown in Fig. 1. In this system, items are inspected after production. Good quality items are stocked and sold to customer immediately. Defective items scheduled for rework. We assume all recoverable items after rework are considered "as new". Rework process is not done immediately after the production process, but it waits until a determined number of production setups. This paper is divided into four sections. Section 1 shows the motivation of the study and literature review. Model development is shown in Section 2.Examples and sensitivity analysis are given in Section 3, and conclusions are drawn in Section 4.

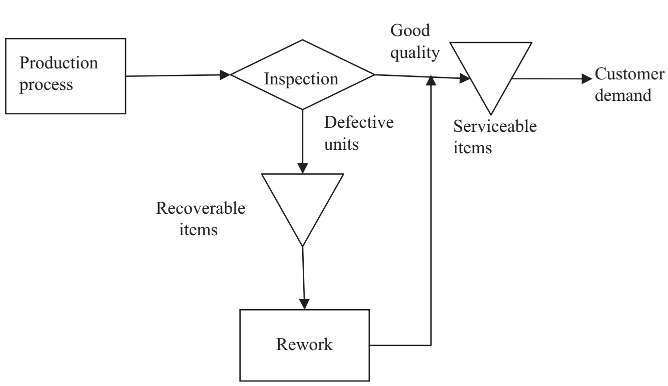

Fig. 1. The production system with rework.

2. Model development

The assumptions:

1. Shortages are not allowed; the rate of producing good quality items and rework must be greater than the demand rate.
2. No machine breakdown occurs in the production run and rework period.
3. Production, rework and demand rate are constant.
4. Deteriorating rate is constant.
5. There is replacement for a deteriorated item.
6. Defective items are generated only during production period. Rework process results in only good quality items.
7. The rate of producing good quality items should be greater than the sum of the demand rate and the deteriorating rate ($\alpha p - d - \theta I_1 t_1 > 0$).

Parameters:

D_i	total deteriorating unit(unit)
p	production rate(unit/year)
p_r	rework process rate(unit/year)
d	demand rate(unit/year)
θ	deteriorating rate(unit/year)
α	percentage of good quality items
m	number of production setup in one cycle
K_s	production setup cost($/setup)
K_r	rework setup cost ($/setup)
h_s	serviceable items holding cost($/unit/year)
h_r	recoverable items holding cost($/unit/year)
D_c	deteriorating cost($/unit)

Variables:

I_1	serviceable inventory level in a production period
I_2	serviceable inventory level in a non-production period
I_{r1}	recoverable inventory level in a production period
I_{r2}	recoverable inventory level in a non-production period
I_{r3}	recoverable inventory level in a rework production period
I_{t1}	total serviceable inventory in a production period
I_{t2}	total serviceable inventory in a non-production period
I_{t3}	total serviceable inventory in a rework production period
I_{t4}	total serviceable inventory in a rework non-production period
TTI	total recoverable inventory in a production period
I_{v1}	total recoverable inventory in m production periods
I_{v2}	total recoverable inventory in non-production periods
I_{v3}	total recoverable inventory in a rework production period
TRI	total recoverable inventory
I_{Mr}	maximum inventory level of recoverable items in a production setup