行政院國家科學委員會專題研究計劃成果報告

電子資訊產業供應鏈管理--子計劃二：
晶圓製造設備備用零件及光罩需求管理之研究

A Study of Demand Management for Spare Parts and Mask in Wafer Manufacturing

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1.中文摘要(關鍵字：存貨政策、備用件、顧客服務水準、存貨成本、存貨週轉率)

本研究的目的在發展一套適合備用件供應的存貨政策。有鑑於此，本研究根據 VMI 的觀念，提出一（t_i, s, S）存貨政策，同時考量需求和供應的層面，並結合連續盤檢的（s, S）型存貨政策。此一存貨政策具有提昇顧客服務水準、降低總存貨成本，以及提高存貨週轉率等潛在優點。

根據本研究所得的結果，有充分的證據指出，在相同的存貨水準之下，以 VMI 為基本理念所發展出的（t_i, s, S）存貨政策較傳統的（s, S）存貨政策能獲致較佳的顧客服務水準和較低的總存貨成本。換言之，採用（t_i, s, S）存貨政策對於提昇顧客服務水準和降低總存貨成本有正面的影響。

Abstract (Keywords: inventory policy, spare part, VMI(vendor managed inventory), customer service level, inventory cost, inventory turns.)

The objective of this research is to develop an appropriate inventory policy for the spare part supplier. A VMI-based inventory policy, (t_i, s, S), which can be properly referred to as a stocking policy for customer i, for joint consideration of demand and supply by incorporating a continuous review (s, S) type inventory policy. The potential advantage of the developed inventory policy is to improve customer service level, to reduce total inventory cost, and to increase inventory turns.

The result of this research presents sufficient evidence to indicate that the VMI-based (t_i, s, S) policy results in higher customer service level and lower total inventory cost than (s, S)policy does under same stock levels. In other words, when adopting the (t_i, s, S) policy, positive effects in the increase of customer service level and decrease of total inventory cost can be obtained.

2.Introduction

This research explores the inventory policy of a spare part supplier in semiconductor equipment industry in Taiwan. The supplier sells equipment to semiconductor manufacturing factories. Most of the equipment the supplier sells is very expensive and costs millions of U.S. dollars. The equipment is critical to the processes in semiconductor manufacturing and its failure may lead to huge lost. Not only selling the equipment, the supplier also provides spare parts of the equipment. Efficient service is essential as it affects the sales of the equipment directly. Inventory management of the spare parts, therefore, is one of the most important activities for the supplier.

If parts are understocked, customer demands cannot be satisfied and customer complaints will emerge. On the other hand, if parts are overstocked, inventory carrying costs will be high which may cause financial problems. Situations where some parts have very high inventory and some others are in shortage are not unusual. In such a service system, an efficient inventory policy is essential.

The spares department of the supplier is responsible for spare part supply. For the ordinary failures of spare parts or at the preventive maintenance, the supplier sells the corresponding spare parts to meet customer demand. The spare parts are procured mostly from the overseas headquarters and partly from local vendors depending on the part characteristics and the existence of the corresponding vendor. At present, the inventory policy is carried out with the so called (s, S) policy, based on the planner's experience.

The objective of this research is to develop an appropriate inventory policy for the spare part supplier under the given environment described above. The potential advantages of the developed inventory policy will be：

- to improve customer service level;
- to reduce total inventory cost;
- to increase inventory turns.

In recent years, the practice of VMI(Vendor Managed Inventory) has been widely discussed. ［Robin, 1995］VMI represents a partnership between the supplier and the customer. It lowers mutual operating costs, optimizes shipment quantities, and achieves excellent service level for the suppliers' customers.

Based on the concept of VMI, this research proposes a new policy, (t_i, s, S), which can be properly referred to as a stocking policy for customer i, for joint consideration of demand and supply by incorporating a continuous review (s, S) type inventory policy, where s is the reorder level and S is the maximum stock level. The operating principle for the inventory policy can be stated as follows :

An amount of spare units must be ordered from the vendor to bring inventory up to a maximum stock level S when inventory depletes to a reorder level s. In addition, a delivery time to customer i is scheduled for t_i days after the corresponding customer order issued date. When the scheduled periodic delivery time arrives, spare units are delivered to customer i in advance provided the spares are available. Otherwise, the spares are delivered as the stock is replenished. If spares are ordered by customer i before the scheduled time, the spares will be delivered as soon as they are available.

Optimal values of the decision variables, (t_i, s, and S), are determined by maximizing customer service level and minimizing total inventory cost per period, where the cost components include inventory related costs for both the supplier and customers. Because of the complexity in formulating a mathematical model for this multi-unit inventory environment, a simulation procedure is employed. Although a user-written simulation program in a general purpose language like C, FORTRAN, or PASCAL could be more flexible in conjoining certain analytical functions, it is usually preferable to use a simulation language such as SLAM, SIMAN, SIMSCRIPT, etc., because of the many built-in functions.〔Kabir and Farrash, 1996〕For modeling a complex system like an inventory management system, the use of a simulation language can save time and effort needed for modeling and program development.〔Pritsker, 1986〕

This research will describe the construction of two SLAM network models for the (s, S) policy and (t_i, s, S) policy respectively and develop a simulation procedure to select the appropriate inventory policy for the supplier based on the result of simulation experiment.

Experimental design is conducted to compare the performance between (s, S) policy and (t_i, s, S) policy. The dominant policy will then be adopted and the level of each decision variable leading to the best performance will be determined by the result of experimental design. The effects of different factors including cost elements, item demand characteristics, and lead time distributions will also be considered.

3.Methology

The objective of this research is to develop an appropriate inventory policy for the spare part supplier in semiconductor equipment industry. The inventory policy may be formulated in a mathematical model. The objective function of the inventory policy is to maximize customer service level and minimize total inventory cost. The constraint may include the limitation of maximum stock quantity, the restriction of inventory replenishment lead time, the stochastic customer demand to face, the minimum inventory turns to maintain, the minimum customer service level to fulfill, the maximum inventory cost to endure, etc. The solution is to find the decision variable of the inventory policy which can achieve the objective function and satisfy the constraint simultaneously.

However, a mathematical model may be difficult to formulate to deal with different demand distributions and the optimal solution of the decision variables may be hard to obtain. On the contrary, it is possible to construct inventory policy in a simulation model. The use of simulation to construct inventory model in this research is suitable because it can clearly and fully model the environment and control the factors affecting the inventory system.

The continuous or periodical review (s, S) policy is the most common policy adopted widely in industry because it is easy to execute. The task is to monitor the inventory position continuously or periodically. An amount must be ordered to bring inventory up to a desired level S when inventory depletes to a reorder level s. However, this policy may suffer by overstocking or understocking when customer demand fluctuates intensively.

(t_i, s, S) policy is the spare parts stocking policy originally adopted by factories which have many types of manufacturing equipment in the shop floor. Kabir and Farrash [1996] made much improvement on this policy. Their research jointly concerns age replacement and spare provisioning by incorporating a continuous review (s, S) inventory policy.

The (t_i, s, S) policy which this research proposes is different from the original one. This research attempts to explore the VMI-based (t_i, s, S) policy for the spare part supplier that has many customers. The basic idea of this policy is to reduce the risk of facing sudden customer demands or inventory shortages by means of periodic delivery in advance. The supplier can periodically deliver spare parts to its customers in order to reduce the demand uncertainty. Consequently, it gives safety stock more capability to serve as a buffer of demand fluctuations. Thus, the spare part supplier can prevent overstocking or understocking while storing the minimum stocks needed and maintaining a satisfactory customer service level.

The spare part suppliers of semiconductor equipment industry often face sudden and uncertain customer demands. In order to penetrate the market, many high-tech companies in Taiwan tend to provide high customer service level by means of increasing the safety stock level. It results in high inventory cost and interests losses. In view of this, we believes that the VMI-based (t_i, s, S) policy is appropriate for the spare part supplier in this industry and this research is worth doing.

4 Research Procedure

This research will be proceeded step by step as follows.

1. To consult relevant people of the supplier and collect necessary data for the convenience of identifying key factors of inventory management policy. The historical customer demand patterns, for example, are the important and necessary data for this research.
2. To list key factors which affect the inventory management system in order to determine the necessary components in the simulation model. The key factors include controllable and uncontrollable factors for the spare part supplier. Customer demand patterns and lead time patterns are uncontrollable factors, while the inventory policies are controllable ones.
3. To adopt the key factors into appropriate simulation components so as to build the inventory model incorporating the inventory policy. The components include attributes and variables of which the simulation entities carry. Part ID, time to demand, type of supply, replenishment lead time, and so on, are some components to be considered.
4. To build two simulation models, one for the (s, S) policy and the other for the VMI-based (t_i, s, S) policy. Because the two inventory policies are distinct, two simulation models need to be constructed and run separately.
5. To run simulation using the inventory models constructed in step 4 under SLAM system. The relevant parameters for the inventory policies are selected in the range of management specification. Customer demand and lead time distributions are acquired from fitting the historical data provided by the supplier.
6. To design experiments to analyze the outcome of each simulation run and compare the performance of the two inventory policies. The key performance indices of the inventory policies comprise customer service level and total inventory cost. The inventory turns will also be evaluated.
7. To have discussion and make conclusions. From the analysis of simulation outcome, the feasibility of VMI-based (t_i, s, S) policy for the supplier will be evaluated, and the appropriate inventory policy for spare part suppliers in semiconductor equipment industry will then be suggested.

5 Key Factors and Performance Indices to Inventory Policies

An inventory management system is composed of policies and processes that work together to accomplish the goal of a company. Thus, in dealing with an inventory system, it is significant to first identify pertinent key factors which influence the policies and processes.

From the supplier's point of view, key factors can be divided into two categories, controllable factors and uncontrollable ones. Customer demand patterns and lead time patterns are uncontrollable factors because the supplier cannot dominate customer demands and its vendor's delivery lead time. However, the inventory policies are controllable factors. The inventory policy is specified by the management and the reason is self-evident.

It is significant to choose appropriate performance indices for inventory policies. The concerns in this research include customer service level and total inventory cost. The inventory turns will also be evaluated.

The customer service level is measured as a whole from the average fulfillment of individual customer orders. If inventory shortages occur, this means that the delivery cannot be executed within a predetermined order promising date or the order quantity cannot be met, the customer service level of the supplier drops. Therefore, the customer service level can be defined as : $CSL = \frac{}{}\%$, where CSL represents customer service level, M represents the number of customer orders which are satisfied by the supplier in a given period, and O represents total number of customer orders which the supplier promises in a given period.

Total inventory cost contains inventory related costs for both the supplier and its customers. The major concern of these costs is carrying cost because of the high price characteristics of spare parts for semiconductor equipment. In addition, the inventory carrying cost for customers is also counted in the total inventory cost while adopting the VMI-based (t_i, s, S) policy. The conception is that when the supplier delivers spare parts to a customer in advance, the inventory carrying cost of the customer can be treated as a penalty cost for the supplier until the time when the customer really needs it. Inventory replenishment cost and stockout cost are also included in the cost function. Therefore, the cost function can be defined as : $TC = CS + CC + RC + SC$, where TC is total inventory cost, CS is inventory carrying costs of the supplier, CC is the inventory carrying costs of customers, RC is inventory replenishment cost, and SC is stockout cost.

Inventory turns is a convenient performance measure of how effectively inventories are being used. It is calculated as : $IT = S / I$, where IT represents inventory turns, S represents the annual cost of goods sold, and I represents average inventory in dollars. Theoretically, the less inventory in the warehouse, the higher inventory turns will be obtained which results in less inventory carrying cost as well. However, customer service level may be degraded while attempting to increase inventory turns. Therefore, this research intends to select a suitable inventory policy ((s, S) or (t_i, s, S))to reduce total inventory cost and satisfy the desired customer service level simultaneously while maintaining the inventory turns at a reasonable level.

6 Discussion and Conclusion

In the industrial case study, a performance comparison between (s, S) policy and the VMI-based (t_i, s, S) policy applying experimental design is made. The result presents sufficient evidence to indicate that (t_i, s, S) policy results in higher customer service level and lower total inventory cost than (s, S) policy does under the same stock level. In other words, adopting the policy of periodic delivery in advance, positive effects in the increase of customer service level and in the decrease of total inventory cost can be obtained. It means that the supplier can improve customer service level and decrease total inventory cost while maintaining the level of inventory turns without increasing stock level by adopting (t_i, s, S) policy. Therefore, the VMI-based (t_i, s, S) policy is identified as the dominant policy in this case study. Although only three critical spare parts are analyzed, the inference can be applied to general spare parts as long as the demand variations of the spares are not too large.

A 3^3 factorial design of (t_i, s, S) policy for the three performance indices is made and the following conclusion is drawn. Both t_i and s affect the customer service level but S does not. Furthermore, all three decision variables affect the total inventory cost. In respect to inventory turns, both s and S have significant effect but t_i does not.

From the result of Duncan's multiple range test, it reveals that combinations of high s, low S, and low to medium t_i will result in high customer service level and low inventory cost. Similarly, as long as s and S are at medium levels, high customer service level and low inventory cost will be generated no matter what t_i value is. In general, all three levels of t_i will give higher customer service level and lower inventory cost if s and S are properly set at the corresponding levels.

To sum up, the contribution of this research can be stated as follows. We propose a VMI-based inventory policy, (t_i, s, S), for a spare part supplier in semiconductor industry in Taiwan. The result of simulation experiment concludes that applying periodic delivery in advance can effectively improve customer service level and decrease total inventory cost while maintaining a desired level of inventory turns. The performance of (t_i, s, S) policy proposed by this research is significantly better than that of (s, S) policy widely used in industry under the same stock level. Therefore, the VMI-based inventory policy is favorable.

Future research on the inventory policy of spare part supplier can be focused on :

- Formulate the impact on the competitors of the supplier since customers may purchase spare parts from a second source if the customer service level cannot be satisfied.
- Consider the relationship between customer interarrival time and the corresponding order quantity while describing the customer demand characteristics.
- Investigate the limitation on different types of spares and the corresponding customer demand patterns while adopting the VMI-based (t_i, s, S) policy.
- Discuss the degrees of the effects from different factors, such as cost elements, item demand characteristics, lead time distributions, etc.

7.計 畫 成 果 自 評

1. 研究內容與原計畫相符程度說明（如低於 50，請將不符處說明於後）

   95

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   可　□發明　□新型　□新式樣

   不可，請說明：

   因本計畫之研究方法，屬管理理論分析模式建立及實例驗證，並無適當專利可申請。

6. 本研究成果發表之建議：

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7. 綜評（請就本研究之核定經費額度與報告之結果、成效、主要發現及其他有關價值等作一綜合評估）

本計畫之執行成效良好，可應用於實務界，主要成效請見本精簡報告書之“結論”部分。

※對本研究成果報告自評等第：□極佳 ☑佳 □中 □可 □劣

8. References

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