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Economic production quantity model for items with imperfect quality

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Abstract

The assumptions necessary to justify the use of economic production quantity (EPQ/EOQ) models are rarely met. To provide mathematical models that more closely conform to actual inventories and respond to the factors that contribute to inventory costs, the models must be extended or altered. This paper hypothesizes a production/inventory situation where items, received or produced, are not of perfect quality. Items of imperfect quality; not necessarily defective; could be used in another production/inventory situation, that is, less restrictive process and acceptance control. The electronics industry gives good examples of such situations. This paper extends the traditional EPQ/EOQ model by accounting for imperfect quality items when using the EPQ/EOQ formulae. This paper also considers the issue that poor-quality items are sold as a single batch by the end of the 100% screening process. A mathematical model is developed and numerical examples are provided to illustrate the solution procedure. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Lot sizing; EPQ/EOQ; Screening cost/time; Imperfect quality

1. Background

Ever since the EPQ/EOQ (economic production/order quantity) inventory control model was introduced in the earliest decades of this century, it appears that it is still widely accepted by many industries today [1]. Regardless of such an acceptance, the analysis for finding an economic order quantity has several weaknesses. The obvious one is the number of unrealistic assumptions. This has led many researchers to study the EOQ extensively under real-life situations. The result was a vast literature on inventory and production models generalizing the economic order quantity (EOQ) model in numerous directions. Examples of such directions are surveyed below.

Yanasse [2] examined the anticipated price increase in a standard EOQ. Mehra et al. [3] analyzed the effect of inflation on order quantity decisions by means of a model that takes into account inflationary trends and time discounting over an infinite time horizon. Tersine and Barman [4] studied the problem of scheduling replenishment orders under the classical EOQ model when both quantity and freight rate discounts are encountered. Pantumsinchai and Knowles [5] presented solutions to the standard container size discount schedule for the economic order quantity (EOQ) case. Min and Chen [6] presented a profit

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Nomenclature

y	order size
c	unit variable cost
K	fixed cost of placing an order
P	percentage of defective items in y
$f(p)$	probability density function of p
s	unit selling price of items of good quality
v	unit selling price of defective items, $v < c$
x	screening rate
d	unit screening cost
T	cycle length
M	expected value of $1/(1-p)$

maximizing EOQ model is extended to the case of symmetric oligopoly consisting of several producers who compete with each other for the same potential buyers. Brill and Chaouch [7] presented a model that incorporates variations in the demand rate at random time points into the inventory planning decision.

A common unrealistic assumption in using the EOQ is that all units produced are of good quality [8]. Bose et al. [9] developed an EOQ inventory model for deteriorating goods with a linear, positive trend in demand allowing inventory shortages and backlogging. They also incorporated the effects of inflation and the time value of money into the model. Cheng [10] proposed an EOQ model with demand-dependent unit production cost and imperfect production processes. He formulated this inventory decision problem is as a geometric program (GP), and it is solved to obtain closed-form optimal solutions. Zhang and Gerchak [11] considered a joint lot sizing and inspection policy studied under an EOQ model where a random proportion of units are defective. They considered a model where the defective units cannot be used and thus must be replaced by non-defective ones. Zhang and Gerchak found that a considerable deviation from the optimal quantity will generally result in only a small increase in objective function value. Schwaller [12] presented a procedure that extends EOQ models by adding the assumptions that defectives of a known proportion were present in incoming lots and that fixed and variable inspection costs were incurred in finding and removing the items. Porteus [13] incorporated the effect of defective items into the basic EOQ model. He assumed that there is a probability q that the process would go out of control while producing one unit of the product. Rosenblatt and Lee [14] assumed that the time between the beginning of the production run; i.e., the in-control state; until the process goes out of control is exponential and that defective items can be reworked instantaneously at a cost. Rosenblatt and Lee [14] concluded that the presence of defective products motivates smaller lot sizes. In a subsequent paper, Lee and Rosenblatt [15] considered using process inspection during the production run so that the shift to out-of-control state can be detected and restoration made earlier. A joint lot sizing and inspection policy is studied under an economic order quantity (EOQ) model where a random proportion of units are defective. Those units can be discovered only through expensive inspections. Thus, the problem is bivariate. Both lot size and fraction to inspect are to be chosen. A model is analyzed in which the only penalty for uninspected defectives is financial. Zhang and Gerchak [16] considered where defective units cannot be used and thus must be replaced by non-defective ones. The effect of defective items on the lot sizing policy is noted in the works of Chakravarty and Shtub [17], Moinzadeh and Lee [18], Urban [19], and Anily [20].

This paper is organized as follows: 1. Background; 2. Introduction; 3. Mathematical model; 4. Numerical example; 5. Summary and conclusions.

2. Introduction

Consider the case where a lot of size y is delivered instantaneously with a purchasing price of c per unit and an ordering cost of K. It is assumed that each lot received contains percentage defectives, p, with a known probability density function, $f(p)$. The selling price of good-quality item is s per unit. Unlike the assumption of Rosenblatt and Lee [14] that defective items can be reworked instantaneously at a cost, in this paper it is assumed that defective items are sold as a single batch at