# 行政院國家科學委員會專題研究計畫　成果報告

## 具隨機需求與可控制前置時間的整合性存貨問題之分析

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# 行政院國家科學委員會專題研究計劃成果報告

## 具隨機需求與可控制前置時間的整合性存貨問題之分析

The study on the integrated inventory models for stochastic demand and controllable lead time

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## 中文摘要

在近代生產管理方面，日本企業界提出及時(Just-in-Time)存貨管理系統以提高企業的生產力，且效果頗為顯著。所謂 JIT 存貨管理系統是強調高品質、低存貨、及短的前置時間(lead time)。欲達成 JIT 的目標，投資資金以降低前置時間，被認為是可行且有效的方法；換言之，傳統存貨策略所經常假設的固定且不可控的前置時間，事實上是可以控制的。縮短前置時間可以降低安全存量、減少資金積壓、提高對顧客的服務水準、並增加企業的競爭能力。尤其在現今競爭激烈的工商業時代，凡事講求時效，能否有效縮短前置時間已成為企業提升競爭能力不可或缺的重要關鍵。

再者，長久以來，存貨模式大都是基於買方或賣方單方面的考量，來探討生產及訂購策略等問題，如此往往使雙方資訊無法整合而造成損失。近年來，及時化的製造策略受到廣泛利用，由於其專注於買方與賣方的整合，因此需要買方與賣方能夠充分合作，方可利用雙方資訊的整合，訂定合理的長期採購合約，做到真正的及時化採購，從而降低相關存貨系統的總成本。

本研究計劃之主要目的，乃在考慮當需求不確定，且前置時間長度可控制的情況下，如何整合買方和賣方的製造與訂購策略，並提出兩個整合存貨模型。在本研究中，我們首先假設前置時間內的需求量服從常態分配，其次探討前置時間內需求量的機率分配為未知的情形，並且利用大中取小分配不拘程式求解。我們亦分別針對此兩種情形(前置時間內需求量的機率分配為常態分配或分配不拘)建立求得最適生產、訂購策略之演算法，並利用數值範例說明買賣雙方整合後的利益，確實是高於整合前的個別利益。同時，本研究也將分析各參數變動對於決策所造成的影響，作為提供給管理者之重要參考依據。

關鍵詞：整合性存貨模式、隨機需求、前置時間、大中取小分配不均程式

## ABSTARCT

Among the modern production management, the Japanese successful experiences

of using Just-In-Time (JIT) production show that the advantages and benefits associated with the efforts to control the lead-time can be clearly perceived. The goal of JIT inventory management philosophies is the focus that emphasizes high quality, keeps low inventory level and lead-time to a practical minimum. Shortening the lead time is recognized as the feasible and effective way to achieve the goal of JIT. In other viewpoints, the factor (lead time) mentioned above is often assumed as fixed constant and uncontrollable in the traditional inventory models, but is controllable in practice. By reducing lead time, we can lower the safety stock, reduce the loss caused by shortage, improve the service level to the customer, and increase the competitive ability in business.

Moreover, most inventory models considered so far assume only one single facility(e.g., a buyer or a vendor) managing its inventory policy so as to minimize its own cost or maximize its won profit. This one-side-optimal-strategy is not suitable for today's global markets anymore. Recently, the issue of JIT has received a lot of interest. Most JIT research has been focused on the integration between vendor and buyer. Once the long-term relationship between both facilities has been built up, both parties can cooperate and share information to reach better benefits. By applying information technologies, order processing time can be reduced and information exchange will become more conveniently, and then the ultimate goal of JIT can be fulfilled and the total costs in inventory system can be reduced.

The purpose of this research is to make a systematic study for the integrated vendor-buyer cooperative inventory models under simultaneously taking account of the stochastic demand and controllable lead time. In this proposal, we first consider the case where the demand of lead time follows a normal distribution, and then consider the case that the form of the distribution function of lead time demand is unknown and apply the minimax distribution free procedure to solve the optimal solution. We also develop an effective algorithm to obtain the optimal ordering strategy for each case (the lead time demand follows normal distribution or distribution free), and numerical examples are used to illustrate the benefits of integration. Furthermore, for all models proposed in this proposal, the effects of parameters will be also included for the decision-making references.

Keywords: integrated inventory model, stochastic demand, lead time, minimax distribution-free procedure.

## SOURCE AND PURPOSE

Most inventory models considered so far assume a single facility (e.g., a buyer or a vendor) managing its inventory policy in order to minimize its own cost or maximize its own profit. This kind of one side optimal strategy seems not suitable for today's global markets any more. In order to face the fierce competition, companies search for new technologies and strategies to allow them to reduce costs and better compete in global markets. Strategies such as just-in-time manufacturing, *kanban*, lean manufacturing, total quality management, and others became very popular and performed well in reducing manufacturing costs. In the last few years, many of these companies discover that the next step they need to take to increase profit or decrease costs is effective supply chain management. Supply chain management is defined as 'a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements' (Simchi-Levi *et al*. [1]). Therefore, integrated inventory management has recently received a great deal of attention (e.g. Viswanathan [2], Villa [3], Yang and Wee [4], Amasaka [5], and Bylka [6]).

One of the first works dealing with the integrated vendor-buyer inventory problem is due to Goyal [7]. He developed an integrated inventory model for a single supplier – single customer problem. Banerjee [8] generalized Goyal's [7] model by assuming that the vendor is manufacturing at a finite rate and considered a joint economic-lot-size model where a vendor produces to order for a buyer on a lot-for-lot basis. Goyal [9] extended Banerjee's [8] model by relaxing the lot-for-lot policy and suggested that the vendor's economic production quantity should be an integer multiple of the buyer's purchase quantity. Ha and Kim [10] further extended the concept and proposed an integrated lot-splitting model of facilitating multiple shipments in small lots. In a recent paper, Huang [11] developed an integrated vendor-buyer cooperative inventory model for items with imperfect quality. Previous researches on the integrated vendor-buyer inventory problem most focused on the production shipment schedule in terms of the number and size of batches transferred between both parties under deterministic demand.

When the demand during the cycle period is not deterministic but is stochastic, lead time becomes an important issue and its control leads to many benefits. In fact, lead time usually consists of the following components (Tersine [12]): order preparation, order transit, supplier lead time, delivery time, and set-up time. In many practical situations, lead time can be reduced by adding an additional crashing cost; in other words, it is controllable. By shortening the lead time, we can lower the safety stock level, reduce the stock-out loss and improve the customer service level so as to gain competitive advantages in business. Liao and Shyu [13] first presented a probability inventory model in which lead time is the unique decision variable. Later, Ben-Daya and Raouf [14] extended Liao and Shyu's [13] model by considering both lead time and ordering quantity as decision variables where shortages are neglected. Ouyang *et al.* [15] generalized Ben-Daya and Raouf's [14] model by allowing shortages. Moon and Choi [16] and Hariga and Ben-Daya [17] further improved and revised Ouyang *et al.*'s [15] model by considering the reorder point as one of the decision variables. The above inventory models focused on determining optimal policy for the buyer only. Such models neglect the opportunity that buyer and vendor can negotiate and cooperate with each other to obtain a better joint policy.

Recently, Pan and Yang [18] improved Goyal's [9] model by considering lead time as a controllable factor in the model and obtained a lower joint total expected cost and shorter lead time. We notice that the reorder point in the above models is either neglected or assumed to be a parameter, and shortages are not allowed.

However, in most ERP (Enterprise Resource Planning) system, *min-max inventory policy* is one of the attractive policies used in practice. This policy means whenever the inventory position reaches the reorder point (*min* quantity), the inventory level should be raised up to a given target level (*max* quantity). Therefore, we think decision making in reorder point is as important as in ordering quantity.

In this study, we assume long-term strategic partnerships between buyer and vendor are well established. Therefore, buyer and vendor are willing to cooperate and share information with each other to benefit both parties. Based on this assumption, we consider an integrated production inventory model with shortage permitted and assumed that lead time is controllable. The purpose of this paper is to extend Pan and Yang's [18] model by simultaneously optimizing ordering quantity, reorder point, lead time and the number of lots delivered in one production cycle. Firstly, we assume that the lead time demand follows a normal distribution, and then try to find the optimal ordering policy. We next relax this assumption and merely assume that the first and second moments of the probability distribution of lead time demand are known and finite, and then solve this inventory model by using the minimax distribution-free approach. Further, numerical examples are provided to illustrate the benefits of integration.

## RESULT AND DISCUSSION

The purpose of this proposal is to make a systematic study for the integrated vendor-buyer cooperative inventory models under simultaneously taking account of the stochastic demand and controllable lead time. In the model, the shortage during the lead time is permitted, and lead time can be reduced at an added cost. Two models are considered here. We first consider the case where the demand of lead time follows a normal distribution, and then consider the case that the form of the distribution function of lead time demand is unknown and apply the minimax distribution free procedure to solve the optimal solution. We also develop an effective algorithm to obtain the optimal ordering strategy for each case (the lead time demand follows normal distribution or distribution free). To help managers understand the effects of optimal solution on changes in the value of the different parameters associated with the inventory system, sensitivity analysis is also performed in the proposal. This research develops a more realistic inventory model, which can enhance the efficiency of an inventory manager in decision-making.

## SELF-EVALUATION

This research corresponds to the original plan and has attended its aim. Hence the paper is of great academic value and suitable for publication in academic journals. International Journal of Production Economics now accepts it.

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