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An imperfect production model under Radio Frequency Identification adoption and trade credit

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ABSTRACT

We develop an economic production quantity model on the basis of radio frequency identification (RFID) adoption, trade credit, and reworking of imperfect products. We determine the optimal values of production cycle time and RFID investment levels for ordering, just-in-time, and operating efficiencies. On the basis of the relationship between the demand and reworking rates, we classify the model into two cases. Furthermore, on the basis of the relationship between production cycle time and credit period, we divide each case into four subcases. We derive the total manufacturing cost for the subcases and develop an algorithm to solve the four-branch piecewise nonlinear problem. Finally, we illustrate the solution approach and perform numerical analyses to discuss the influences of system parameters on decisions.

1. Introduction

The traditional economic production quantity (EPQ) inventory model is widely used in practical inventory control. However, the assumption of a perfect production process may not always apply. Hence, numerous studies (e.g., [1,2]) have discussed the influence of an imperfect production process on the EPQ model. Salameh and Jaber [3] extended the traditional EPQ/economic order quantity (EOQ) model by including imperfect quality items in the EPQ/EOQ formulae. Hayek and Salameh [4] determined the production lot sizing under the rework of imperfect quality products. Chan et al. [5] addressed a similar problem and classified the defective products into two categories: those that can and be reworked and those that cannot. Jamal et al. [6] developed two operational policies for reworking imperfect quality products in the EPQ model. Konstantaras et al. [7] developed an economic ordering policy for an item with imperfect quality subject to in-house inspection. By stating that acceptable products are shipped in batches and defective items are reworked, Khan et al. [8] summarized the current research extending the EOQ model for imperfect items developed by Salameh and Jaber [3].

More recently, Yoo et al. [9] proposed a profit-maximizing EPQ model that included imperfect quality items and Type I and Type II inspection errors. Wahab and Jaber [10] presented an EPQ model for items with imperfect quality, different holding costs, and learning effects. Chang and Ho [11] used the renewal reward theorem for the first model proposed by Konstantaras et al. [7]. Tsao et al. [12] studied the problem of reworking imperfect quality products on the basis of trade credit. Konstantaras et al. [13] investigated an EOQ model with imperfect quality items and shortages, where the fraction of imperfect quality in each shipment reduces because of learning. Sinha [14] established an optimal EPQ model with items of imperfect quality, exponential declining demand, and regular preventive maintenance. Jaber et al. [15] presented an entropic

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version of an EOQ model with imperfect quality items. Zhou et al. [16] developed EPQ models for items with imperfect quality and one-time-only discount.

Most studies have assumed that ordering and production costs are constant. This assumption, however, can be relaxed when we consider the advantages of radio frequency identification (RFID) technology, such as reduced labor costs, increased efficiency, simplified manufacturing processes, and improved inventory information accuracy. Hence, RFID can reduce ordering and production costs. Scholars have also addressed the influence of RFID on operations management. In addition, Szmerekovsky and Zhang [17], Ustundag and Tanyas [18], Szmerekovsky et al. [19], Shin and Eksioglu [20], and Leung et al. [21] have discussed the influence of RFID on supply chain profits and strategies of adopting RFID. Lee and Lee [22] focused on the production process improvement effect of RFID and formulated a supply chain RFID investment evaluation model. Zhang et al. [23] proposed an RFID-enabled real-time manufacturing information tracking infrastructure to assess manufacturing data and track manufacturing information processing methods to improve extended enterprises. Choy et al. [24] developed an RFID-based storage assignment system to improve storage location assignment problems in a supply chain. Cui et al. [25] proposed a joint replenishment and delivery problem using RFID for investment evaluation and to consider random demand. Fan et al. [26] discussed the use of RFID to address retailers' inventory shrinkage problems by using a newsvendor model.

Another widely discussed factor that should be considered in extending EPQ model is trade credit. Goyal [27] discussed the buyer's optimal ordering policy when delayed payment is allowed. Following Goyal [27], many scholars have discussed similar concerns (refer to Chang et al. [28] and Seifert et al. [29] for an extensive review of trade credit). For instance, few studies have developed EPQ models that include delay in payments. Feng et al. [30] investigated retailers' optimal cycle and payment time by using suppliers' cash discount and trade credit policy within the EPQ framework. Chen et al. [31] developed economic production quantity models for deteriorating items with upstream full trade credit and downstream partial trade credit. Tsao [32] developed a piecewise nonlinear model for a production–inventory model considering maintenance, variable setup costs, and trade credits.

The contributions of this study are as follows: first, no previous EPQ studies have considered RFID adoption, whereas this study estimates the influence of RFID adoption on efficiencies and costs and determines RFID investment levels (i.e., how much money). Second, few EPQ models have addressed the management of imperfect quality products; therefore, we consider reworking of imperfect products in the EPQ model to cope with more practical situations. Third, we develop an algorithm to solve the four-branch piecewise nonlinear problem and simultaneously determine the optimal production lot size and RFID investment level. Finally, we conduct numerical analyses to demonstrate the solution procedures and determine the effects of the relevant model parameters on decisions and costs.

We consider an imperfect EPQ model with RFID adoptions, trade credit, and reworking of imperfect products. We determine the optimal production cycle time and RFID investment levels for ordering, just-in-time (JIT), and operating efficiencies to minimize the total variable cost, which expands the traditional EPQ model to align with real-world scenarios.

2. Model formulation

We use following notations:

P_1 rework rate of imperfect quality items in units per year
P production rate in units per year
d production rate of imperfect quality items in units per year
C production cost per item
λ demand rate in units per year
x percentage of imperfect quality items produced
R ordering efficiency
C_k investment level for ordering efficiency
W JIT efficiency
C_v investment level for JIT efficiency
J operating efficiency
C_y investment level for operating efficiency
Q total items produced during a production cycle
H inventory level when rework of imperfect quality items is completed
H_1 inventory level when original production is completed
C_r repair cost per item of imperfect quality
C_s setup cost for each production run
h holding cost of perfect items per item per year
h_1 holding cost of imperfect quality items being reworked per item per year
S_p selling price of perfect quality items
M manufacturer's credit period offered by the supplier
C_p material purchasing cost per item, that is, the material cost that the manufacturer pays to the supplier
I_e interest rate earned per dollar per year
I_p interest rate charged per dollar per year