行政院國家科學委員會補助專題研究計畫成果報告

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※　　　　**在製程不完備的批量請購點模型中改善品質、**　　　　※
※　　　　　　　降低設置成本與縮短前置時間
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※　　**Quality Improvement, Setup Cost and Lead Time**　　※
※　　**Reductions in Lot Size Reorder Point Models**　　※
※　　**with an Imperfect Production Process**
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執行期間：89 年 8 月 1 日 至 90 年 7 月 31 日

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行政院國家科學委員會專題研究計畫成果報告

在製程不完備的批量請購點模型中改善品質、降低設置成本與縮短前置時間

Quality Improvement, Setup Cost and Lead Time Reductions in Lot Size Reorder Point Models with an Imperfect Production Process

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摘　　要

本研究旨在探討涵括變動前置時間與缺貨部份待補的批量/請購點存貨模型，其中生產過程是不完備的。文中，我們考慮改善生產過程品質與降低設置成本的投資方案，以及前置時間可藉由趕工縮短的情形。模型的目標是決定最佳化的訂購批量、請購點、品質水準、設置成本及前置時間，以使期望總成本達最小化。首先，我們假設前置時間內需求量的機率分配服從常態，對此模型建立一個求解問題最適解的演算法。接著，我們放寬需求量服從常態分配的假設，考慮分配型式為未知，但其平均數與標準差為已知的情形；我們運用分配自由大中取小準則，求此問題之最適解。最後，以兩個數值範例來說明所建構模型的結果。

關鍵詞：存貨、品質改善、設置成本降低、前置時間縮減、大中取小分配不拘程序

ABSTRACT

This paper investigates the lot size, reorder point inventory model involving variable lead time with partial backorders, where the production process is imperfect. The options of investing in process quality improvement and setup cost reduction are included, and lead time can be shortened at an extra crashing cost. The objective is to simultaneously optimize the lot size, the reorder point, the process quality, the setup cost, and the lead time. We first assume that lead-time demand follows a normal distribution and develop an algorithm to find the optimal solution. Then, we relax the assumption of normality to consider a distribution-free case where only the mean and standard deviation of lead-time demand are known. We apply the minimax distribution-free procedure to solve this problem. Furthermore, two numerical examples are given to illustrate the results of proposed models.

Keywords: Inventory; Quality improvement; Setup cost reduction; Lead time reduction; Minimax distribution-free procedure

SCOPE AND PURPOSE

In the classical production/inventory models, such as the economic order quantity (EOQ) model, the setup/ordering cost and lead time are constant and quality is assumed to be fixed. In other words, these elements are treated as givens and not subject to control. However, this may not be realistic. For example, in many practical situations, lead time can be shortened at an added cost, and hence lead time is controllable. The Japanese successful experience of using Just-In-Time (JIT) production has evidenced that substantial advantages and benefits can be obtained from shortening the lead time. The underlying goal of JIT is to eliminate waste; specifically, from an inventory standpoint, it is to produce small lot sizes with good-quality products. In addition to lead-time reduction, other actions such as setup cost reduction and quality improvement are also recognized as effective ways to achieve the JIT goal.

During the past two decades, the issues of investing in changing the levels of lead time, setup cost, and process quality in production/inventory systems have received a great deal of attention. We note that Silver, Pyke, and Peterson [1] call such issues as "changing the givens," with givens defined as the parameters that generally can be assumed as fixed. Concerning lead time reduction, Liao and Shyu [2] first presented a probabilistic inventory model in which the order quantity is predetermined and lead time is a unique variable. Ben-Daya and Raouf [3] extended Liao and Shyu's [2] model by considering both lead time and order quantity as decision variables. Ouyang, Yeh, and Wu [4] generalized the Ben-Daya and Raouf [3] model by allowing shortages with partial backorders. Moon and Choi [5] and Hariga and

Ben-Daya [6] revised the Ouyang et al. [4] model to include the reorder point as one of the decision variables. These papers [2-6] focused on the benefits from lead-time reduction where the quality-related issues are not taken into account and the setup cost is treated as a fixed constant.

In real a production environment, it can often be observed that there are defective items being produced. These defective items must be rejected, repaired, reworked, or, if they have reached the customer, refunded. In all cases, substantial costs are incurred. Therefore, it is more appropriate to take the quality-related cost into account in determining the optimal ordering policy. In the literature, Porteus [7] and Rosenblatt and Lee [8] are among the first to explicitly elaborate on the significant relationship between quality imperfection and lot size. Specifically, Porteus studied the effects of investment in quality improvement and setup cost reduction, alone and jointly. His work has encouraged many researchers to deal with modeling the quality improvement issue (see, e.g. Keller and Noori [9], Hong and Hayya [10], Hwang, Kim, and Kim [11], Moon [12]). Besides, the concept and framework of setup cost reduction was initially presented in another paper by Porteus [13]. Because by [13], there are several papers that discuss setup cost reduction (see, e.g. Keller and Noori [14], Paknejad, Nasri, and Affisco [15], Sarker and Coates [16]).

From the above literature review, we find that though there is no shortage of those studying lead time reduction, quality improvement, and setup cost reduction, little work has been done on considering them simultaneously. Silver [17] said that “if mathematical models are to be more useful as aids for managerial decision making, then they must represent more realistic problem formulations, particularly permitting some of the aforementioned givens to be treated as decision variables”. He then utilized two numerical examples to illustrate the effect of changing a given, one is determining the economic order quantity by changing the setup cost, another is selecting the reorder point by changing the standard deviation of demand (forecast errors) over the lead time. Following the theme presented in [17], we propose a model in which the lot size, reorder point, process quality, setup cost, and lead time are decision variables.

In this study, the task is to extend Moon and Choi’s [5] model to include the possible relationship between quality and lot size and then investigate the joint effects of quality improvement and setup cost reduction on the model. That is, we consider a lot size, reorder point inventory model in which shortages are allowed with partial backorders and the production process is imperfect. We simultaneously optimize the lot size, reorder point, process quality, setup cost, and lead time with the objective of minimizing the total relevant costs. We first consider the case where lead-time demand follows a normal distribution and develop an algorithm to find the optimal solution. Then, we relax the assumption on the distributional form of lead-time demand and merely assume that the first and second moments are known and finite. For this case, we solve the problem by applying the minimax distribution-free approach, originally proposed by Scarf [18] and disseminated by Gallego and Moon [19]. Furthermore, we note that the previous work on the distribution-free approach, setup reduction, and lead time reduction are well documented in Silver et al. [1].

RESULT AND DISCUSSION

In this paper, we extend Moon and Choi’s [5] model to include the possible relationship between quality and lot size and then investigate the joint effects of quality improvement and setup cost reduction. We simultaneously optimize lot size, reorder point, process quality, setup cost, and lead time, with the objective of minimizing the total relevant cost. The models are utilized with complete and partial information about the lead-time demand distribution. An algorithm for finding the optimal solution is developed, and two numerical examples are given to illustrate the results.

The issues of quality improvement, setup cost, and lead time reductions studied in this article belong to ‘*changing the givens*’ approach recommended in Silver et al. [1]. They are consistent with the JIT philosophy. Also, we note that this article employs a logarithmic investment function for quality improvement and setup cost reduction. The logarithmic function is one of many possible investment functions, and it may be an interesting research topic to consider a general investment function (see, e.g. [10, 12]).

SELF-EVALUTION

This research corresponds to the original plan and has attained its aim. Hence, the paper is of great academic value and suitable for publication in academic journals. It is now being accepted by *Computers & Operations Research*.

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