



Optimal Lot Sizing with Unreliable Production System

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Abstract—The classical lot sizing model deals with economic lot sizing for production in a deterministic framework. In real life, various forms of uncertainty affect the production. These include machine breakdown, quality variations, and so on. This paper develops a model with unreliable production systems and under alternative repair option strategies. © 2000 Elsevier Science Ltd. All rights reserved.

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1. INTRODUCTION

In a batch production system, items are produced in lots. Economic manufacturing quantity (EMQ) deals with the determination of the optimal lot size to minimize the total cost per item produced.

The classical EMQ model assumes a deterministic framework where demand per unit time is assumed to be constant, the setup and holding costs do not depend on the lot size and the process produces items at a constant rate. The optimal lot size to minimize the total cost (comprising setup and holding costs) can be found in [1,2].

In reality, there are many types of uncertainty which affect the production process and this in turn impacts on the economic lot size. Quality variations and unreliable production systems are two such uncertainties. A review of the literature in EMQ with these types of uncertainties is given in Section 2.

This paper deals with a new model for EMQ with unreliable production systems. When the production system breaks down, one has the option of either terminating the lot or continuing with the lot production after repair. Two types of repair are considered. The paper examines a combined repair and termination strategy and lot sizing to minimize the asymptotic cost per item produced. Section 3 gives the details of the model formulation. In Section 4, the analysis of the model is carried out and, in Section 5, a numerical example is presented. We conclude with a brief discussion of some topics for future research in Section 6.

2. REVIEW OF THE LITERATURE

A variety of lot sizing models with uncertainty have been studied. Porteus [3] and Rosenblatt and Lee [4] deal with models with uncertain quality. In these models, the process can go out of control after a random time and start producing nonconforming items. They show that the optimal lot size with quality uncertainty is smaller than that for the classical deterministic EMQ.

Meyer *et al.* [5], Cheng [6], Posner and Berg [7], Groenevelt *et al.* [8], and Berg *et al.* [9] have studied lot sizing with machine failure or unreliable production system. Groenevelt *et al.* [8] developed a lot sizing model where the machine has a constant failure rate. The model examines two policies—one involving repair and continuation and the other termination. Only one type of repair is considered and the machine goes back to the original conditions after each repair. It is shown that the optimal lot size is greater than that for the deterministic classical EMQ.

3. MODEL FORMULATION

It is assumed that the production system can fail while producing an item. When a new lot production starts, the machine can break down with probability γ_1 while producing an item. We consider two types of repair actions which we shall denote as Type 1 and Type 2. After Type 1 repair, the machine can fail again with probability γ_1 . After Type 2 repair, the probability of breakdown is γ_2 with $\gamma_2 > \gamma_1$. The costs for the two types of repair are C_{R1} and C_{R2} , respectively, with $C_{R1} > C_{R2}$.

The policy we have chosen in this model for termination or repair is as follows.

Let \tilde{L} denote the number of items produced since the start of lot production to when the machine has a breakdown. If $\tilde{L} \leq L_1$, then the machine is subjected to Type 1 repair and the lot production is continued. If $L_1 < \tilde{L} \leq L_2$ (with $L_2 > L_1$), then the machine is subjected to Type 2 repair and the lot production is continued. If $L_2 < \tilde{L} \leq L$ (with $L \geq L_2$), then the production is terminated. In the last case the lot size is \tilde{L} (a random variable). If no failure occurs during the production of items from $L_2 + 1$ to L , then the production ceases after the L^{th} item in the lot is produced. As a result, the lot size is L . We assume that all items produced when breakdowns occur are reworked and the rework cost is included in C_{R1} and C_{R2} .

As in the deterministic EMQ model, we consider the following costs. The setup cost for each lot production is C_s and the holding cost/item/(unit time) is c_h . Finally, we assume a constant demand D units/(unit time) and the production rate is P units/(unit time). The objective is to determine the optimal L , L_1 , and L_2 which minimizes the total asymptotic cost per item.

4. ANALYSIS OF THE MODEL

4.1. Asymptotic Cost Per Item Produced

Let \tilde{L}_k denote the number of items produced in lot k . \tilde{L}_k is less than L if the lot is terminated due to machine failure during the production of items from $L_2 + 1$ to L . If not, it is L .

Let \tilde{N}_{1k} and \tilde{N}_{2k} represent the number of Type 1 and Type 2 repairs in the k^{th} lot. Then, following the standard classical EMQ approach, the total cost associated with lot k is given by

$$\tilde{C}_k = C_s + \frac{c_h(1 - D/P)\tilde{L}_k^2}{2D} + \tilde{N}_{1k}C_{R1} + \tilde{N}_{2k}C_{R2}. \tag{1}$$

The asymptotic cost per item produced is given by

$$Z(L_1, L_2, L) = \lim_{m \rightarrow \infty} \left\{ \frac{\sum_{k=1}^m \tilde{C}_k}{\sum_{k=1}^m \tilde{L}_k} \right\}. \tag{2}$$

From the weak law of large numbers [10], we have

$$Z(L_1, L_2, L) = \frac{E[\tilde{C}_k]}{E[\tilde{L}_k]}. \tag{3}$$

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