# 國立政治大學

## 企業管理研究所(MBA 學位學程)

碩 士 學 位 論 文

# 供應商管理庫存：

在跨國照明公司的影響

# Vendor Managed Inventory Application:

Case based on a Multinational Lighting Company

指導教授：洪叔民

研 究 生：明琳

中華民國 104 年 7 月



DOI:10.6814/NCCU202101735

DOI:10.6814/NCCU202101735

DOI:10.6814/NCCU202101735

# Acknowledgments

First and foremost, praises and thanks to God, the Almighty, for letting me through all the difficulties and challenges. I have experienced your guidance and your power day by day.

I cannot express enough thanks and give my deep appreciation to my boss Dr. James Pan who encouraged me to and allowed me to continue my superior studies in Taiwan.

I would like to express my sincere gratitude to my advisor Dr. Horng, Shuw-Min who made this work possible. His guidance and advice carried me through all the stages of writing my project. I could not have a better advisor and mentor for my research.

My sincere thanks also go to my committee members for letting my defense be an enjoyable moment, and for your brilliant comments and suggestions, thanks to you.

I am extremely grateful to my grandparents Victor Mineur, Gilda Ayala de Mineur and my family as a whole for their love, prayers for their continuous support and understanding when undertaking my studies. Your prayer for me was what sustained me this far.

Finally, my thanks go to all the people in Taiwan who have supported me in this long stay.





DOI:10.6814/NCCU202101735

# 摘要

近年來，台灣企業在 LED 產業中獲得了較大的市場份額。 他們的業務和製造業務也逐年增加。 台灣在全球電子產品供應鏈中扮演著重要角色。 台灣企業在節能減排產品方面也處於世界領先地位。 這包括製造發光二極管 (LED) 和太陽能電池的公司。 這兩款產品均屬於台灣綠色能源行業增長最快的細分市場。

台灣公司的顯著發展和進步，導致形成具有顯著優勢的大產業，使台灣公司成為任何產品或原材料的優秀供應商、設計支持和快速商業化。 最近的報導指出，台灣排名的上升主要歸功於研發方面的強勁表現，尤其是在專利技術和原始設計製造（ODM）方面。

台灣的照明產業已經發展到一個大規模多元化的規模，許多大公司將製造單位與品牌分開，以便在這些運營領域實現更大的專業化。 為促進台灣產業的發展，政府加大營銷力度，以提高台灣經濟貿易在海外的競爭力。台灣品牌計劃涉及兩個最終目標：一是整合資源，協助建立品牌，創造良好的發展環境。 二是助力台企品牌發展，提升台灣國際品牌在海外的價值。

本文通過定義和分析與該主題相關的最重要元素，介紹了庫存管理和 VMI（供應商管理庫存）模型在一家生產 LED 燈管的跨國公司中的應用。 此外，本文還旨在對使用 VMI 計算補貨量的方法中提出的兩種方法進行比較評估，並將其與研究中實施的方法進行比較。

*關鍵詞：LED 照明、供應鏈管理、庫存管理、VMI、ROP、安全庫存、定額訂單、定間隔模型*



DOI:10.6814/NCCU202101735

# Abstract

In recent years, Taiwan companies have acquired a large market share in the LED industry. Their business and manufacturing operations have also increased yearly. Taiwan plays a key role in the global supply chain for electronics products. Taiwan companies are also among the world leaders in energy saving and reduce carbon emissions products. This includes companies that manufacture light-emitting diodes (LEDs) and solar cells. Both products are among the fastest growing segments in Taiwan's green energy industry.

The significant development and advance of Taiwanese companies, has led to the formation of large industries that offers significant advantages, making Taiwan companies an excellent supplier, design support and rapid commercialization of any product or raw materials. Recently reports noted that Taiwan's rise in ranking is owed mainly to the strong performance in R&D, particularly regarding patented technology and Original Design Manufacturing (ODM's).

The Taiwan's lighting industry has grown to a size that has resulted in substantial diversification, and many large companies have separated manufacturing units from branded to allow greater specialization in these operations areas. To promote the industry in Taiwan, the government has made the increase of marketing to raise the competitiveness of Taiwan's economy trade at overseas. There are two ultimate goals involved in the Branding Taiwan program: the first is integrate resources to assist in the establishment of brands and create a favorable development environment. The second is to aid Taiwan enterprises in brand development and increase the value of Taiwan's international brands at overseas.

This paper presents the application of Inventory Management and model of VMI (Vendor Managed Inventory) in a transnational company that produces LED tubes, by defining and analyzing the most important elements related to this subject. In addition, this paper aims to also present a comparative evaluation of two methods proposed in the methodology for calculating the amount of replenishment with VMI, which are compared with the method implemented in the study.

*Keywords: LED lighting, Supply Chain Management, Inventory Management, VMI, ROP, Safety Stock, Fixed Amount Order, Fixed Interval Model*



DOI:10.6814/NCCU202101735

# Table of Contents

***CHAPTER I INTRODUCTION*** ..... ***1***

1.1 Rationale of Research ..... 1

1.2 Statement of the problem ..... 2

1.3 Research Questions and the Objectives ..... 3

***CHAPTER II LITERATURE REVIEW*** ..... ***4***

2.1 Inventory Management ..... 4

2.2 Vendor Managed Inventory (VMI) ..... 8

*History and development* ..... 8

*Concept* ..... 9

*VMI Models* ..... 9

2.3 Information systems associated with Inventory management ..... 11

2.4 Material Requirements Planning (MRP) ..... 12

***CHAPTER III CASE DESCRIPTION*** ..... ***14***

3.1 Lighting Industry ..... 14

3.2 Luxul Technology Incorporation ..... 16

*History and Background* ..... 16

*Company Product* ..... 18

*Operational Management* ..... 21

*Current Issues* ..... 23

*Empirical Analysis* ..... 23

3.3 Economic Order Quantity Model (EOQ) ..... 26

3.4 Total Inventory Cost ..... 27

3.5 Optimal Policy ..... 60

*Fixed-Order-Interval Model* ..... 62

*Quantity Discount Model* ..... 72

3.6 Internal VMI ..... 76

***CHAPTER IV CONCLUSIONS AND SUGGESTIONS*** ..... ***81***

***REFERENCES*** ..... ***82***



DOI:10.6814/NCCU202101735

# Table of Figures

*Figure 1. Collaborative Planning Model flow.....10*
*Figure 2.Cost Transference Model flow.....10*
*Figure 3.Fully Automated Replenishment Model Flow .....11*
*Figure 4. LED Industry 2014 Market share distribution. .....15*
*Figure 5. Manufacturing Operation.....17*
*Figure 6.Total T8/4FT/4000K Tubes sold in USA in 2014.....18*
*Figure 7.EazyLux LED tubes.....19*
*Figure 8.LED Lamp parts .....20*
*Figure 9.Company's suppliers map.....21*
*Figure 10. Luxul's Transnational Operations mode .....22*
*Figure 11.EOQ for constant Demand & Lead Time .....26*
*Figure 12.Reorder Point with constant demand.....29*
*Figure 13.Safety Stock.....30*
*Figure14.Service Level or % of time inventory will meet demand during lead time.....30*
*Figure 15. Inventory with Reorder Point .....62*
*Figure 16.Transnational ERP system.....79*

# Table of Tables

*Table 1.Luxul's LED tubes classification .....19*
*Table 2 . Shipments quantity from Taiwan to USA in 2014. .....24*
*Table 3. Air freight quotation provided by Luxul's forwarders.....24*
*Table 4. Packing information for 4ft tubes' PCBA shipments. .....25*
*Table 5. Expected Number Out of Stock versus Standard Deviation.....31*
*Table 6. Luxul exported PCBA record in 2014 (Eazylux T8/4ft/4000K).....32*
*Table 7. Shipping PCBA T8/4FT/4000K by air freight cargo from Taiwan to USA (Santa Clara-California). .....33*
*Table 8. Shipping by air freight reference. .....34*
*Table 9. Total cost results for 2 days intransit mode.....38*
*Table 10. Optimal Quantity and Reorder Point with Constant Demand using a 2 days intransit 39*
*Table 11 Optimal Quantity and Re-order Point with a 50% Service level using 2 days intransit.40*
*Table 12 Optimal Quantity and Re-order Point with a 95% Service level for a 2 days intransit .42*


DOI:10.6814/NCCU202101735

*Table 13 Optimal Quantity and Re-order Point with a 99% Service level using 2 days intransit 44*
*Table 14 Total cost results for 3~5 days shipping days.....52*
*Table 15 Optimal Quantity and Reorder Point with Constant Demand using 3~5 days intransi .53*
*Table 16 Optimal Quantity and Re-order Point with a 50% Service level for a 3~5 days intransit .....55*
*Table 17 Optimal Quantity and Re-order Point with a 95% Service level for a 3~5 days intransit .....57*
*Table 18 Optimal Quantity and Re-order Point with a 99% Service level for a 3~5 days intransit .....59*
*Table 19. Total cost results for 2 and 3~5 days intransit .....60*
*Table 20. Shipping by Sea freight from Taiwan to USA (Santa Clara- California).....64*
*Table 21 Optimal Quantity and Re-order Point with a 95% Service level.....67*
*Table 22 EOQ Model with Quantity Discounts .....75*




DOI:10.6814/NCCU202101735

# Chapter I Introduction

## 1.1 Rationale of Research

Extreme competitiveness in today's economy and the effects of globalization is forcing industries to find new ways of interacting and satisfying customers. An optimized supply chain assumes efficiency improvements that can reduce inventory requirements, reduction in transportation costs and other distribution expenses. For this reason, the study should cover all elements to optimize the chain as a whole, such as marketing functions, manufacturing, distribution, vendor management, discharge processes, production scheduling, enlistment, and load times route optimization among others. In the beginning of the supply chain, includes relationships with suppliers.

Various problems could occur during this relationship in areas such as, sending and receiving orders, delivery times, the conformities of deliveries, returns, etc., which largely determines the cost variance at beginning of the chain. Flexible management and solutions implemented on this problem of constant changes, depends on the success of logistics strategy adopted.

Today, the development of information technology makes it possible for actors in the supply chain to share information and thus cooperate to improve the efficiency of the chain. Effective coordination between units in a supply chain has come to play a key role in focusing on innovation, flexibility and speed, creating a competitive advantage necessary to survive in the global competition.

To achieve levels of cost minimization in the system, we must look to improve on optimizing inventory joint policies, through negotiation with suppliers and thus achieve greater collaboration possible in a party's important in the procurement process: inventory levels in order to reduce the gap between what is offered or produced and defendant. Such a process requires developed in an environment of trust, due to the firm belief that share risks and invest in changes will result in mutual benefits.


DOI:10.6814/NCCU202101735

## 1.2 Statement of the problem

To implement an inventory system, managers should consider control over inventory and costs. The common base of all inventory is representing a cost associated with it, the costs associated with the process of holding inventory include:

**Cost of product:** The cost or value of the product is the amount paid to the supplier for the product received, or direct manufacturing costs if it occurs. Normally, it is equal to the purchase price.

**Cost of acquisition:** Acquisitions costs are those incurred in placing the purchase order or if it comes to manufacturing are considered as preparation costs. These might vary directly with each purchase order placed. Acquisition costs include costs of mail service, probably phone calls to suppliers, paper work, handling fee, in purchasing and accounting.

**Cost of inventory management:** The inventory management costs are the actual costs, that "out of pocket" and relate to having available inventory. These costs "pocket" include insurance, rent warehouse, energy, taxes, and losses due to theft, decomposition products or breakage and obsolete products.

**Costs for lack of inventory:** These are caused by the demand, when inventory are depleted, that is, are the costs of lost sales or unfilled orders. When sales are lost due to lack of inventory the company loses profit margin of lost sales and customer confidence.

**Cost of operating the information processing system:** Either by hand or by computer, companies must update records as stock levels changes. In those systems where no inventory levels are recorded by daily, in order to get an accurate physical inventory count this incurs in a high operating cost. Often these operating costs are more fixed than variable within a considerable margin (volume). Therefore, as the fixed costs are irrelevant for the establishment of the doctrine of operation, it is not considered taking into account the production process.

**Cost for logistics and transportation:** Another aspect to be considered when establishing the level of inventory is that inventories are not concentrated just in one storage location or in one fixed place, but can be spread over the entire logistics supply chain (different providers warehouses, the different assembly factories that have the company needs to provide materials or moving to distribution centers, etc.).

Transportation costs from the production site to the consumption center force to buy the raw material (monthly, quarterly, etc.) depending forecast and the volume.


DOI:10.6814/NCCU202101735

This means that the inventory level management must be comprehensive: we must not only meet all levels of our business or production chain, but also control the inventory of our own suppliers. If we know the deadlines of our suppliers, and also know their inventory, we can respond more demand security that comes our way.

The fact that there is insufficient inventory may entail a number of disadvantages:

- Lost sales.
- Image loss.
- Loss of customer confidence.

### 1.3 Research Questions and the Objectives

Inventory breakage costs are difficult to quantify, it is difficult to know how many is left. Therefore, we must strive to maintain an optimal level of inventory; that is sufficient to avoid short of materials and avoid having inventory excess. To achieve this, I have to ask some questions:

1. How many units of each item should be stored?
2. How much should apply on each order?
3. When do we issue an order?

When calculating the inventory as needed, several problems arise:

*1.* The difficulty of accurately forecasting the future behavior of demand and sales
*2.* The need for a varied assortment and a quantity of each item.
*3.* The supply and delivery problems and repetitive and periodic costs

To answer these questions, we need to know information about the company which it is generally not easily accessible. Therefore, procurement and planning management should be targeted to achieve the following objectives:

1. Establish a sufficient inventory
2. Minimize investment in inventory
3. Know the order point

In addition, there are a number of variables that accept inventory management:

1. The level of service offered
2. Sales forecasts in each particular period
3. Management costs and stockpiles
4. Supplier’s delivery time


DOI:10.6814/NCCU202101735

# Chapter II Literature Review

The purpose of this chapter is to provide a review of the literature relevant to the inventory management, the VMI and its application.

## 2.1 Inventory Management

Inventory management is a core area in any industry and / or commercial. Besides other benefits of proper management it reduces inventories amount of current required to meet day to day needs, reduces space for normal operation and adjusts the flow of materials for business needs. Such information is usually associated with the demand for products, supply (costs and deadlines), storage and manage inventories.

The reason that the first inventories were created was the need to meet a substantially constant demand for staples with seasonal and intermittent production (examples include power, heating ...) Sometimes, however, the production can be as stable as desired, while demand is variable. Besides stable production and demand, various economic reasons prevent buying the right product in the required amount.

Other reason why companies will have inventory is because they will think that in a more or less near future products will rise in price, which will be won the difference. It is said that in times of inflation it is important to own products. The financial motive also appears when large purchases are made at the end of tax accounting period to reduce benefits.

Although demand is stable it may be that for some reason not be strictly constant but varies with a certain randomness. The same we can tell from the production machine or the provider may stop (fault, strike, etc.). The protection against such randomness is one of the reasons why to be stored.

Finally, production requirements may require the existence of inventory. By example if demand covers several similar products using the same machine (detergents, paper ...) is necessary to create batches and therefore some inventories.

Thus, we can summarize that 6 are the basic reasons for the existence of inventory:

1. Change in supply versus demand
2. Variation and seasonality of demand


DOI:10.6814/NCCU202101735

3. Economic constraints
4. Financial reasons or speculation
5. Protection against irregularities
6. Regulation of production

Inventories can be classified by:

Functions:

1. Cycle inventory: The active or cycle inventory consists of items that the company has to deal with the demand during a period of time. This inventory evolves between a maximum and a minimum level, which is set according to the storage capacity, the capital invested in stocks and their management costs. Its location can be part of a presentation inventory or warehouse stock. For example, cleaning supplies, canned food ... (placed on the shelf) or shirts and shoes (displayed in the window) inventory part of the presentation but we also have in store a certain amount of the same products.

2. Buffer or Safety inventory: Safety stock is complementary of cycle inventory and is created to avoid stock-outs during the term of supply. The safety inventory serves to meet demand when there is uncertainty of it. That is, when there is an unexpected demand from customers or occurs when providers delay the delivery of orders. If any of these situations, if demand is higher than estimated may result a "broken inventory" and warehouse stocks cannot meet the needs of either the center of the requested manufacture or sales. To avoid this situation an additional inventory that can absorb fluctuations in consumption or other incidents order is created.

3. Anticipation or certainty inventory: The inventory speculation is created in advance needs arise and serves to meet an expected change in demand, supply or price. This inventory usually occurs in times of strikes, war or when in the near future could not obtain supplies of the relevant article. For example, when a car model stops manufacturing, repair shops accumulate spare parts; or when we know in advance the rising price of gasoline, gas stations often make a special provision. Seasonal Inventory are example of this function the inventory seasonal or seasonal created to deal with an expected increase in sales, change of season or season. The articles in this inventory are those without continuous sales throughout the year, for example, toys, stoves, bathing suits, etc. Sometimes these items are acquired for strategic reasons or special events like a product promotion, rebates, local festivals, etc.


DOI:10.6814/NCCU202101735

4. Transit or pipeline inventory: The inventory in transit is one that is between the various stages of procurement processes, production or distribution. It is also the inventory is on its way, in transit or storage premises located between the store of the vendor and the purchaser. Manufacturers generally do not respond instantly to orders placed by the dealer, so this addition to the inventory of its own warehouse, provides a common store item that need until the manufacturer sends the order placed.

5. Decoupling stock: Inventories can also be useful when operations are disengaged and when the supply operation is independent of other supplies. This decoupling function serves two purposes: first, if required inventories reduce the dependencies between successive stages of operation, so that failures, material shortages, or other fluctuations in production in one step, no cause actual stages further have to stop. A second purpose of the decoupling using inventories is that organizations units programmed operations in a manner independently with respect to other units.

By its form:

1. Raw Materials: Any company that its activity is industrial, it has several articles and materials known as raw materials when subjected to processes a finished or finished article is obtained. So, we can define that the raw material is that or those items subjected to a manufacturing process that eventually will become a finished product.

2. Work in Process (WIP): Any item or items used in a production process are defined as in-process inventory whose feature that increases its value with each transformation process to become finished product. They are partly finished products that are at an intermediate level of production that were applied direct labor and production process inherent overhead at any given time. And its final processing is called Final Assembly and Test (FA&T).

3. Finished goods: These products have completed their production process and are in the warehouse of finished products and have not yet been sold. Inventory levels are directly related to sales, i.e., levels are given by the application seeking.

4. Maintenance, repair and operations (MRO): The MRO inventory include all maintenance parts hauled to respond to both planned maintenance and unexpected shutdowns, covers all parts to keep the process working, covering the entire inventory held by OEMs (Original Equipment Manufacturers in Spanish Original Equipment Manufacturer) to give servicing equipment that they sell, covering all inventory stored by providers becomes inventory.


DOI:10.6814/NCCU202101735

By the nature of its demand:

1 Inventory with dependent demand: Dependent stocks are those demand that are subordinated directly by internal company decisions, and usually comes to decision making that product, in what quantity and at what time.

2 Inventory with independent demand: The inventory is independent, because their demand is given by sources outside the company, as is the case of items required by an external client. And it is of this nature, because reason is practically no inventory subject to the decision of the company. Among independent inventories, as he had named earlier have usually what is the inventory of finished products, i.e., those items already completed and are ready for purchase by the customer.




DOI:10.6814/NCCU202101735

## 2.2 Vendor Managed Inventory (VMI)

### *History and development*

VMI (Vendor Managed Inventory) is the process in which the seller assumes the tasks of generating purchase orders for replenishment of inventory at customers. This system breaks with the traditional inventory management, in which the dealers who decide how, when and where to order the material they need, increasing the costs associated with inventory management at each individual stage of the supply chain, which is known as RMI -Retailer Managed Inventory-(Silver, Pyke and Peterson, 1998; Bowersox, Closs and Cooper, 2002; Hugos, 2003; Taylor, 2008).

It is a practice used in the management and control of inventory in the supply chain. This inventory is monitored, planned and managed by the vendor on behalf of the consuming organization, based on the expected demand and the minimum and maximum levels of inventory that are previously agreed (Blatherwick, 1998).

VMI is based on providers for have a better understanding of management and inventory control to known production capacities delivery times. Also, by allowing the suppliers manage inventory reduces the number of intermediaries in the supply chain, increase common chain visibility and reducing overall inventory levels along it. Other terms for VMI are continued supply. However, the vendor takes more responsibility with this initiative, because it determines inventory levels and frequency of entry to maintain continuous availability without depleted inventories (Reddy, 2008) and to implement VMI, must be provided to vendor sales data via electronically or by RFID.

The VMI is a system that can computerize inventory management and supply chain, where the supplier is responsible for making decisions about the amount of inventory replenishment. This tool is also known as continuous replenishment process and was popularized from the eighties by companies like Wal-Mart, K-Mart and Procter & Gamble (Taylor, 2008). In addition, VMI offers the ability to synchronize the associated decisions between storage and transportation management (TMS). Moreover, VMI also provides the benefits of improving customer service and reducing demand uncertainty (Khai, 1988)

Traditionally, the successful management of Supply Chain Management derives from understanding and the differential between the cost of inventory and service level. VMI projects can result in improvements along both dimensions.


DOI:10.6814/NCCU202101735

***Concept***

VMI (Vendor Managed Inventory), supplier managed inventory or just in time II and is very similar to Continuous Replenishment Program (CRP), but used in different industries. According Claassen, van Weele and van Raaij VMI originated in the 80s, when retailers take responsibility demanded to replenish inventories vendors, based on actual sales figures.

This type of practice does the provider and responsible seller for the flow of goods into the plant, warehouse or customer location, instead of the manufacturer with a more accurate planning process, replenishment, forecasting, information analysis management indicators, application of models Min / Max / EOQ or replenishment forecasts and the implementation of integrated communication systems that together allow the process to make more accurate demand planning and procurement of supplies, and numerical simulations and experimentation, it has been shown that the benefits are best obtained without adopting VMI under a cooperation policy.

Therefore, this paper will attempt to describe the most important aspects and glimpse the tools to implement VMI, to be used as a valuable option in choosing the best strategy to increase the maximum value to the logistics processes of the organization, cost reduction, and dictates important parameters to create the supply policy inside.

***VMI Models***

Pan-Pro (2004) states that the implementation of VMI in the world is held in three categories:

1. Collaborative Planning Model: A collaborative model is to share information and develop joint production plans for companies that implement the VMI. According to Pan-Pro (2004), collaborative process occurs at the tactical level. This scheme works so that the "buyer" collaborates with the "seller" in the plans of demand / consumption of each stored reference (SKU stock keeping unit), which set demand forecast is set, it will used by both parties in the development of plans for refueling. In Figure 1 this collaborative model is outlined. (*see **Figure 1***).


DOI:10.6814/NCCU202101735

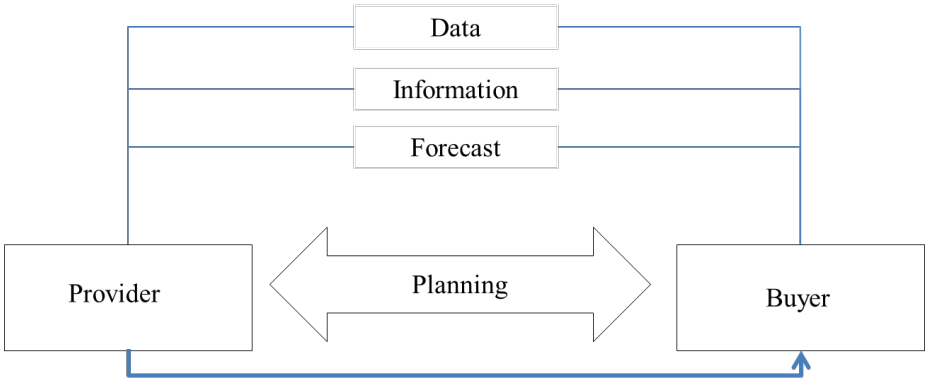


*Figure 1. Collaborative Planning Model flow*

2. Cost Transference Model: It is a simple process, where the main objective of the buyer (client) is to transfer the activity and inventory management costs to the supplier (seller). The implementation of this model is simple and, in some cases, requires minimal or no integration effort of the parties involved. The process can be as basic as the mere fact that the supplier sends a person to the customer site for it to perform the inventory count and make replenishment orders.

One of the most attractive features of the model for the customer is that, at any moment, worries about the work required, nor responsibility for inventory management. (See **Figure 2**.)

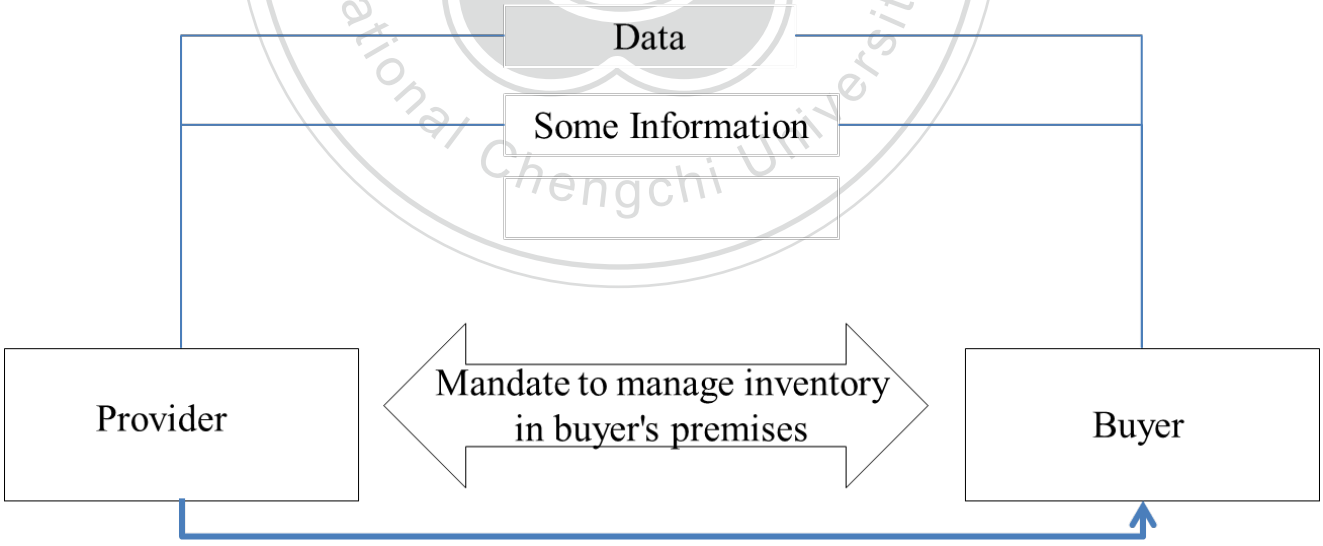


*Figure 2.Cost Transference Model flow*

3. Fully Automated Replenishment Model: The fully automated model combines the positive elements of each of the above models, including the main aim of reducing total costs for the supply chain. It consists of four stages: collaboration, planning, execution and evaluation.


DOI:10.6814/NCCU202101735

The model starts with the macro process of collaboration between the parties, in which the objectives and constraints of the implementation of VMI are established. A software tool is used to run the replenishment strategy to achieve the objectives at the lowest cost and with the best customer service possible.

Execution refers to the implementation of the action replenishment, from the demand information provided by the buyer. This stage, which is operating order, should be performed daily to ensure proper operation of the VMI. Finally, it is necessary to carry out an evaluation process, which should analyze the performance of the VMI tool to observe the quality of replenishment operations, the status of the proposed objectives, planning activities and feedback model. (See ***Figure 3***).

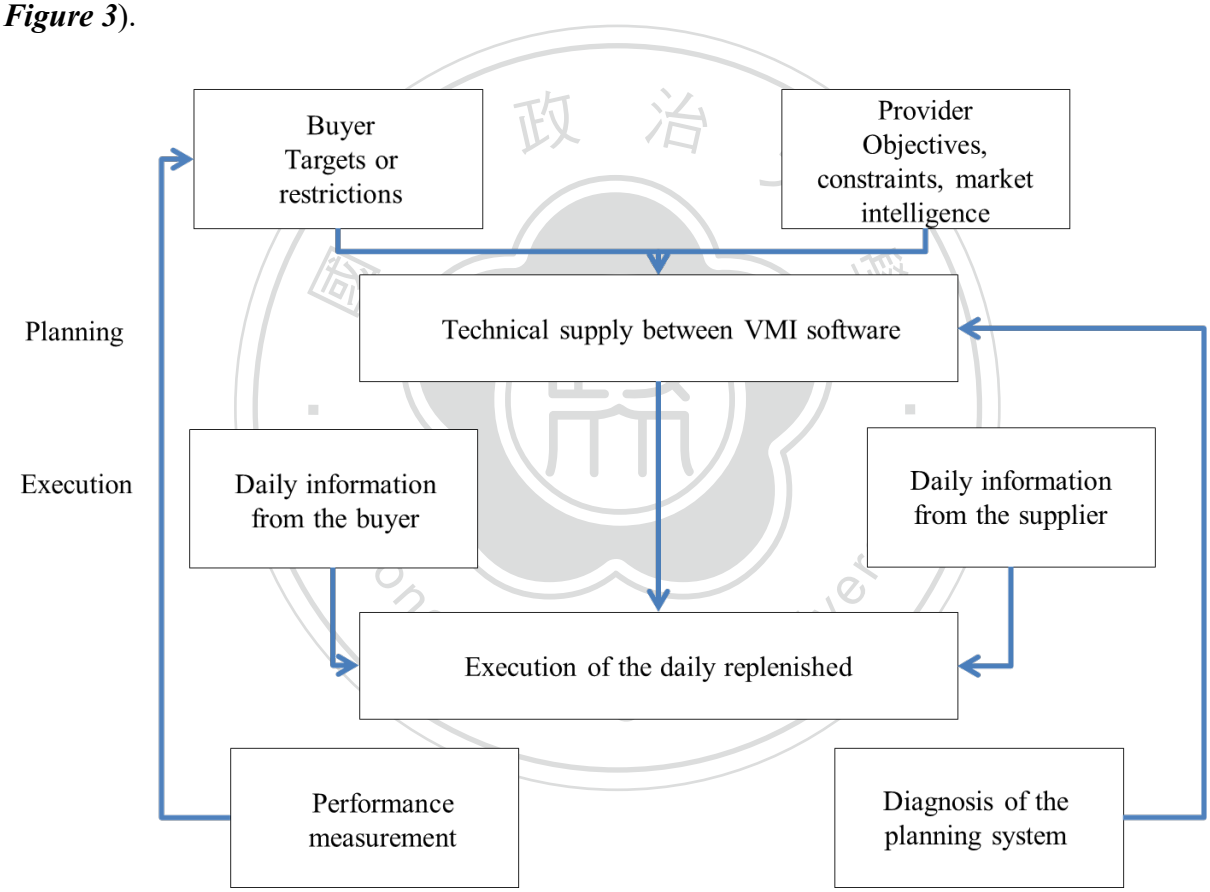


*Figure 3.Fully Automated Replenishment Model Flow*

**2.3 Information systems associated with Inventory management**

Enterprise Resource Planning (ERP)

Enterprise Resource Planning (ERP) is management information systems that integrate and manage many of the businesses associated with the operations of production and distribution aspects of a company in the production of goods or services.


DOI:10.6814/NCCU202101735

ERP systems typically handle the manufacturing, logistics, distribution, inventory, shipping, billing and accounting for the company in a modular way. However, the enterprise resource planning or ERP software can intervene in the control of many business activities such as sales, deliveries, payments, production, inventory management, quality management and human resource management.

The systems are ERP information management systems that automate many of the business practices associated with operating or productive aspects of a company.

ERP applications are comprehensive management systems for the company. They are characterized by being composed of different modules. These parts are different in use, ex: production, sales, purchasing, logistics, accounting (of various types), project management, GIS, inventory and warehouse control, purchase orders, payroll, etc. The opposite would be considered a simple billing program as an ERP for the simple fact that a company integrates only that part.

The main objectives of ERP systems are:

1. Optimization of business processes.
2. Access to information.
3. Sharing of information between all components of the organization.
4. Eliminating unnecessary data and re-engineering operations.

The fundamental purpose of ERP is to provide support to business clients, fast response times to their problems, and efficient management information enabling timely decision making and lower total operating costs.

The benefits it can bring ERP tool are summarized in the resolution of accounting, commercial and tax problems of the company. It can also allow greater control of assets in the permanent inventory, bank reconciliation, payment of taxes, etc.

**2.4 Material Requirements Planning (MRP)**

MRP planner or material requirements planning system is the materials and computerized inventory management that answers the questions of how and when to stock up on supplies. This program purchase orders within the company resulting from the process of material


DOI:10.6814/NCCU202101735

requirements planning ensuring the prevention and resolution of errors in the procurement of raw materials as well as production control and inventory management system was trying to establish what wants to do in the future and with what materials or just where appropriate, are needed to make all production tasks.

There are three basic MRP Inputs:

1. Master production schedule: Based on customer orders and demand forecasts tells us that the end product necessary to manufacture and in what deadlines must be completed. It also contains the amounts and dates of availability of plant products that are subject to external demand (finished products and spare parts). The function of the master plan is to adjust production at the factory according of the external demand. Once established this, the role of the rest of the system is its compliance and enforcement with maximum efficiency. For this the master production plan is based a time that is set for the calculation of the dates of production and supply. It has standardized this time to be in a workweek.

2. Inventory record: Inventory status shows the amounts of each reference plant that are available or being manufactured. And in this case the date of receipt. The information system must update the status of the actual inventory and the status of current orders to monitor compliance with the terms of supply. In short, there must be a perfect knowledge of the situation of the inventory, both materials purchased from external suppliers and the components in the preparation of higher-level assemblies.

3. Structured Bill of Materials (BOM): From the standpoint of production control, it is important to know the components involved in the final assembly, showing successive stages of manufacture. The manufacturing structure has an accurate and complete list of all materials and components required for the manufacture or assembly of the final product.

To define this structure there are two requirements:

1. Each component or material involved must be assigned a code that identifies precisely.

2. Each element corresponds to a level in the structure, assigned downstream. Thus, the final product corresponds to the zero level. Components and materials involved in the final assembly operation are level one.

In summary, lists of materials must be organized to meet the needs of the same, including facilitating the permanent knowledge.


DOI:10.6814/NCCU202101735

# Chapter III Case Description

## 3.1 Lighting Industry

Lighting Emitting Diode, LED, is a solid-state semiconductor lighting technology with electronic components, through current drive, converting electrical energy into light patterns output. The technology was first seen in 1962, which compared to the traditional way of lighting, the lamps compact size, long life, shock resistance, low power consumption makes it more advantageous. An LED element production process can be divided into the sapphire substrate and wafer upstream, midstream epitaxial growth (Epitaxy) and grain production (Chip) production and testing, as well as downstream packaging (Packaging) and modules. Epitaxial growth is a technique that dimension in the process of semiconductor manufacturing, grow new crystal on the original wafer process technology to produce new semiconductor layer. The Crystal Package downstream manufacturing is because of the different needs for different shapes.

Because of the high threshold in the upstream technology and financial barriers to the development of Taiwan's first start since 1973 in the field downstream from the package until 1985, ITRI developed epitaxial technology, was established in 1993 by the League of Nations optoelectronics, Taiwan LED.

According to the green energy sector information network, Taiwan LED lighting industry totaled 158. Although the supply of raw materials was weak, there were plenty of LED components industry supply chain, to become the world's third largest supplier. (See details in ***Figure 4***).


DOI:10.6814/NCCU202101735

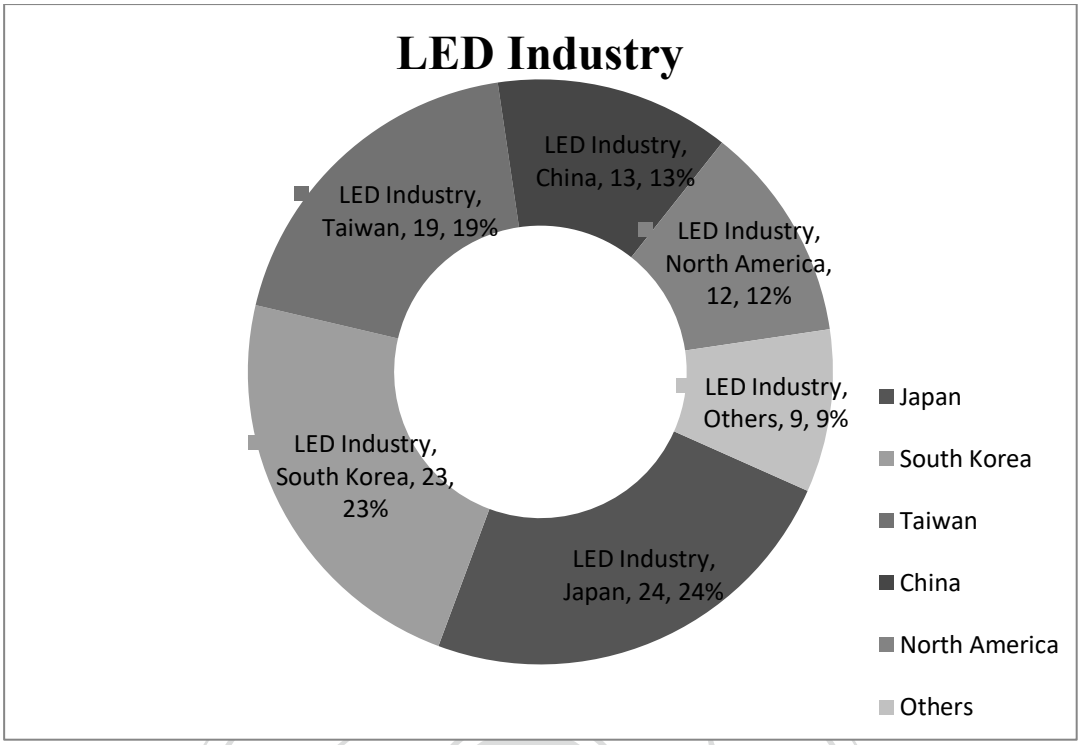


*Figure 4. LED Industry 2014 Market share distribution.*

*Source: Based on the Industrial Technology Research Institute Data Integration*

LED lighting industry competition overview

Global LED industry leader is Philips (Philips), but its competitor Osram Lighting (Osram) is the major supplier of lighting applications in residential and retail. And residential lighting is the biggest market share of more than four percent, retail lighting account for about one percent.

In the past, because specifications were not yet unified, products on the market were uneven, and since 2009, the countries have to develop LED standards, the current total of ten standards certifications.

After the standards were established, there were no R&D capabilities and quality control for small firms to compete, and after the 2011 financial economic crisis the LED market declined significantly, also many manufacturers did not have enough money so they had to withdraw from the market.

Moreover, the LED lighting market product development was still trend to replace traditional light bulbs and tubes. But due to LED high price in comparison to traditional lighting, a race began to for the development of high-performance efficiency and lower prices LEDs as a competitive policy in recent years, this competition began to be difficult for new lighting companies to break


DOI:10.6814/NCCU202101735

into the market. Recently some manufacturers are trying to open up new market applications opportunities by developing smart lighting.

Smart lighting, are a technological system that integrates lighting systems, sensors and controllers with the ultimate goal of making efficient use of lighting resources, reducing operational costs and maintaining the appropriate level of brightness in the areas where it is required. The smart lighting systems not only consider the technology of the luminaires, but also control the moment they turn on and off, they can regulate the level of luminosity required according to the needs.

With incandescent lamp, fluorescent lamp being the main lighting source of residential life and industrial filed. For energy savings alternatives, new lighting source such as LED are required and LED is a major candidate as a replacement. In this design guide, it is shown how LED component could be used as a lighting alternative to traditional lamps and what the main design factors are.

### 3.2 Luxul Technology Incorporation

For the methodology analysis and application of inventory control, we will basically base on some operational inventory of a transnational company: “Luxul Technology Incorporation” and in the way it manages and controls the inventory. In order to keep inventory control, we proceeded to apply the EOQ model, Total Inventory cost, and Fixed Interval model, to solve the inventory control problems and complete proposals and action plans that cover the minimum activities and the means settled the achievement of its objectives.

***History and Background***

Luxul Technology is the world’s first company that patented an LED tube lamp product (EazyLux), which is "Direct-retrofit" (no re-wiring required) and UL certified. Luxul’s EazyLux T5 and T8 LED lamps are the world’s first LED tube lights that are fully compatible with existing fluorescent lamps using E-ballasts, and dimmable when interfaced with dimmable ballasts and switches. The company contributed capital is about 163 million Taiwan Dollars.

Luxul Technology Inc. is located in United States, it has a professional R&D team in Silicon Valley the United States and Taiwan consist of engineers from such disciplines as electrical, optical, mechanical, software, graphic and art designs, providing global customers immediate business and technical services


DOI:10.6814/NCCU202101735

Dr. James Pan founded Luxul Technology in 2010 after earning his Ph.D. in Electrical Engineering from Stanford University. Since then, Luxul's vision has focused on green innovation, providing customers with high quality LED lamps that increase efficiency while lowering installation and energy costs.

Luxul Technology's Backed by more than fifty (50) worldwide patents, their mission remains focused on applying world-class technologies to lighting products that benefit end users, while promoting energy and environment conservation.

In 2014, Luxul Technology moved all assembly from Taiwan to the United States, with the goal of becoming the #1 American-made LED tube products on the market. (See ***Figure 5***).


*Figure 5. Manufacturing Operation.*

*Source: Department of Economic Development, Taipei City Government, Visit in 2014*

In recent years, the financial crisis, the global economic downturn, plus a lot of cheap labor competition from mainland China, resulting in the relocation of many assemblies manufacturing base, the US unemployment serious low-end. The company created a US brand, and consolidate the US market, it echoed the Obama administration's "Made in USA" policy by hiring a lot of veterans, unemployed workers and women, and others American citizens for their employees, in order to win American consumers. Currently Luxul company has more than 600 distribution partners and suppliers in the United States. In the first year of production in USA, they reach a visible growth in the market. (See ***Figure 6***).


DOI:10.6814/NCCU202101735

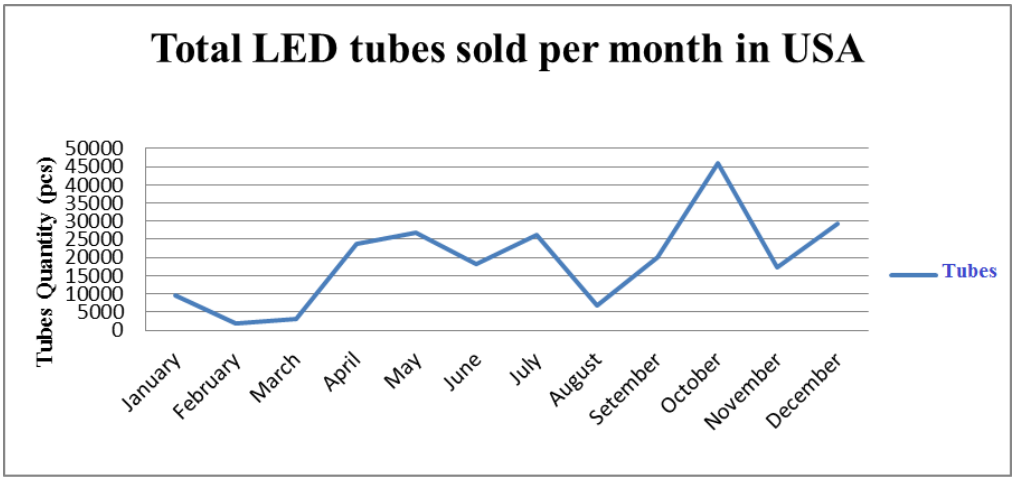


*Figure 6.Total T8/4FT/4000K Tubes sold in USA in 2014*

*Source: Luxul's internal report*

Dr. Pan said: Luxul Technology's competitive advantage is its R&D team in power IC, in addition to LED lamp products, we also plan the next step toward smart lighting: a WIFI module placed in the electronic ballast, allowing users to not only change LED tubes color temperature, but also the light source can be controlled remotely."

The company slogan is: "Simplicity over complexity. That's Luxul Technology. Re-imagine what is possible".

Luxul Technology current market share in US is still lower than Philips and Cree, but there is still room for potential future growth, as it is estimated that the market value will reach $ 40 billion by 2016 in US market.

The company's continued commitment with academic research institutions (University Laboratory) for research and development and innovation, but also actively through self-production and marketing channels to reduce unit costs, so the company can expand with confidence towards the direction and scale of production.

***Company Product***

Luxul produces four series of LED tubes. It can be classified by Diameter, Luminance, Length, Cover Lents, Color temperature, Base and Watts, total 15,552 combinations. (See ***Table 1***).


DOI:10.6814/NCCU202101735

| Series | Diameter | Luminance | Length | Cover Lens | Color Temperature | Base | Watts (LED) |
|---|---|---|---|---|---|---|---|
| D-Lux | T8 | Normal | 2FT | Frosted | 3000k | G13 | Low |
| E-Lux | T5 | HO | 3FT | Clear | 3500k | FA8 | Normal |
| Q-Lux | | | 4FT | | 4000k | R17d | High |
| U-Lux | | | 5FT | | 5000K | | |
| | | | 6FT | | 5700k | | |
| | | | 8FT | | 6500k | | |
| | | | $1\,5/8$"(1.65) | | | | |
| | | | $3\,5/8$"(3.628) | | | | |
| | | | 6” | | | | |

*Table 1.Luxul's LED tubes classification*

*Source: Luxul’s Official flier*

***E-Lux LED Series***

Luxul Technology’s most famous and popular product is the E-Lux Series. (See **Figure 7**). It is the world’s first direct retrofit LED lighting tube that is compatible with all traditional fluorescent lamps with electronic ballasts. E-Lux offers a simple and cost-effective solution which requires no rewiring or replacement of existing fluorescent luminaires.

E-Lux series have a lifespan of 50,000 hours, reduces power consumption by over 50%, and comes with a standard 5 years warranty, available in either T5 or T8, 2 to 8 feet in length, and also High Output type tubes (for T5 only).


*Figure 7.EazyLux LED tubes*
*Source: Luxul’s official website*


DOI:10.6814/NCCU202101735

Product Main Parts Description

LED lamps principal parts are: Aluminum Lamp Profile, Plastic Lamp Shade, Printed Circuit Board Assembly (PCBA) and Lamp Cap with Pin (see ***Figure 8***).

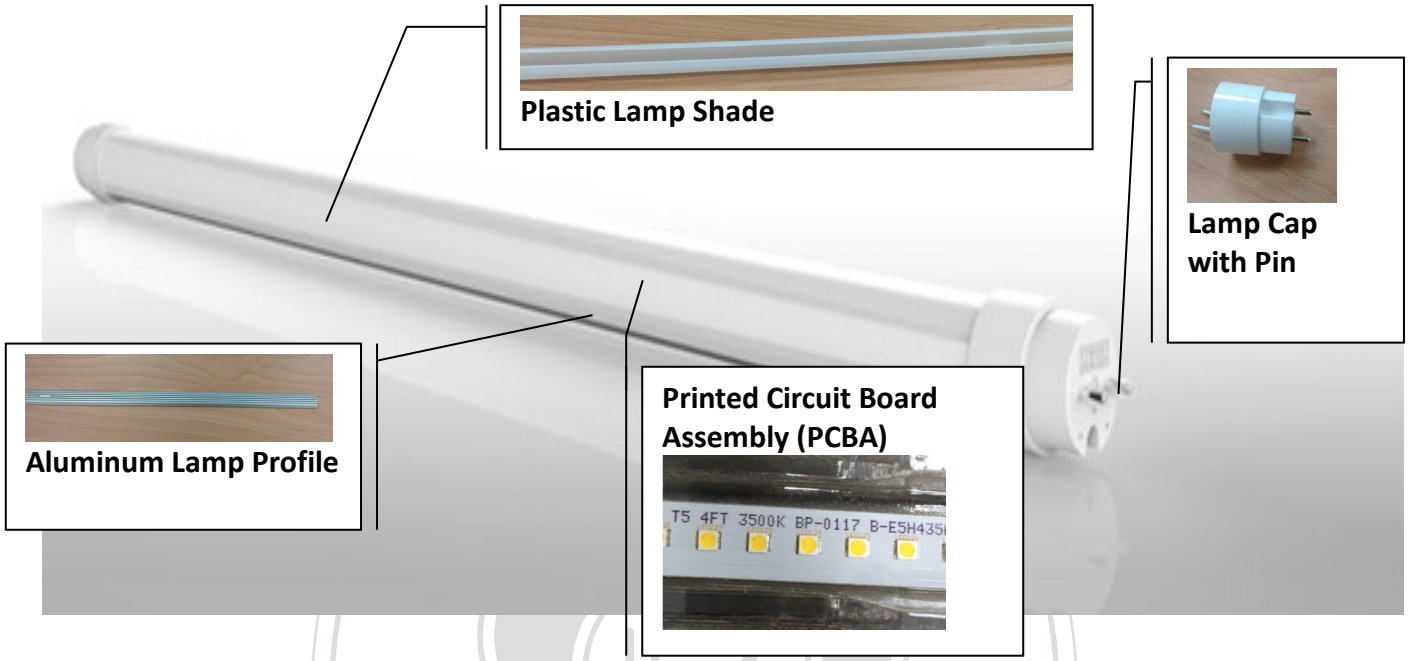


*Figure 8.LED Lamp parts*

Aluminum Lamp Profile: Most of the LED tube lights use aluminum plate, or some customers would use fiberglass panels in order to save costs.

Difference: the heat dissipation of aluminum plate is better than that of fiberglass, but aluminum plate is high-priced than the glass plate, but the heat is directly concerned with the lifespan of the LED and light failure, for the LED tubes, therefore aluminum plate is the best option to use.

Plastic Lamp Shade: PC covers which can be divided into high transparent cover and diffusion cover.

Transparent cover: As the name suggests, the transparent cover is transparent PC cover, and the LED chipsets can be seen through the lens. There are several disadvantages to humans from using transparent covers, including feeling of dizziness.

Diffusion cover: This lens cover is common for manufacturers use. They cover the LED chipset and lower the light intensity coming directly from the chipsets.


DOI:10.6814/NCCU202101735

Printed Circuit Board Assembly (PCBA): After the printed circuit board (PCB) is completed, electronic components must be attached to form a functional printed circuit assembly or PCA (sometimes called a "printed circuit board assembly" PCBA). In the PCB, LED components are inserted in holes. This is made by a SMT (SMT - surface mount technology). These are electrically and mechanically fixed to the board with a molten metal solder. PCBA's has many product numbers depending of series, color temperature, diameter, and length. Total 2,592 combinations.

Lamp Cap with Pin: Fluorescent has several different pin types. G13 socket is largely used in T-8, T-10 and T-12. G5 is used in T-5 which has higher optical efficiency rather than T-8 due to shorter diameter. Single pin and double contact pin are used partially.

***Operational Management***

Company's (Supplier management)

Although the assembly factory is located in the United States- Silicon Valley, but R&D, Admin and Component Sourcing are in Taiwan. This way they guarantee the quality of the products with a reasonable price. Most of their raw materials are made in Taiwan. (See ***Figure 9***).

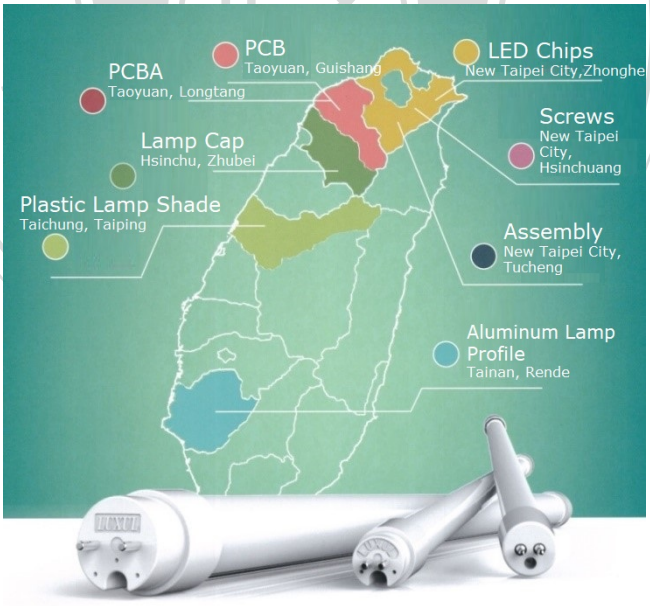


*Figure 9.Company's suppliers map.*

*Source: Luxul's Taiwan promotion flier*


DOI:10.6814/NCCU202101735

Luxul Taiwan Operations Flow

After their USA headquarter receive customer's order, they request Luxul's Taiwan's branch to provide the materials, especially the PCBA according to customers order and quantity. In some cases, if customer's orders are small, the PCBA quantity still will provide it a little more that the customer required quantity for complete a Minimum Packing Quantity (MPQ). PCBA's are produced by the Taiwanese supplier in 3 days and 15 days for large quantities depending of the LED chips inventory. In this case, after the supplier provides the PCBA's, they are exported by air cargo (direct fly or indirect fly depending how urgent is to assembly the tubes). Other heavy raw materials that could be used inmost their available tubes models specifications (ex: aluminum. lens, caps, etc.) are shipped out monthly by sea. Once USA receive Taiwan's exported raw materials, then they start assembly process and will be ship out to customers in the USA and around the world. Taiwan side is only responsible for procurement of raw materials and materials logistics head, and does not carry out any assembly work, in other words, Luxul Taiwan is a procurement center with a separate finance report, but in order to build an effective supply chain, both departments could be merged in only one Operations Center (Headed in Taiwan). (See details in ***Figure 10***).

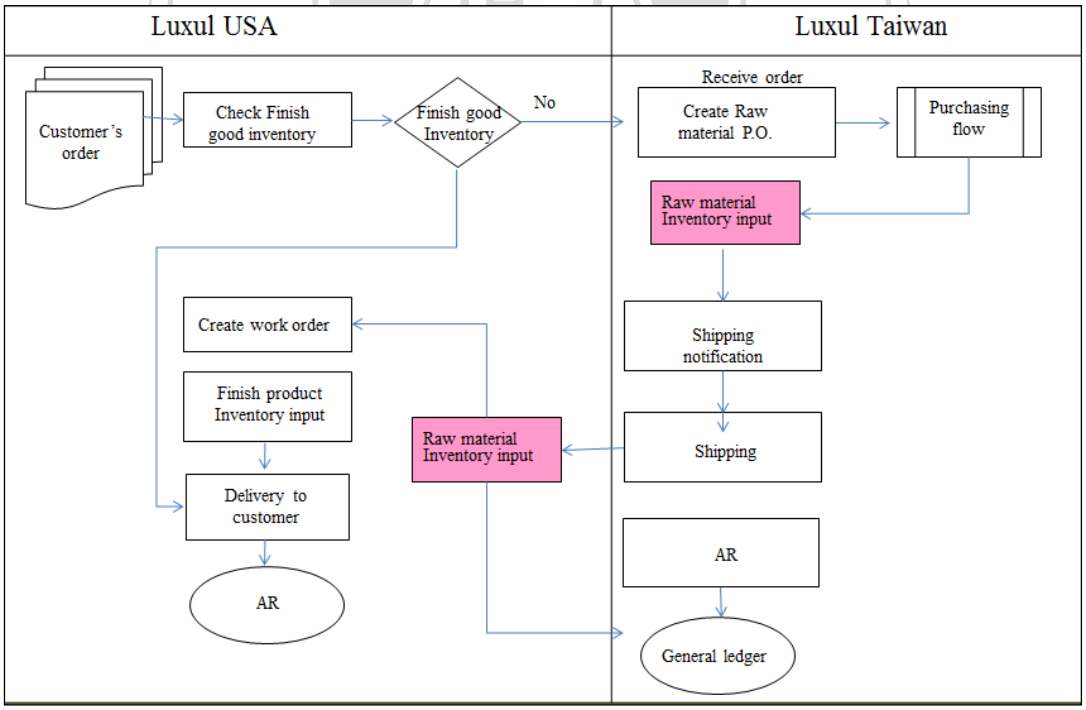


*Figure 10. Luxul's Transnational Operations mode*

*Source: Luxul's Taiwan Internal report*


DOI:10.6814/NCCU202101735

***Current Issues***

Due to MTO production time, short deadlines, and issues from Taiwanese suppliers to provide the PCBA on time, some materials do not arrive in the estimate day. Costs of customer dissatisfaction reflected in lost sales, loss of fidelity of them, actions for damages for failure in the delivery time, etc. When some required materials are not meeting the minimum order quantity and the quantity is small, then the unit prices for the raw materials are very high

The basic objective is to meet the customer's delivery required delivery time, so the decision to send the raw materials shipping it by Direct flight or Indirect flight, involves a trade-off between the transit time by air versus the higher cost to ship.

***Empirical Analysis***

In order to get customer's satisfaction on delivery time, most PCBA's are sent by air from Taiwan to USA (Santa Clara), in some emergency is send it by Express companies like DHL or FEDEX and in some case these materials are taking by hand carry when managers or personnel are traveling from Taiwan to the USA. Mechanical raw materials like aluminum, plastic lamp shade, and caps, are mainly send it by Sea freight. (See ***Table 2***).

| Shipping Mode | Shipments type to USA | Shipments Frequency |
|---|---|---|
| Air- Normal | AIR CARGO (Including: Non-stop flight, Multiple stop flights) | 71 |
| Air-Express | DHL Economy | 1 |
| Air-Express | Fedex Economy | 2 |
| Air-Express | Fedex International Economy | 2 |
| Air-Express | Fedex International Priority | 23 |
| Air-Express | HAND CARRY | 3 |
| Sea | 20' CONTAINER | 1 |
| Sea | 40' CONTAINER | 6 |
| Sea | 40 HQ CONTAINER | 1 |
| Sea | LCL 3 CBM | 1 |
| Sea | LCL 8.18 CBM | 1 |
| Sea | LCL 5 CBM | 1 |
| | **Total shipments in 2014** | **116** |


DOI:10.6814/NCCU202101735

*Table 2 . Shipments quantity from Taiwan to USA in 2014.*
*Source: Luxul's Taiwan Internal report*

The weight and cost of an item can justify centralized stocking with air shipments. The more expensive an item is, the higher the inventory carrying costs will be.

If the total costs, transportation and transit, for air- and sea shipments is compared, the mode of transportation that should be selected is the one that results in lower total costs. Only just considering the transportation costs is misleading. The inventory costs during transit must be considered as well.

Air Freight is calculated by the chargeable weight. It might be physical actual weight or Volume Weight.

Forwarders charges the cost of a shipment depending of the space that it occupies on an aircraft. Rather than the actual weight. After comparison between these two kinds of weights, the higher weight is used to calculate the shipment cost.

Chargeable weight is calculated from a combination of the weight and size of a shipment. Ex: +300 kgs, +500kgs, +1000kgs.

The air freight quotation is listed as below (***Table 3***)

| Shipping mode | Flight type | Frequency | Estimate Intransit delivery days | Chargeable Kgs | Total Cost per KG |
|---|---|---|---|---|---|
| Air Cargo | Multiple stop flights | Daily | 5 Days | + 300 | $6.03 |
| Air Cargo | Non-Stop flight | 3,5,7 | 3~4 | + 500 | $5.31 |
| Air Cargo | Non-Stop flight | 3,5,7 | 3~4 | + 1,000 | $4.86 |
| Air Cargo | Non-Stop flight | Daily | | + 1,000 | $7.19 |

*Table 3. Air freight quotation provided by Luxul's forwarders.*
*Source: Luxul's Taiwan Internal report*

The size of the pallets or the carton is very important to the reduction of air shipment cost. For example, if some carton boxes have been sent are almost empty, but the products volume weight is still high this could make air shipping cost more expensive. In another case, if some


DOI:10.6814/NCCU202101735

pallets volume weights are very high, the forwarders can provide better prices. In other words, when more quantity of materials are shipping out together, the air freight cost per pcs would be cheaper.

The volume weight of the shipment is a calculation based on the dimension of the product. It is calculated by the formula: V.W.: Length x Weight x Height /6000.

Example: In the case of an Air Freight shipment, if a pallet size of PCBA's is 127cm x 114cm x 142 cm, then its Volume Weight is 342.65kg, but its actual weight is only 267kg then forwarders will use the Volume Weight to multiply by the Total Cost per Kgs. in the specified chargeable weight. (See ***Table 4***).

| | | (L)cm | (W)cm | (H)cm | Volume Weight | CTN/ Pallet | Box Weight | Total box weight + pallet Weight | Pcs per carton | Pcs per pallet |
|---|---|---|---|---|---|---|---|---|---|---|
| Pallet | 1 | 127 | 114 | 142 | 342.65Kg | 28 | 8.5 Kg | 267 Kg | 100 | 2,800 |
| Pallet | 2 | 127 | 114 | 142 | 685.29Kg | 56 | 8.5 Kg | 534 Kg | 100 | 5,600 |
| Pallet | 3 | 127 | 114 | 142 | 1,027.94Kg | 84 | 8.5 Kg | 801 Kg | 100 | 8,400 |
| Pallet | 4 | 127 | 114 | 142 | 1,370.58Kg | 112 | 8.5 Kg | 1,068Kg | 100 | 11,200 |
| Pallet | 5 | 127 | 114 | 142 | 1,713.23Kg | 140 | 8.5 Kg | 1,335Kg | 100 | 14,000 |
| Pallet | 6 | 127 | 114 | 142 | 2,055.88Kg | 168 | 8.5 Kg | 1,602Kg | 100 | 16,800 |

*Table 4. Packing information for 4ft tubes' PCBA shipments.*
*Source: Luxul's Taiwan Internal report*

In the case of sea shipments, the forwarders offer prices according the container size, which is normally the standard container sizes (20' and 40' being the most common sizes).

If they shipping Less than a Container Load (LCL), the price is often determined by cubic meter (CBM)

As forwarders charge Air shipments freight cost by weight, larger and heavier shipments, it is much cheaper to ship by sea.


DOI:10.6814/NCCU202101735

### 3.3 Economic Order Quantity Model (EOQ)

The first model inventory is considered a model of fixed amount reorder. With this type of model, it is necessary to determine a fixed amount that should be ordered or reordered whenever there is an indication for ordering. To simplify the analysis, the following assumptions are made:

1. The demand is uniform (constant and continuous)
2. The supply must be all together, not in partial supply.
3. Parts delivery time is constant
4. All costs are constant
5. It's not allowed missing

Although these assumptions rarely, if ever, are certain in the long run, they are often short-term reasonable approximations. (See ***Figure 11***).

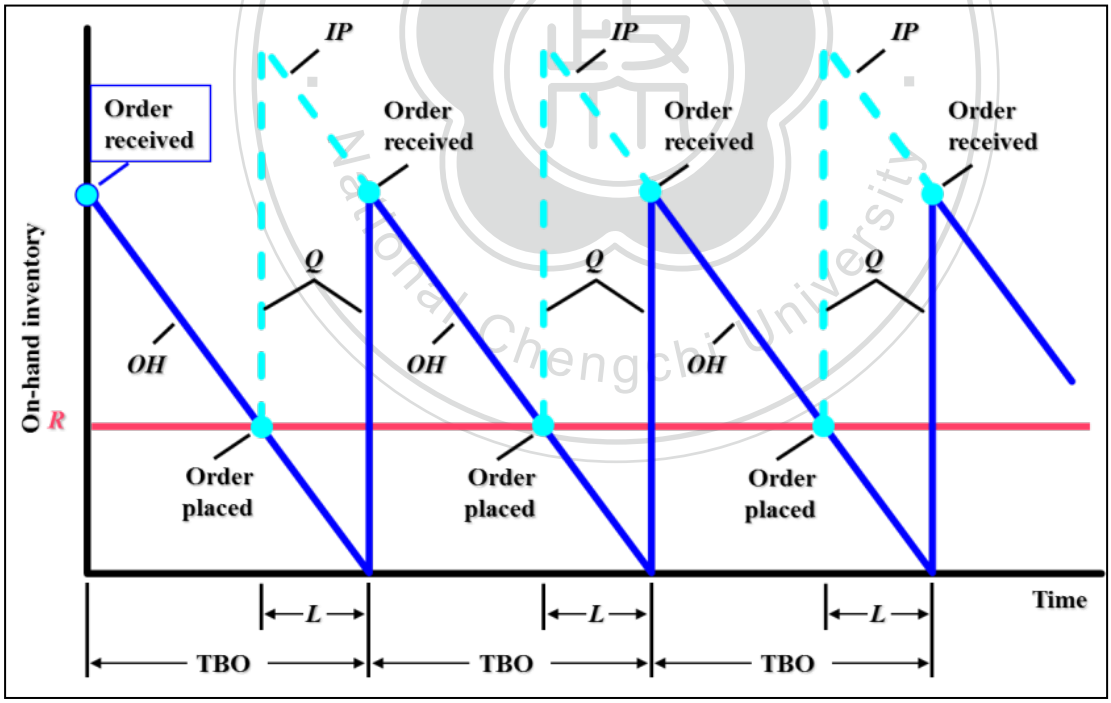


*Figure 11.EOQ for constant Demand & Lead Time*


DOI:10.6814/NCCU202101735

OH is the quantity of inventory On-Hand. Demand is uniform units per unit of time (year). Q global supply units are received. The inventory level begins at a peak point of Q units and declines steadily to a reorder point R, at this time a new order is placed Q units. TOB means Time Between Orders. When the order is received, the inventory level returns to its peak and the cycle repeats. As the delivery time is constant, there is no reason they occur missing.

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$$

*Where:*

$D$ = Annual demand

$S$ = Cost of placing an order or setup

$H$ = Annual holding cost

### 3.4 Total Inventory Cost

The purpose of this model is to determine the optimal order quantity and the time it should be done, i.e., How many to order and when to order. The inventory replenishment is instant; it follows that the order must be carried out as soon as the inventory is depleted. Therefore, the goal is to determine the economic order quantity. This is the reason why this model is called model of economic order quantity.

The costs involved in inventory management are:

1. The annual cost of ordering.
2. The annual cost of purchasing
3. The annual cost of carrying.

The objective is to minimize the model annual cost function is given by combined annual cost of ordering, plus annual holding costs, plus the annual cost of purchasing the items. In short, the objective function is:

**Total Annual Inventory cost: = Annual Purchase Cost + Annual Ordering Cost + Total Annual Holding Cost**

$$TC_{EOQ} = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$


DOI:10.6814/NCCU202101735

$$TC_{EOQ=DC\left(\frac{D}{Q}s\right)+\left(\frac{Q}{2}H\right)}$$

*Where:*

*TC* = Total annual cost

*D* = Annual demand

C= Cost per unit

*Q* = Quantity to be ordered

*H* = Annual holding cost

*S* = Cost of placing an order or setup cost

Reorder Point

It is the moment when we must make an order to prevent breakage of stock and supply problems to our customers. The outcome is no only the interruption in production or any fulfillment activities, but also the total amount of inventory on hand can be minimized (see ***Figure 12***).

*Reorder Point with constant demand*=Average demand during lead time (d*L)

$$R = \bar{d}L$$

*Where:*

$\bar{d}$ = Average daily demand

*L* = Lead Time





DOI:10.6814/NCCU202101735

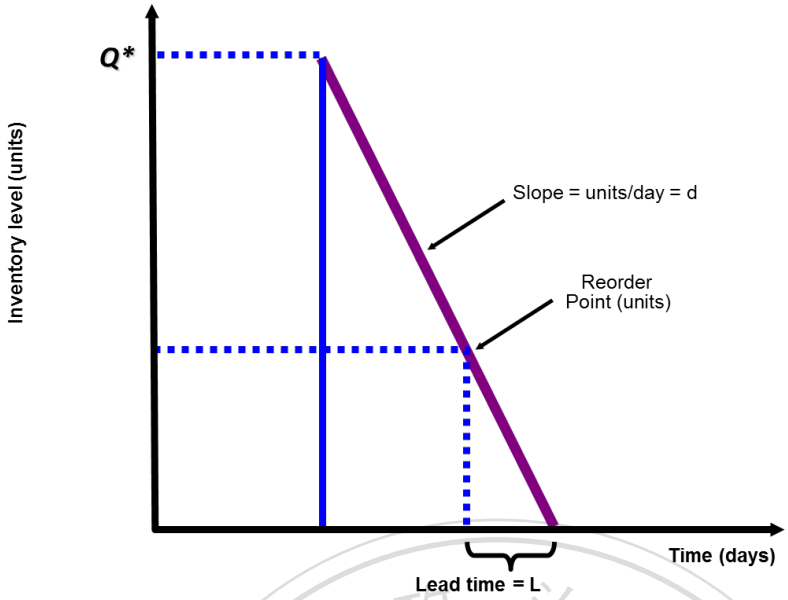


*Figure 12.Reorder Point with constant demand*

Reorder Point with Variable Demand= Average demand during lead time (d*L)+ safety stock. This model can be used when the demand during each day of lead time is uncertain, independent, and can be described by a normal distribution.

$$R = \bar{d}L + z\sigma_d\sqrt{L}$$

*Where:*

$\bar{d} =$ Average daily demand

$L =$ Lead Time

$z=$ Number of Standard variations corresponding to service level probability

$\sigma_D =$ Standard deviation of demand during lead time (days or weeks).

$z\sigma_d\sqrt{L} =$ (Safety Stock), where $\sigma_d\sqrt{L}$means square root of the sum of the daily variances during lead time.


DOI:10.6814/NCCU202101735

Safety stock is the amount by which the reorder point exceeds the expected (average) lead time demand (see ***Figure 13***). The complement of this chance is called the service level.

Service level is defined as the probability of not incurring a material shortage during any one lead time. The higher the probability inventory will be On Hand; the more likely customer demand will be met.

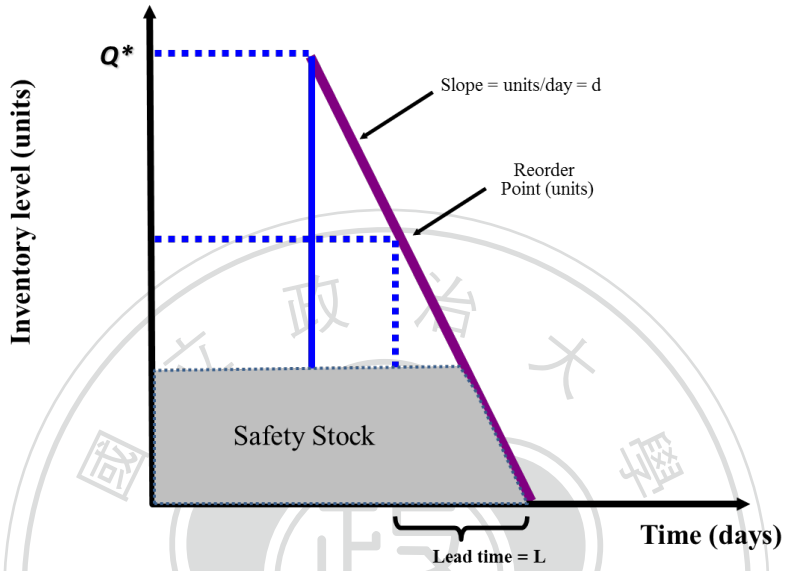


*Figure* 13.*Safety Stock*

Service level of 95% it means that there is a 0.95probability that demand will be met during lead time and 0.05 probability of a material shortage or stockout. (See details *in* ***Figure 14, Table 5***).

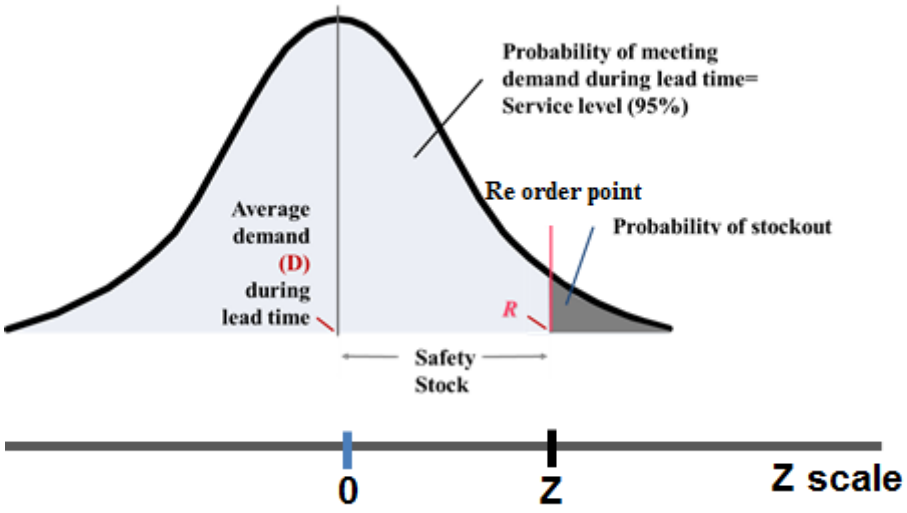


*Figure14.Service Level or % of time inventory will meet demand during lead time*


DOI:10.6814/NCCU202101735

| (Normalized to a Standard Deviation of 1) | | |
|---|---|---|
| **SL** | **z** | Risk of Stock-out |
| 50.00% | 0.00 | 50% |
| 55.17% | 0.13 | 44.83% |
| 60.26% | 0.26 | 39.74% |
| 65.17% | 0.39 | 34.83% |
| 70.19% | 0.53 | 29.81% |
| 75.17% | 0.68 | 24.83% |
| 80.23% | 0.85 | 19.77% |
| 85.08% | 1.04 | 14.92% |
| 90.15% | 1.29 | 9.85% |
| 95.05% | 1.65 | 4.95% |
| 9.00% | 3.26 | 0.06% |

*Table 5. Expected Number Out of Stock versus Standard Deviation*

For this case study, we will focus on one of the most popular tubes sold in the USA: the "T8/4ft/ 4000k". It represents the 86% of the total demand between the others tubes.

When Luxul Taiwan would like to send has an annual demand of 76,597 pcs of PCBA for their Eazylux T8/4FT/4000k, with a service level of 50%, 95% and 99% and assuming their holding cost is 5 US$. Their cost per order depends on the kind of air freight selected. The purchasing lead time to give Luxul Taiwan an order is 10 and 13 days and a standard deviation of around 205 pcs per day. See details in ***Table 6, 7, 8***).

| Year | Shipping date | Product Name | Cap | Tubes sizes | Color Temperature | Total |
|---|---|---|---|---|---|---|
| | January | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 405 |
| | February | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 1,055 |
| | March | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 1,260 |
| 2014 | Apr | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 1,817 |
| | May | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 5,827 |
| | Jun | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 6,254 |
| | Jul | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 9,580 |
| | Aug | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 1,947 |


DOI:10.6814/NCCU202101735

| | | | | | | |
|---|---|---|---|---|---|---|
| | Sep | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 6,416 |
| | Oct | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 1,7082 |
| | Nov | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 5,920 |
| | Dec | Printed Circuit Board Assembly | T8 | 4FT | 4000k | 19,034 |
| Grand Total | | | | | 76,597 | |
| Num= | | 12 | | | | |
| Mean= | | 6,383.083333 | | | | |
| Standard Deviation | | 6,150.936 pcs (Monthly) | | | | |
| | | 205 (Daily) | | | | |

*Table 6. Luxul exported PCBA record in 2014 (Eazylux T8/4ft/4000K).*
*Source: Luxul's Internal report*




DOI:10.6814/NCCU202101735

| Pallet qty | Qty of pcs per pallets | Estimate Volume Weight per pallet | Non-Stop Flights (2 days intransit) Cost | Multiple stop flights (5 days intransit) Cost | Multiple stop flights (Only on Wed, Fri, Sun) | Difference between cost | Cost Non-Stop flights per pcs | Cost Multiple stop flights per pcs | Difference in percentage |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2,800 | 342.65kgs | $2,433.82 | $2,037.49 | | $396.33 | $0.869 | $0.728 | 19.45% |
| 2 | 5,600 | 685.29kgs | $4,342.98 | $3,512.63 | | $830.35 | $0.776 | $0.627 | 23.64% |
| 3 | 8,400 | 1,027.94kgs | $6,252.14 | | $4,907.82 | $1,344.32 | $0.744 | $0.584 | 27.39% |
| 4 | 11,200 | 1,370.58kgs | $8,161.30 | | $6,371.54 | $1,789.76 | $0.729 | $0.569 | 28.09% |
| 5 | 14,000 | 1,713.23kgs | $10,070.46 | | $7,835.26 | $2,235.20 | $0.719 | $0.56 | 28.53% |
| 6 | 16,800 | 2,055.88kgs | $11,979.61 | | $9,298.98 | $2,680.63 | $0.713 | $0.554 | 28.83% |
| 7 | 19,600 | 2,398.52kgs | $13,888.77 | | $10,762.69 | $3,126.08 | $0.709 | $0.549 | 29.05% |
| 8 | 22,400 | 2,741.17kgs | $15,797.93 | | $12,226.41 | $3,571.52 | $.705 | $0.546 | 29.21% |
| 9 | 25,200 | 3,083.81kgs | $17,707.09 | | $13,690.13 | $4,016.96 | $0.703 | $0.543 | 29.34% |

*Table 7. Shipping PCBA T8/4FT/4000K by air freight cargo from Taiwan to USA (Santa Clara- California).*

*Source: Luxul's Internal report*

Then for better analysis we simplify information as following:



DOI:10.6814/NCCU202101735

In the whole analysis we will focus in the major range of the shipments, by the qty of pcs per pallet classified intro three groups: <8400, <8400, 16800>, and >16800 and its lead time.

We define Lead time as the cycle time that we need for fulfill an order. It starts from receive the order, process the order, produce the material, and the intransit time from Taiwan to USA

The intransit time depends what kind of freight service is required and might vary its costs.

| **Flight type** | **Lead time** | **Estimate Intransit delivery days** | **Qty of pcs per pallets** | **Total Cost** | **Cost per pcs** |
|---|---|---|---|---|---|
| Non-stop Flight | 10 Days | 2 Days | <8,400 | $6,252.14 | $0.744 |
| | 10 Days | 2 Days | <8,400,16,800> | $11,979.61 | $0.713 |
| | 10 Days | 2 Days | >16,800 | $15,797.93 | $0.709 |
| Multiple stop Flight | 13 Days | 3~5 Days | <8,400 | $4,907.82 | $0.584 |
| | 13 Days | 3~5 Days | <8,400,16,800> | $9,298.98 | $0.554 |
| | 13 Days | 3~5 Days | >16,800 | $12,226.41 | $0.546 |

*Table 8. Shipping by air freight reference.*

*Source: Luxul's Internal report*


DOI:10.6814/NCCU202101735

Now we will calculate the EOQ when Luxul would like to send the products in 2 days intransit.

When PCBA quantity is between 0~8,400 pcs for 2 days Intransit by Non-stop flight

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *S* = | $ 6,252.14 | (Shipping cost for 2 shipping days) |
| *H* = | $5.00 | |

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(6{,}252.14)}{5}}$$

$\text{EOQ(Order quantity)} =$ 13,841Pcs, which will be rounded to 8400 MPQ

***Total Annual Holding and Ordering Cost:***

We use EOQ as 8400pcs, then:

$$TC_{EOQ} = DC\left(\frac{D}{Q}\,S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *C*= | $0.744 | Per pcs (when qty is 8400pcs) |
| *Q*= | 8,400 | EOQ |
| *S* = | $ 6,252.14 | (Shipping cost for 2 intransit days) |
| *H* = | $5.00 | |

$$TC_{EOQ} = 76{,}597\text{x}\$0.744\left(\frac{76{,}597}{8{,}400}\;6{,}252.14\right) + \left(\frac{8{,}400}{2}5\right)$$

$$TC_{EOQ} = \$134{,}999.50$$


DOI:10.6814/NCCU202101735

When PCBA quantity is between 8,400~16,800 for 2 days intransit

***EOQ:*** $\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *S* = | $ 11,979.61 | (Shipping cost for 8,400~16,800 pcs of PCBA-2 days intransit) |
| *H* = | $5.00 | |

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(11{,}979.61)}{5}}$$

$\text{EOQ(Order quantity)} =$ 19,159pcs which will be rounded to 16,800 MPQ

***Total Annual Holding and Ordering Cost:***

$$TC_{EOQ} = DC\left(\frac{D}{Q}\,S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *C*= | $0.713 | Per pcs (when qty is 8,400~16,800pcs) |
| *Q*= | 16,800 | EOQ |
| *S* = | $ 11,979.61 | (Shipping cost for 2 days intransit) |
| *H* = | $5.00 | |

$$TC_{EOQ} = 76{,}597x0.713 + \left(\frac{76{,}597}{16{,}800}\ \$\ 11{,}979.61\right) + \left(\frac{16{,}800}{2}5\right)$$

$TC_{EOQ} = \$151{,}232.84$


DOI:10.6814/NCCU202101735

When PCBA quantity is between 16,800~22,400 for 2 days intransit

$$\textbf{EOQ}(\textbf{Order quantity}) = \sqrt{\frac{2DS}{H}}$$

***EOQ:***

$$\text{EOQ}(\text{Order quantity}) = \sqrt{\frac{2DS}{H}}$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *S* = | $15,797.93 | (Shipping cost for 16,800~22,400pcs of PCBA-2 days intransit) |
| *H* = | $5.00 | |

$$\text{EOQ}(\text{Order quantity}) = \sqrt{\frac{2(76{,}597)(15{,}797.93)}{5}}$$

$$\text{EOQ}(\text{Order quantity}) = 22{,}001\text{pcs}$$

***Total Annual Holding and Ordering Cost:***

We use EOQ as 22001pcs, then:

$$TC_{EOQ} = DC\left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *C*= | $0.709 | Per pcs (when qty is <16,800pcs) |
| *Q*= | 22,001 | EOQ |
| *S* = | $15,797.93 | (Shipping cost for 2 days intransit) |
| *H* = | $5.00 | |

$$TC_{EOQ} = 76{,}597x\ 0.713\left(\frac{76{,}597}{22{,}001}\ 15{,}797.93\right) + \left(\frac{22{,}001}{2}5\right)$$

$$TC_{EOQ} = \$164{,}310.64$$


DOI:10.6814/NCCU202101735

After these three calculations we get the following results in the *Table 9*:

| Total cost | 2 days Intransit mode |
|---|---|
| (1) | $134,999.50 |
| (2) | $151,232.84 |
| (3) | $164,310.64 |

*Table 9. Total cost results for 2 days intransit mode*

So, the minimum cost for two days shipping is $134,999.50 with an EOQ of 8,400pcs

*Re-order Point with Constant Demand (*see *Table 10)*

$$\boldsymbol{R = \bar{d}L}$$

*Where:*

$\bar{d}$ = 210 pcs per day (76,597/365days)

$L$ = 10 Days

$R = 210 * 10$

$R = 2{,}100$ pcs





DOI:10.6814/NCCU202101735

*Table 10. Optimal Quantity and Reorder Point with Constant Demand using a 2 days intransit*

Re-order Point with a 50% Service level using 2 days intransit mode

$$\boldsymbol{R = \bar{d}L + z\sigma_d\sqrt{L}}$$

*Where:*

| | | |
|---|---|---|
| $\bar{d}$= | 210 | pcs per day (76,597/365days) |
| *Q*= | 8,400 | EOQ |
| *H*= | $ 5 | |
| *S*= | $6,252.14 | (Shipping cost for 0~8400pcs of PCBA -2 days intransit) |
| *L*= | 10 | Days |
| *Z*= | -0 | Z value for 50% Service Level |
| $\sigma_d$= | 205 | Standard Deviation |

Safety Stock $= z\sigma_d\sqrt{L}$

Safety Stock $= (0)(63)\sqrt{10}$

Safety Stock = 0 pcs

$R = (210)(10) + (0)(205)\sqrt{10}$

$R = 2{,}100 + 0$

$R = 2{,}100\text{pcs}$

So, when the inventory of PCBA reach the quantity of 2,100 pcs. Luxul Taiwan must order PCBA to send it to USA. Then, their safety stock will be 0 pcs. *(*See ***Table 11)***


DOI:10.6814/NCCU202101735

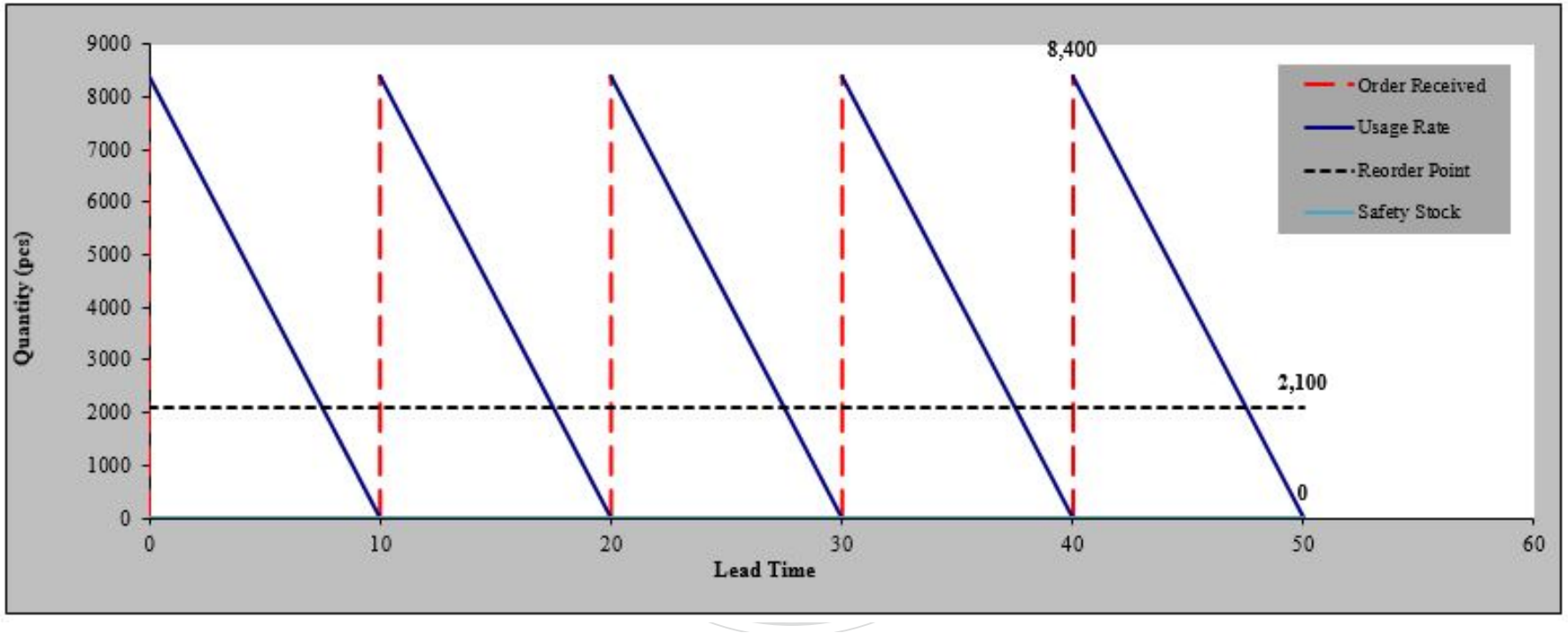


*Table 11 Optimal Quantity and Re-order Point with a 50% Service level using 2 days intransit*



DOI:10.6814/NCCU202101735

Re-order Point with a 95% Service level using 2 days intransit

$$\boldsymbol{R = \bar{d}L + z\sigma_d\sqrt{L}}$$

*Where:*

| | | |
|---|---|---|
| $\bar{d}$ = | 210 | pcs per day (76,597/365days) |
| *Q*= | 8,400 | EOQ |
| *H*= | $ 5 | |
| *S*= | $6,252.14 | (Shipping cost for 0~8400pcs of PCBA -2 intransit days) |
| *L*= | 10 | Days |
| *Z*= | 1.64 | Z value for 95% Service Level |
| $\sigma_d$= | 205 | Standard Deviation |

Safety Stock $= z\sigma_d\sqrt{L}$

Safety Stock $= (1.64)(205)\sqrt{10}$

Safety Stock = 1,063 pcs

$R = (210)(10) + (1.64)(205)\sqrt{10}$

$R = 2{,}100 + 1{,}063$

$R = 3{,}163\text{pcs}$

So, when the inventory of PCBA reaches the quantity of 3,163 pcs. Luxul Taiwan must order PCBA to send it to USA. Then, their safety stock will be 1, 063 pcs. *(*See ***Table 12)***


DOI:10.6814/NCCU202101735

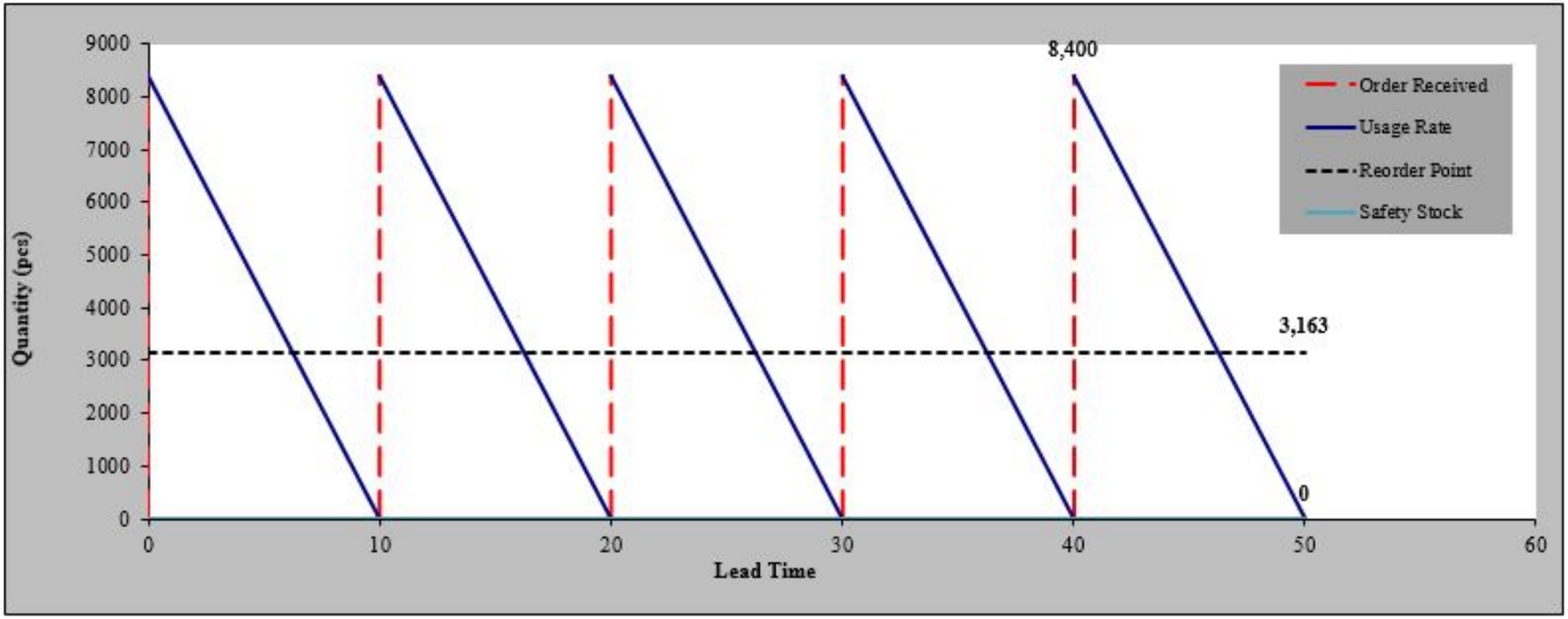


*Table 12 Optimal Quantity and Re-order Point with a 95% Service level for a 2 days intransit*



DOI:10.6814/NCCU202101735

Re-order Point with a 99% Service level using 2 days intransit

$$\boldsymbol{R = \bar{d}L + z\sigma_d\sqrt{L}}$$

*Where:*

| | | |
|---|---|---|
| $\bar{d}$ = | 210 | pcs per day (76,597/365days) |
| *Q*= | 8,400 | EOQ |
| *H*= | $ 5 | |
| *S*= | $6,252.14 | (Shipping cost for 0~8400pcs of PCBA -2 days intransit) |
| *L*= | 10 | Days |
| *Z*= | 2.32 | Z value for 99% Service Level |
| $\sigma_d$ = | 205 | Standard Deviation |

Safety Stock $= z\sigma_d\sqrt{L}$

Safety Stock $= (2.32)(205)\sqrt{10}$

Safety Stock = 1,504 pcs

$R = (210)(10) + (2.32)(205)\sqrt{10}$

$R = 2{,}100 + 1{,}504$

$R = 3{,}604$ pcs

So, when the inventory of PCBA reaches the quantity of 3,604 pcs. Luxul Taiwan must order PCBA to send it to USA. Then, their safety stock will be 1,503 pcs. *(*See ***Table 13)***


DOI:10.6814/NCCU202101735

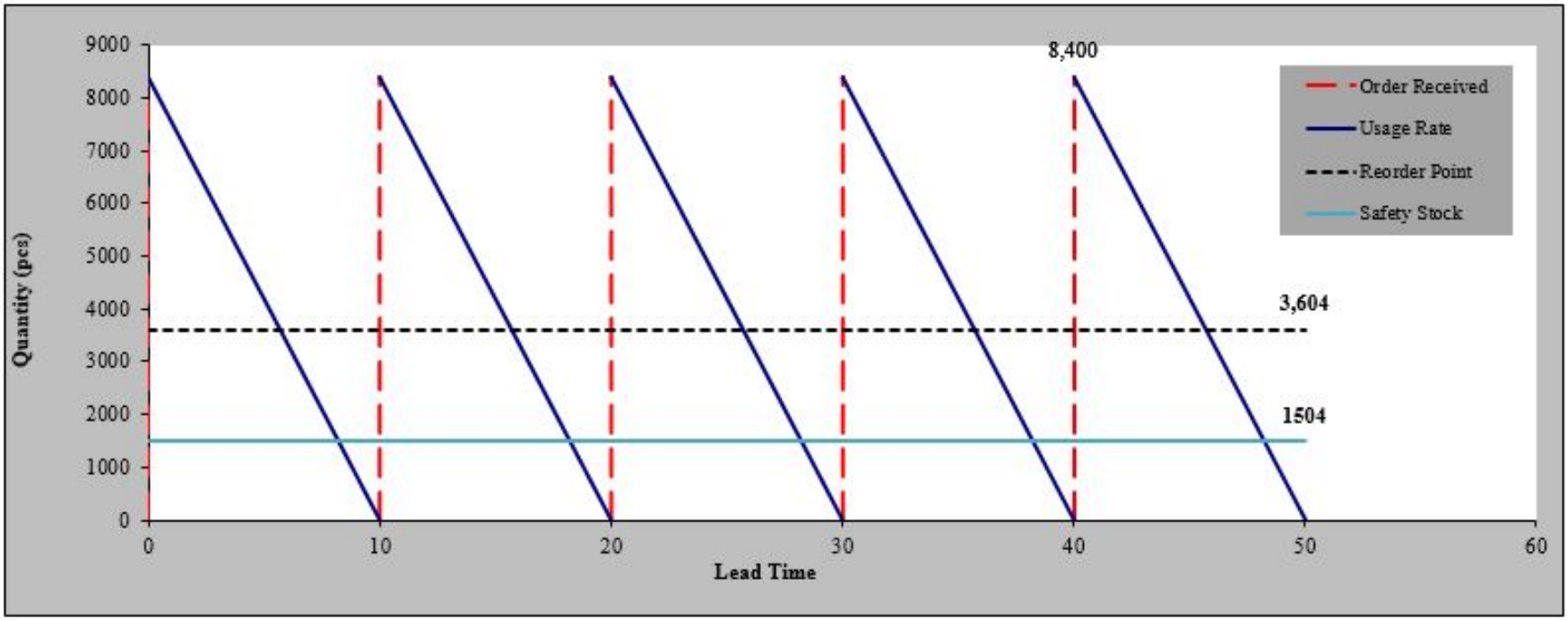


*Table 13 Optimal Quantity and Re-order Point with a 99% Service level using 2 days intransit*



DOI:10.6814/NCCU202101735

Now we will calculate when Luxul would like to send the products in 3~5 days intransit

When PCBA quantity is between 0~8,400 pcs for 3~5 days intransit.

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *S* = | $ 4,907.82 | (Shipping cost for 3~5 days intransit) |
| *H* = | $5.00 | |

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(4{,}907.82)}{5}}$$

$\text{EOQ(Order quantity)} =$ 12,263pcs which will be rounded to 8,400 MPQ

***Total Annual Holding and Ordering Cost:***

$$TC_{EOQ} = DC\left(\frac{D}{Q}\,S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *C*= | $0.584 | Per pcs (when qty is <8,400) |
| *Q*= | 8,400 | EOQ |
| *S* = | $ 4,907.82 | (Shipping cost for 3~5 days intransit) |
| *H* = | $5.00 | |

$$TC_{EOQ} = 76{,}597x0.584\left(\frac{76{,}597}{8{,}400}\;4{,}907.82\right) + \left(\frac{8{,}400}{2}5\right) TC_{EOQ} = \$110{,}485.54$$


DOI:10.6814/NCCU202101735

When PCBA Qty. is between 8,400~16,800 for 3~5 days intransit

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *S* = | $ 9,298.98 | (Shipping cost for 8,400~16,800 pcs of PCBA- for 3~5 days intransit) |
| *H* = | $5.00 | |

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(9{,}298.98)}{5}}$$

$\text{EOQ(Order quantity)} =$ 16,880pcs which will be rounded to MPQ 16,800

***Total Annual Holding and Ordering Cost:***

$$TC_{EOQ} = DC\left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *C*= | 0.554 | |
| *Q*= | 16,800 | EOQ |
| *S* = | $ 9,298.98 | (Shipping cost for 3~5 shipping days) |
| *H* = | $5.00 | |

$$TC_{EOQ} = 76{,}597\ x\ 0.554\left(\frac{76{,}597}{16{,}800}\ 9{,}298.98\right) + \left(\frac{16800}{2}5\right)$$

$$TC_{EOQ} = \$126{,}832$$

When PCBA Qty. is between 16,800~22,400for 3~5 shipping days



DOI:10.6814/NCCU202101735

$$\textbf{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$$

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H}}$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *S* = | $ 12,226.41 | (Shipping cost for 16800~22,400pcs of PCBA- for 3~5 days intransit) |
| *H* = | $5.00 | |

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(12{,}226.41)}{5}}$$

EOQ(Order quantity) = 19,355pcs which will be rounded to 22,400 MPQ

***Total Annual Holding and Ordering Cost:***

$$TC_{EOQ} = DC\left(\frac{D}{Q}\,S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 76,597 | pcs |
| *C*= | $0.546 | |
| *Q*= | 22,400 | EOQ |
| *S* = | $ 12,226.41 | (Shipping cost for 3~5days intransit) |
| *H* = | $5.00 | |

$$TC_{EOQ} = 76597\ x\ 0.546\left(\frac{76{,}597}{22{,}400}\ 12{,}226.41\right) + \left(\frac{22{,}400}{2}5\right)$$

$TC_{EOQ}$ =$139,630.28

After these three calculations we get the following results in the ***Table 14***:

DOI:10.6814/NCCU202101735

| Total cost for | 3~5 days intransit |
|---|---|
| **(1)** | $110,485.54 |
| **(2)** | $126,832 |
| **(3)** | $139,630.28 |

*Table 14 Total cost results for 3~5 days shipping days*

So, the minimum cost for 3~5 days intransit is $110,485.54 with a EOQ of 8400 pcs.

Re-order Point with Constant Demand (see ***Table 15***)

$$\boldsymbol{R = \bar{d}L}$$

*Where:*

$\bar{d} = 210$ pcs per day (76,597/365days)

$L = 13$ Days

$R = 210 * 13$

$R = 2{,}730$ pcs




DOI:10.6814/NCCU202101735

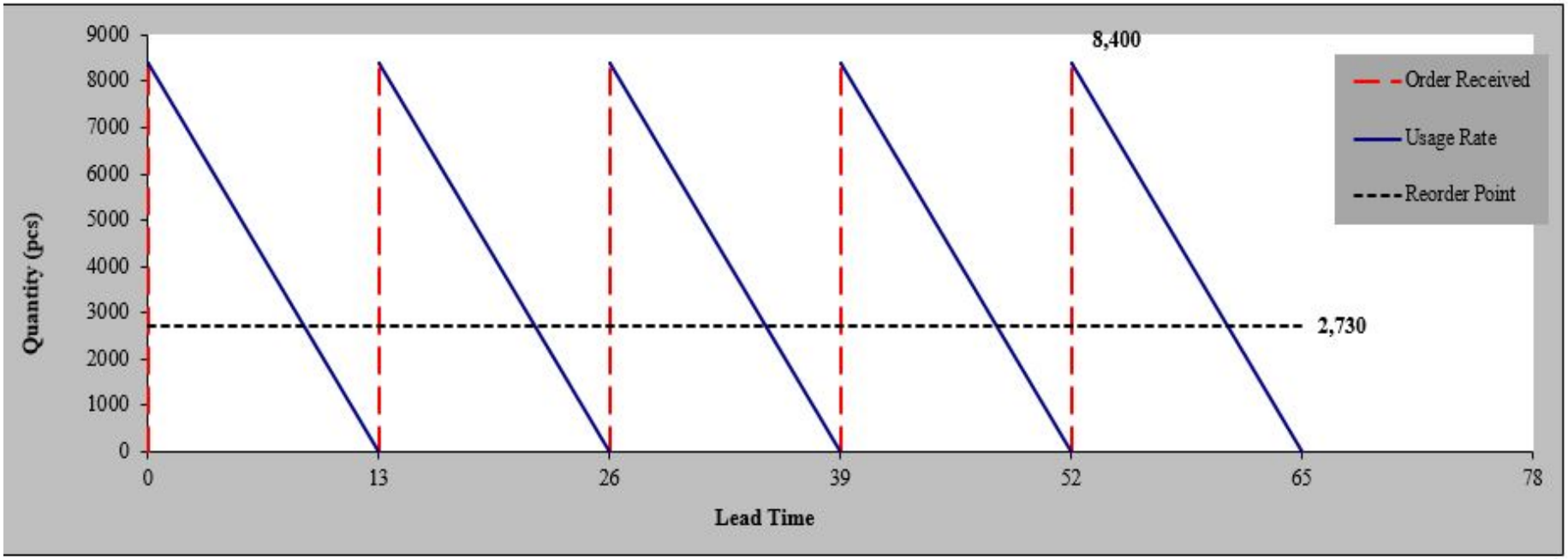


*Table 15 Optimal Quantity and Reorder Point with Constant Demand using 3~5 days intransi*



DOI:10.6814/NCCU202101735

Re-order Point with a 50% Service level:

$$\boldsymbol{R = \bar{d}L + z\sigma_d\sqrt{L}}$$

*Where:*

| | | |
|---|---|---|
| $\bar{d}$ = | 210 | pcs per day (76,597/365days) |
| *Q* = | 8,400 | EOQ |
| *H* = | $ 5 | |
| *S* = | $4,907.82 | (Shipping cost for 0~8400pcs of PCBA -3~5 days intransit) |
| *L* = | 13 | Days |
| *Z* = | 0 | Z value for 50% Service Level |
| $\sigma_d$ = | 205 | Standard Deviation |

Safety Stock =$z\sigma_d\sqrt{L}$

Safety Stock =$(0)(56)\sqrt{13}$

Safety Stock = 0 pcs

R= $(210)(13) + (0)(205)\sqrt{13}$

R= 2730+0

R= 2,730 pcs

So, when the inventory of PCBA reaches the quantity of 2,730 pcs. Luxul Taiwan must order PCBA to send it to USA. Then, their safety stock will be 0 pcs. (See ***Table 16***)



DOI:10.6814/NCCU202101735

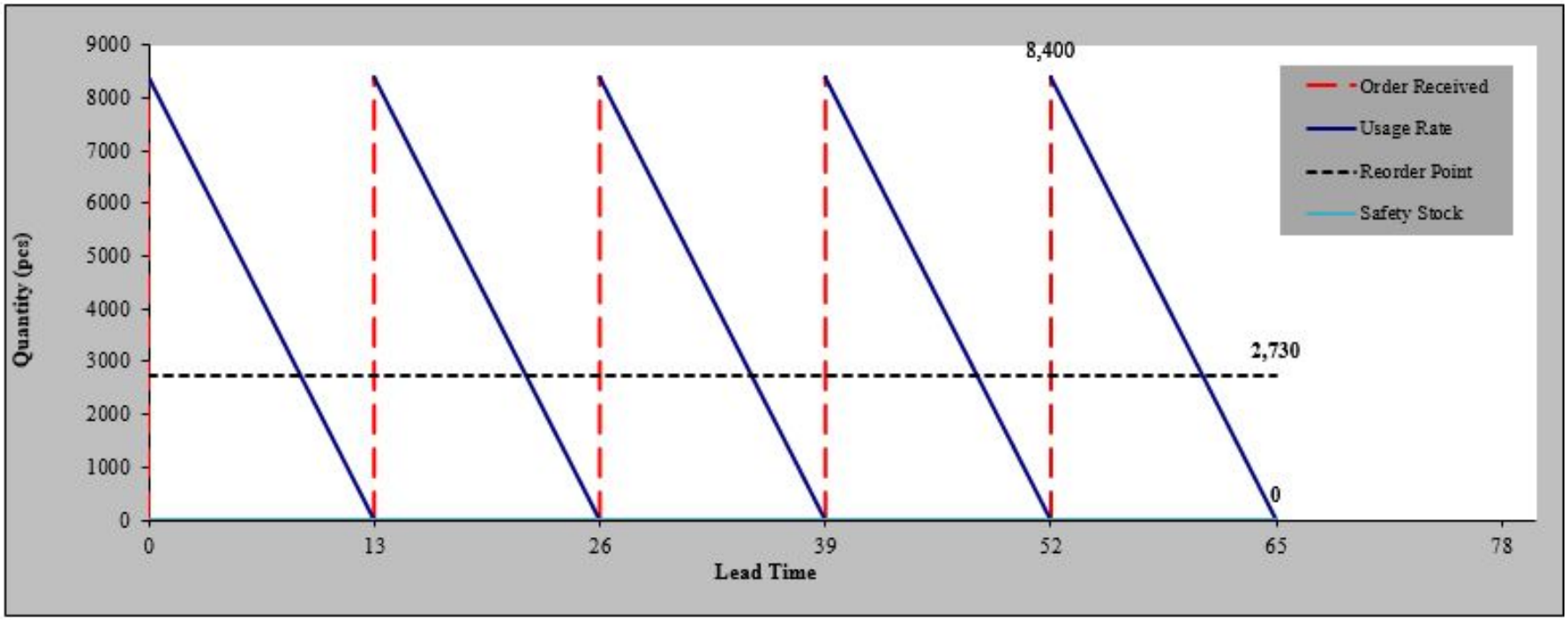


*Table 16 Optimal Quantity and Re-order Point with a 50% Service level for a 3~5 days intransit*



DOI:10.6814/NCCU202101735

Re-order Point with a 95% Service level:

$$\boldsymbol{R = \bar{d}L + z\sigma_d\sqrt{L}}$$

*Where:*

| | | |
|---|---|---|
| $\bar{d}$ = | 210 | pcs per day (76,597/365days) |
| *Q*= | 8,400 | EOQ |
| *H*= | $ 5 | |
| *S*= | $4,907.82 | (Shipping cost for 0~8,400pcs of PCBA -2 shipping days) |
| *L*= | 13 | Days |
| *Z*= | 1.64 | Z value for 95% Service Level |
| $\sigma_d$= | 205 | Standard Deviation |

Safety Stock =$z\sigma_d\sqrt{L}$

Safety Stock =$(1.64)(205)\sqrt{13}$

Safety Stock = 1213 pcs

$R = (210)(13) + (1.64)(205)\sqrt{13}$

$R = 2{,}730 + 1{,}212$

$R = 3{,}942\text{pcs}$

So, when the inventory of PCBA reaches the quantity of 3,942 pcs. Luxul Taiwan must order PCBA to send it to USA. Then, their safety stock will be 1,212 pcs. (See ***Table 17***)



DOI:10.6814/NCCU202101735

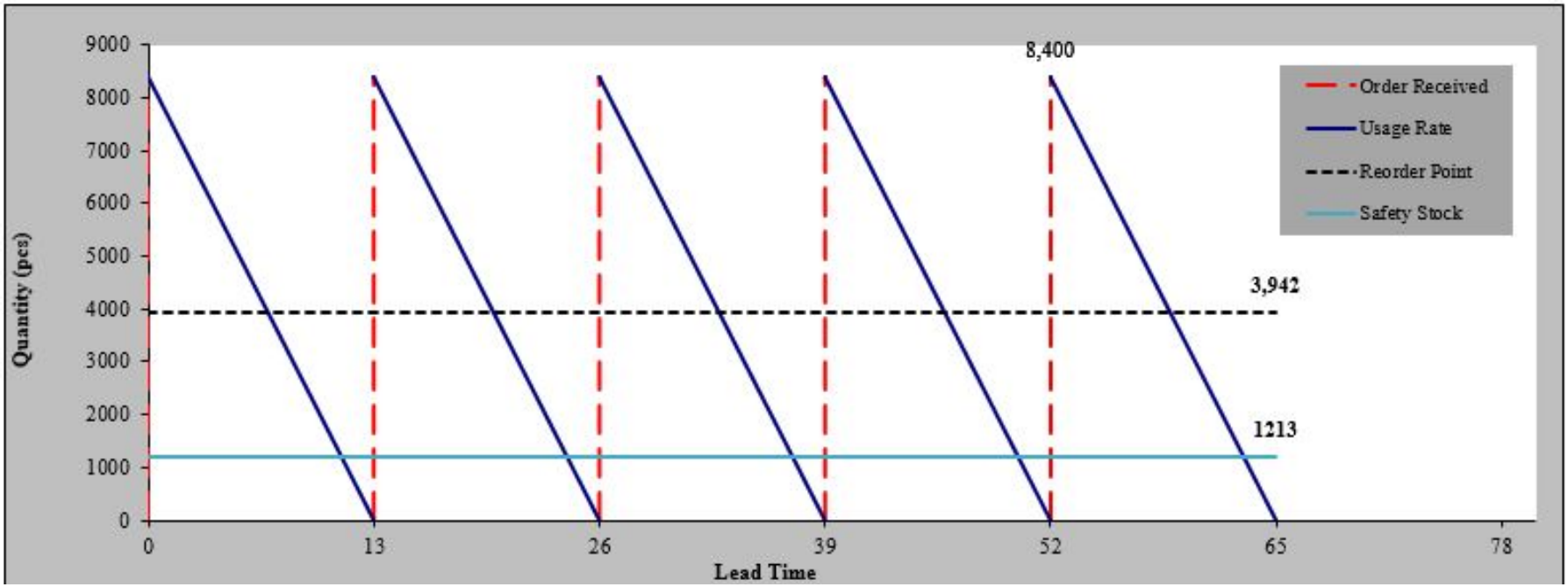


*Table 17 Optimal Quantity and Re-order Point with a 95% Service level for a 3~5 days intransit*



DOI:10.6814/NCCU202101735

Re-order Point with a 99% Service level:

$$\boldsymbol{R = \bar{d}L + z\sigma_d\sqrt{L}}$$

*Where:*

| | | |
|---|---|---|
| $\bar{d}$ = | 210 | pcs per day (76,597/365days) |
| *Q*= | 8,400 | EOQ |
| *H*= | $ 5 | |
| *S*= | $ 4,907.82 | (Shipping cost for 0~8400pcs of PCBA -2 shipping days) |
| *L*= | 13 | Days |
| *Z*= | 2.32 | Z value for 99% Service Level |
| $\sigma_d$= | 205 | Standard Deviation |

Safety Stock $= z\sigma_d\sqrt{L}$

Safety Stock $= (2.32)(205)\sqrt{13}$

Safety Stock = 1715 pcs

$R = (210)(13) + (2.32)(205)\sqrt{13}$

$R = 2{,}730 + 1715$

$R = 4{,}445$ pcs

So, when the inventory of PCBA reaches the quantity of 4,445 pcs. Luxul Taiwan must order PCBA to send it to USA. Then, their safety stock will be 1,715 pcs. (See ***Table 18***)



DOI:10.6814/NCCU202101735

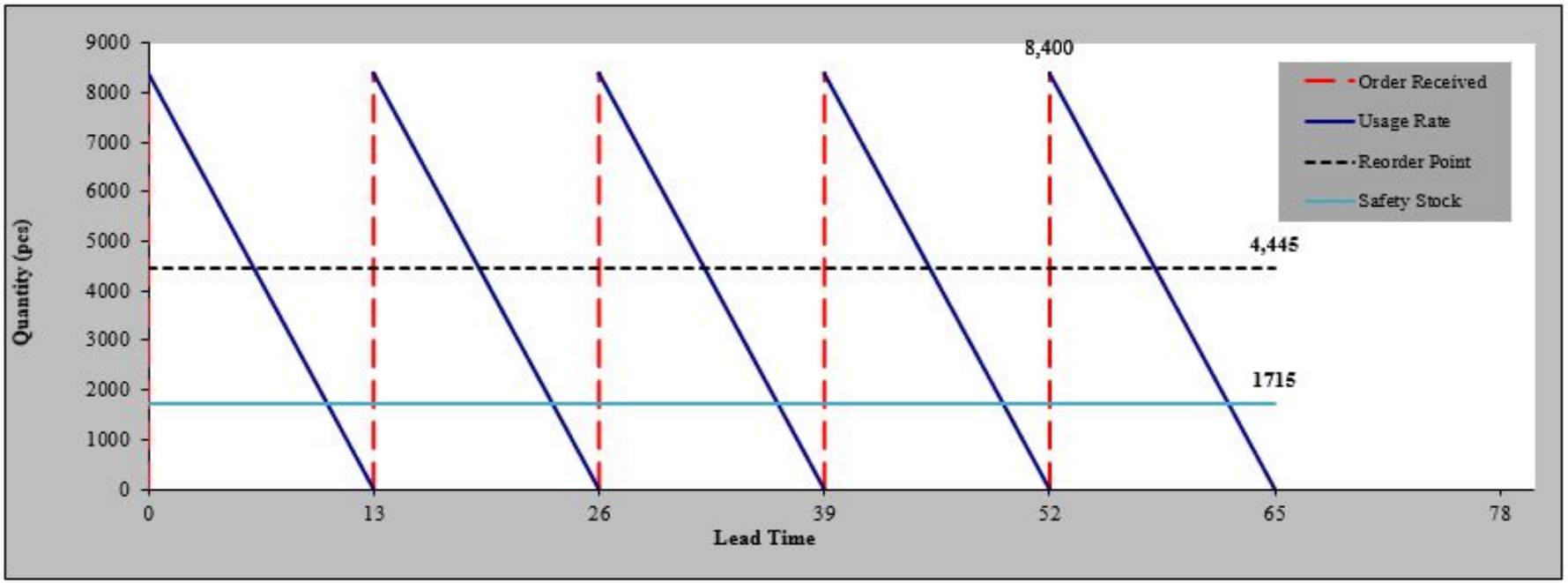


*Table 18 Optimal Quantity and Re-order Point with a 99% Service level for a 3~5 days intransit*



DOI:10.6814/NCCU202101735

### 3.5 Optimal Policy

After get the two deliveries (2 days, 3~5 days shipping days total cost we have (see ***Table 19***) :

| | **Total Cost (TC) per pcs** | **EOQ** |
|---|---|---|
| **2 Days** | $ 134,999.50 | 8,400 |
| **3~5 Days** | $ 110.485.54 | 8,400 |

*Table 19. Total cost results for 2 and 3~5 days intransit*

In order to know how many times per year does Luxul reorder, we use the following formula:

*For 2, 3~5 days intransit*

Number or orders per year = $\frac{D}{Q}$

Number or orders per year = $\frac{76,597}{8,400}$

Number or orders per year = 9.11

*Current cost:*

Annual quantity= 76,597 pcs

Cost per pcs= $ 0.744 (2 days intransit freight cost per pcs when Luxul send only 3 pallets)

76,597* $ 0.744

TC= $ 56,988.168 (for 2 shipping days)

Cost per pcs= $ 0.584(3~5 days intransit freight cost per pcs when Luxul send only 3 pallets)

76,597* $ 0.584

TC= $ 44,732.64

*Condition 1: No policy change with 20% sales Increase*

TC= $ 56,988.168 (2 shipping days cost) *1.2



DOI:10.6814/NCCU202101735

TC= $ 68,385.80

TC= $ 44,732.64 (3~5 shipping days cost) *1.2

TC= $ 53,679.168

*Condition 2: No policy with 30% sales Increase*

TC= $ 56,988.168 (2 shipping days cost) *1.3

TC= $ 74,084.61

TC= $ 44,732.64 (3~5 shipping days cost) *1.3

TC= $ 58,152.432

*Condition 3: Optimal Policy*

For 2 shipping days

TC= $ 134,999.50

For 3~5 shipping days

TC=$ 110,485.54

*Condition 4: Optimal Policy with 20% sales increase*

For 2 shipping days

TC*1.2

$ 134,999.50*1.2= $161,999.4

For 3~5 shipping days

TC*1.2

$ 110,485.54*1.2= $132,582.648

*Condition 5: Optimal Policy with 30% sales increase*

For 2 shipping days

TC*1.3

$ 134,999.50*1.3= $175,499.35

For 3~5shipping days

TC*1.3

$ 110,485.54*1.3= $143,631.202



DOI:10.6814/NCCU202101735

***Fixed-Order-Interval Model***

In order to reduce shipping cost, Luxul sends the mechanical parts (aluminum, Plastic Lamp shape, and caps) by ship. Most of these parts are jointly used with other models. Quantities are fixed.

When the demand rate and lead time are constant, then the fixed-period model will have a fixed-order quantity that will be made at specified time intervals, which is the same as the fixed-quantity (EOQ) model under similar conditions. (See ***Figure 15***)

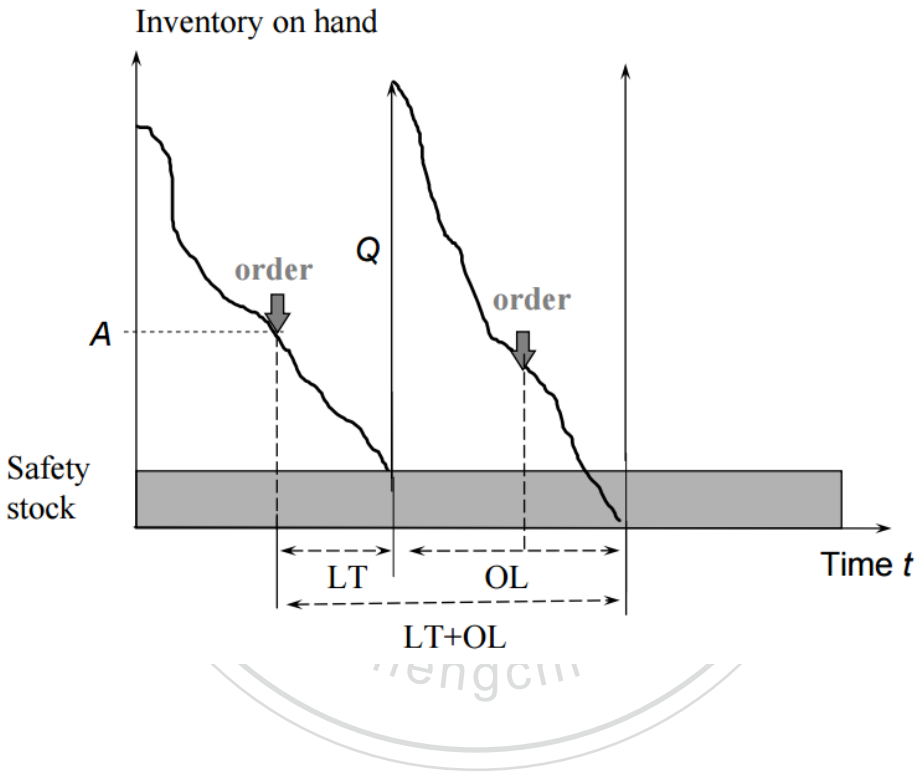


*Figure 15. Inventory with Reorder Point*



DOI:10.6814/NCCU202101735

$$Q = \bar{d}(t_b + L) + z\sigma_d\sqrt{t_b + L} - I$$

*Where:*

$Q$ = Quantity to be ordered

$\bar{d}$ = Average demand rate

$\sigma_d$ = Standard deviation of daily demand

$t_b$ = Time between orders

$L$ = Lead Time

$I$ = Inventory in Stock

$Z$ = the number of standard deviations for a 95% service level)

By the Fixed Interval Model, it can help to determine the order size for this order period that will enable Luxul USA to maintain a 95% service level.

Reasons of why Luxul can use this model include:

1. Luxul Taiwan's might encourage orders at fixed intervals;
2. Grouping orders for items can produce savings in shipping costs;
3. Do not require continuous monitoring of inventory levels, only periodic check is needed.

If the average demand for the any T8/4FT Aluminum is 482 pcs per day, with a standard deviation of 28.53. An inventory personnel is checking the stock every 15 days. During one check, he realized had 800 pcs in stock. The shipping cost per pcs when is sent it by Sea freight is $0.23. The lead time to receive an order is 45 days. The shipping cost is $2,300. We will determine the order size for this order period that will enable Luxul USA to maintain a 95% service level (see details in ***Table 20***).



DOI:10.6814/NCCU202101735

| Demand | | | | | |
|---|---|---|---|---|---|
| **Years** | **Month** | **Product Name** | **Cap** | **Size** | **Total** |
| | January | Aluminum | T8 | 4FT | 6,474 |
| | February | Aluminum | T8 | 4FT | 1,460 |
| | March | Aluminum | T8 | 4FT | 1,984 |
| | April | Aluminum | T8 | 4FT | 23,174 |
| 2014 | May | Aluminum | T8 | 4FT | 22,197 |
| | June | Aluminum | T8 | 4FT | 16,082 |
| | July | Aluminum | T8 | 4FT | 11,522 |
| | August | Aluminum | T8 | 4FT | 5,608 |
| | September | Aluminum | T8 | 4FT | 17,539 |
| | October | Aluminum | T8 | 4FT | 36,329 |
| | November | Aluminum | T8 | 4FT | 11,746 |
| | December | Aluminum | T8 | 4FT | 21,667 |
| **Grand Total** | | | | | **175,782** |
| **Num=** | | **12** | | | |
| **Standard Deviation=** | | **28.53** | | | |

*Table 20. Shipping by Sea freight from Taiwan to USA (Santa Clara- California)*

*Source: Luxul's Internal report*

$$Q = \bar{d}(t_b + L) + z\sigma_d\sqrt{t_b + L} - I$$

*Where:*

$\bar{d}$ = 482 pcs per day (175,782/365 days)

$\sigma_d$= 28.53

$t_b$ = 15 days

$L$ = 45 days

$I$= 800 pcs



DOI:10.6814/NCCU202101735

$z$= 1.645 for a 95% service level

$$\boldsymbol{Q} = (482)(15+45) + (1.64)(28.53)\sqrt{15+45} - 800$$

$$\boldsymbol{Q} = 28{,}482 \text{ pcs}$$

So, the quantity to be ordered for refill a T8/4ft Aluminum is 28,482





DOI:10.6814/NCCU202101735

Reorder Point for a 95% service level

$R = \bar{d}L + z\sigma_d\sqrt{L}$

$R = 482(45) + (1.64)(28.53)\sqrt{45}$

R=22,004pcs

Safety Stock $= z\sigma_d\sqrt{L}$

Safety Stock $= (1.64)(28.53)\sqrt{45}$

Safety Stock =314 pcs

Total Annual cost:

$$TC_{EOQ} = \left(\frac{D}{Q}\ S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 175,782 | pcs |
| *Q*= | 28,482 | EOQ |
| *S* = | $ 2,300 | Shipping cost |
| *H* = | $5.00 | |

$$TC_{EOQ} = \left(\frac{175{,}782}{28{,}482}\ 2300\right) + \left(\frac{28{,}482}{2}5\right)$$

$$TC_{EOQ} = \$85{,}400.74$$



DOI:10.6814/NCCU202101735

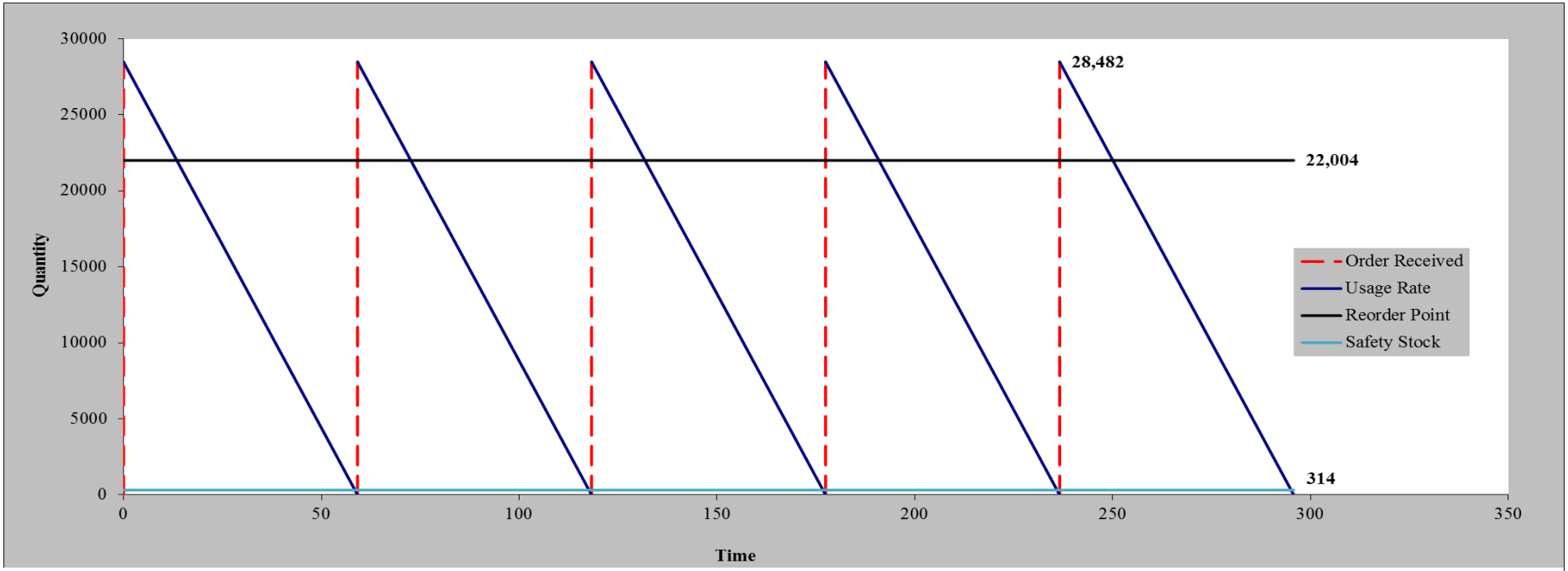


*Table 21 Optimal Quantity and Re-order Point with a 95% Service level*



DOI:10.6814/NCCU202101735

Now we will calculate determine the order size for this order period that will enable Luxul USA to maintain a 99% service level.

$$Q = \bar{d}(t_b + L + z\sigma_d\sqrt{t_b + L} - I$$

*Where:*

$Q$ = Quantity to be ordered

$\bar{d}$ = Average demand rate

$\sigma_d$ = Standard deviation of demand

$t_b$ = Time between orders

$L$ = Lead Time

$I$ = Inventory in Stock

$Z$ = the number of standard deviations for a 95% service level)

$\bar{d}$ = 482 pcs per day

$\sigma_d$ = 28.53

$t_b$ = 15 days

$L$ = 45 days

$I$ = 800 pcs

$z$ = 2.326 for a 99% service level



DOI:10.6814/NCCU202101735

$$\boldsymbol{Q} = (482)(15 + 45) + (2.326)(28.53)\sqrt{15 + 45} - 800$$

$$\boldsymbol{Q} = 28{,}633\text{pcs}$$

So, the quantity to be ordered for refill a T8/4ft Aluminum is 28,633





DOI:10.6814/NCCU202101735

Reorder Point for a 95% service level

R=$\bar{d}L + z\sigma_d\sqrt{L}$

R=$482(45) + (2.326)(28.53)\sqrt{45}$

R= 22,135pcs

Safety Stock =$z\sigma_d\sqrt{L}$

Safety Stock =$(2.326)(28.53)\sqrt{45}$

Safety Stock = 445pcs

Total Annual cost:

$$TC_{EOQ} = \left(\frac{D}{Q}\,S\right) + \left(\frac{Q}{2}H\right)$$

*Where:*

| | | |
|---|---|---|
| *D*= | 175,782 | pcs |
| *Q*= | 28,633 | EOQ |
| *S* = | $ 2,300 | Shipping cost |
| *H* = | $5.00 | |

$$TC_{EOQ} = \left(\frac{175{,}782}{28{,}633}\,2300\right) + \left(\frac{28{,}633}{2}5\right)$$

$$TC_{EOQ} = \$85{,}701.93$$

*Current cost:*

Annual quantity= 76,597 pcs

175,782* $0.23

TC= $ 40,429.86



DOI:10.6814/NCCU202101735

*Condition 1: No policy change with 20% sales Increase*

TC= $ 40,429.86*1.2

TC= $ 48,515.832

*Condition 2: No policy with 30% sales Increase*

TC= $ 40,429.86*1.3

TC= $ 52,558.818

*Condition 3: Optimal Policy*

TC=$ 87,761.48

*Condition 4: Optimal Policy with 20% sales increase*

TC*1.2

87,761.48*1.2=

$105,313.776

*Condition 5: Optimal Policy with 30% sales increase*

TC*1.3

$87,761.48*1.3=

$ 114,089.924



DOI:10.6814/NCCU202101735

***Quantity Discount Model***

This formula can be used for describe and analyze the different cost when we have different unit prices and cost depending of the quantity. When greater is the ordered quantity, less is the cost. In this case means above a certain order quantity level, all units in the order are discounted.

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right) + PD$$

*Where:*

**P=** *Per unit price of item*

**D=** *Annual Demand*

**S=** *Setup cost*

**H=** *Annual Holding cost rate*

**Q=** *Quantity*

Suppose Luxul order the following discount pricing plan:

| | |
|---|---|
| Order less than 1000 | $4.03 / unit |
| Order 1000 to less than 2000 | $4.00 / unit |
| Order 2000 or more | $3.97 / unit |

Then, Luxul's annual holding cost rate is 10%, cost per order is $5.00annual requirement is 76,597 units.

**Price 1=**



DOI:10.6814/NCCU202101735

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H * P}}$$

*Where:*

*D*= 76,597 pcs

*S* = 10%

*H* = $5.00

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(5)}{10 * 4.03}}$$

EOQ(Order quantity) = 138 Pcs

$TC = (308{,}686) + (2778) + 2778$

$TC = 314{,}242$

**Price 2=**

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H * P}}$$

*Where:*

*D*= 76,597 pcs

*S* = 10%

*H* = $5.00



DOI:10.6814/NCCU202101735

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(5)}{10 * 4.00}}$$

$\text{EOQ(Order quantity)} = \ 138 \ \text{Pcs}$

$TC = (306{,}388) + (383) + 20{,}020$

$TC = 326{,}791$

**Price 3=**

***EOQ:***

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2DS}{H * P}}$$

*Where:*

*D*= 76,597 pcs

*S* = 10%

*H* = $5.00

$$\text{EOQ(Order quantity)} = \sqrt{\frac{2(76{,}597)(5)}{10 * 3.97}}$$

$\text{EOQ(Order quantity)} = \ 139 \ \text{Pcs}$

$TC = (304{,}090) + (191) + (39{,}720)$

$TC = 344{,}001$



DOI:10.6814/NCCU202101735

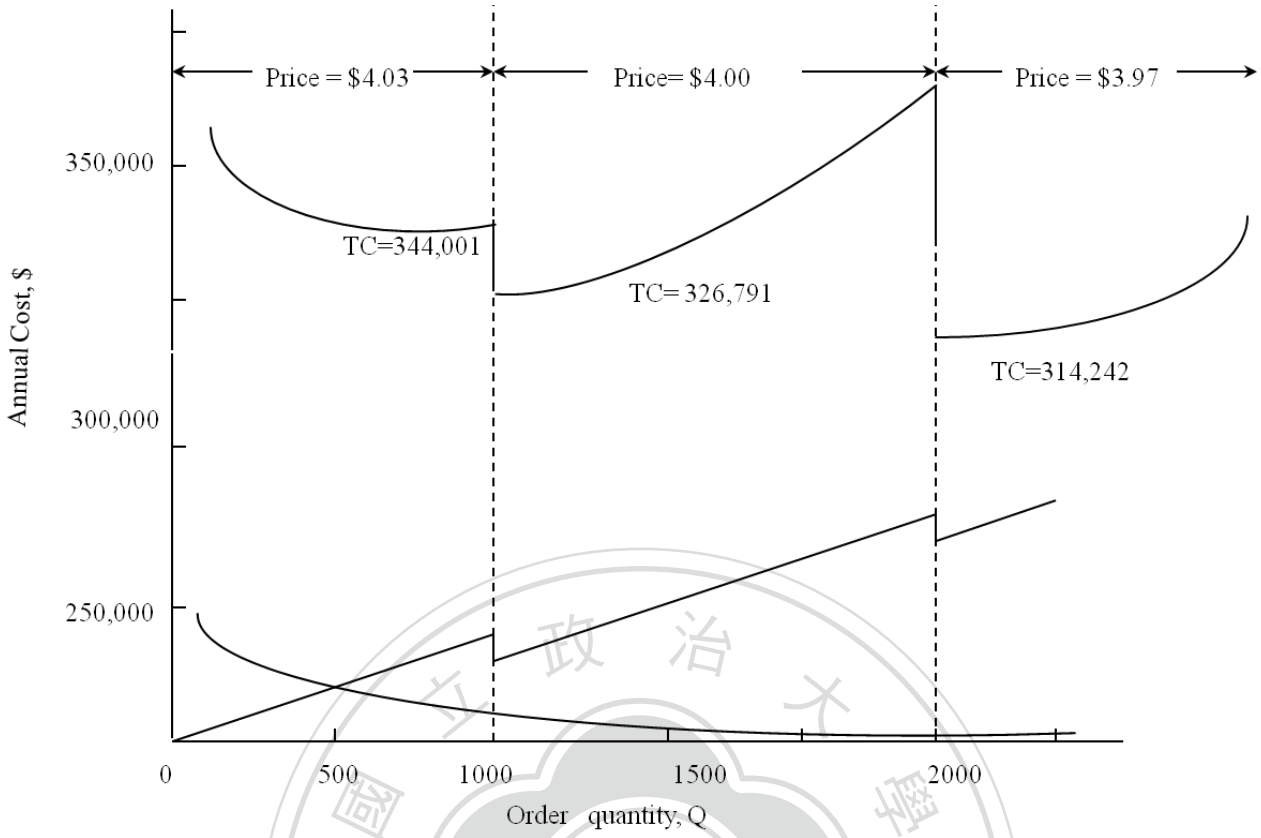


*Table 22 EOQ Model with Quantity Discounts*

| | **Results** |
|---|---|
| Optimal Q | 138 |
| Total Variable Cost | $314,242 |





DOI:10.6814/NCCU202101735

### 3.6 Internal VMI

Approach: Since Luxul USA and Luxul Taiwan are the same company, but their finance operations are separated acting as Supplier (Luxul Taiwan) and Customer (Luxul USA) is easy more easy exchange information about any status and it will avoid any misunderstanding. For better control in inventory in Luxul USA, Luxul Taiwan could take control of the inventory management and calculate different scenarios to help to reduce cost. In order to determine the effect of applying VMI between the production plant (in this case the supplier of materials) and distribution centers (buyers) of a multinational company, average total operating costs of maintaining analyzed inventory replenishment operation, using VMI, by studying the Total Annual Cost of Inventory, EOQ and the Re-order point trying to find the optimal quantity and also can reduce operations lead time.

Expectations (Savings): By VMI, Luxul Taiwan can monitor Luxul's USA inventory and can monitor which raw materials might have shortage risk. This can avoid expend high freight cost and can reduce even almost a 30% in shipping cost.

Goals: The objectives pursued by the company when planning provision are:

1. Establish a sufficient inventory, so production line would not lack raw materials

2. Determine the optimum order volume, production quantity, physical storage capacity, cost of invested capital, etc.

3. Minimize investment in inventory, reduce storage costs for loss and damage of the product, such as lower obsolescence or perishable items.



DOI:10.6814/NCCU202101735

4. Establish an efficient information system between the sections involved (purchasing, planning, production, distribution, etc.)

5. Cooperate with the purchasing department to achieve economic and efficient transportation management including the activities of shipping and receipt of goods.

6. Reduce supply lead time.

7. Control in real time the raw materials inventory and finish good products inventory.

8. Let minimize common mistakes and human error during operations.

Implementation plan (short term, long term): This stage is the most complex of all, because that is where it is manifested most strongly logical resistance to change, but at the same time is the most important because it is where really can show out the effectiveness. It should be noted that precisely at this process, is where need more emphasis on making adequate and systematic inventory calculation to make possible to enhance integrated logistics process management implementation, raise its efficiency and effectiveness in its operations. Briefly promote change, their effective management and generate an internal capacity for continuous improvement.

Communication and information challenge: It must be kept constant at all stages of the same, since it is essential to systematic interaction with all supply chain personnel, and they are the ones who best know the activities also constitute themselves as the protagonists of all changes, and ultimately are which should contribute their ideas and engage in work. In fact, communication and adequate information helps to improve it, and keep updated all personnel actions that are taking place, with utmost to incorporate



DOI:10.6814/NCCU202101735

their own ability to change and constant handling.

VMI Implementation: When the key activities reside mainly in the supplier or manufacturer, we can consider the following to start implementing VMI model:

1. Collection of information: acquisition of data warehouse and retail data information

2. Sales Forecast: is made on the outputs of the distribution centers and on the analysis of detailed sales reports.

3. Forecast Request: is the responsibility of the manufacturer and is done on inventory levels and costs agreed transport, which can plan outings.

4. Generation of orders: this activity is performed by the supplier to replenish inventory.

5. Delivery of orders: the delivery of the order retailer.

6. Full Shipping cost analysis

7. Common Monitoring system (ERP system) where the supplier can monitor the actual inventory.

The ERP (Enterprise resource planning) is a software that acts as a Planner of Business Resources. This ERP solution is aimed at its use in large and small or medium-sized companies, allowing them to automate each and every one of the business processes.

Depending of the budget, ERP companies can offer a Web interface and can be linked within transnational companies (see example ***Figure 16***). The advantage of this



DOI:10.6814/NCCU202101735

type of interface is that it requires the installation of a client application. As an internet connection will have (or local enterprise network, as appropriate), we can access the Web-based ERP through typical web browser allowing connection and data monitoring in anywhere.


*Figure 16.Transnational ERP system*

*Source:* Data Systems Consulting Co., Ltd. Website

Benefits to Luxul USA: Some of VMI benefits to Luxul USA can be listed as:

1. Achieve operational efficiencies cost,
2. Reduction in transportation cost because of surges in demand or a poor inventory planning.
3. The reduction in delivery times and avoid obsolete of materials.
4. Luxul can set priorities according to the production and replenishment, as a result of the inventory monitoring and visibility.
5. Reduced planning costs order generation



DOI:10.6814/NCCU202101735

6. VMI reduces product shortages

7. Luxul USA is more focused on providing good service to distributors, which in part helps distributors and business together.

Benefits to Luxul Taiwan:

1. Joint forecasts and accurate forecasts are achieved, resulting in a reduction in the material shortages or excess.

2. Producers can plan for priority-based replenishment.

3. Reduce order errors distribution.

4. Reduction in the time of supply (lead times) associated with the producer.

5. Increased return on investment.

Multiple benefits

1. The correct inventory information helps both parties to have better customer service.

2. VMI produces the benefits of providing the right material at the right time, thus improving the customer service in general.

3. It reduces the time and cost of generating orders.

4. The number of errors associated with inventory management and distribution of the goods is reduced.



DOI:10.6814/NCCU202101735

# Chapter IV Conclusions and Suggestions

We conclude in this study that inventory management technique such as VMI, reduces the overall costs of distribution systems and storage between producers and distributors.

By establishing the inventory in upper echelons of the supply chain, and managed by a single company, it can achieve the elimination of double inventories and reducing some storage costs.

A fundamental conclusion about the VMI tool and models that allow their replenishment plans is the need for information to flow effectively and efficiently between the distributor and seller. Information is the main driver of the reduction of the quantities to order, given the degree of knowledge that can be obtained on demand. This confirms the importance and the need for technology transfer information between companies seeking to implement VMI, such as ERP system.

After analyzing the result of using VMI in the same company, it can be concluded that the best method for calculation of replenishment should not be based on complexity but taking in count their principal challenge: Shipping cost and Inventory shortages. What is really important is to analyze, in particular, each company and its market characteristics, and then determine the most appropriate model of VMI used.



DOI:10.6814/NCCU202101735

# References


Silver, E. A., Pyke, D. F., & Peterson, R. 1998. ***Inventory management and production planning and scheduling*** (3rd. ed.). New York: John Wiley & Sons.

Baris, B. K., íster, H., & Çetinkaya, S. 2010, December). ***Integration of strategic and tactical decisions for vendor selection under capacity constraints.*** *37*(12), 2182-2191.

Keskin, B. B., Üster, H., & Çetinkaya, S. 2010. ***Integration of strategic and tactical decisions for vendor selection under capacity constraints.*** *Computers & Operations Research*, *37*(12), 2182-2191.

Bowersox, D., Closs , D., & Cooper, M. 2002. **Supply Chain Logistics Management (1st ed.)**. New York, N.Y.: McGraw-Hill/Irwin. Retrieved 2002

Chopra, S., & Meindl, P. 2008. ***Administración de la cadena de suministro Estrategia, planeación y operación (3rd ed.)***. México D.F., México: Pearson Prentice Hall.

Escudero Serrano, M. 2011. **Gestión de aprovisionamiento : administración (3rd ed.)**. Madrid, España: Ediciones Paraninfo, SA. Retrieved 2006

Frazelle, E., & Sojo, R. 2007. ***Logistica de almacenamiento y manejo de materiales de clase mundial.*** Bogotá: Grupo Editorial Norma.

Ghiani, G., Laporte, G., & Musmanno, R. 2004. **Introduction to Logistics Systems Planning and Control.** West Sussex, England: JohnWiley & Sons Ltd.

Goldsby, T., & Martichenko, R. 2005. ***Lean Six Sigma Logistics.*** Boca Raton, Florida: J. Ross.

Hugos, M. 2003) ***Essential of Supply Chain Management.*** Hoboken, New Jersey: John Wiley & Sons Inc.

Kendall, G., & Ayob, M. 2008, May 1 . ***A survey of surface mount device placement machine optimisation: Machine classification. European Journal of Operational Research****, 186*(3), 893–914. doi:10.1016/j.ejor.2007.03.042

Kwak, C., Kim, C. O., Kwon, I.-H., & Choi, J. S. 2009, July. ***Situation reactive approach to Vendor Managed Inventory problem***. (E. Ltd., Ed.) *Expert Systems with Applications, 36*, 9039-9045. doi:10.1016/j.eswa.2008.12.018




DOI:10.6814/NCCU202101735

LED lamp. 2015, March 3. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/LED_lamp

Poler Escoto, R., Mula Bru, J., Ortiz Bas, A., & Lario Esteban, F.-C. 2006. ***Un modelo de Empresa Virtual para la Gestión del Proceso de Previsión Colaborativa en Cadenas de Suministro.*** *X Congreso de Ingeniería de Organización*, (p. 2). Valencia. Retrieved September 07,08, 2006

*Product Overview*. 2015. Retrieved from Luxul Technology Official Website: http://www.luxultek.com/p2pro_led_show.asp?Class1=aBWJaB39

Sallenave, J.-P. 2002. ***La gerencia integral. ¡No le tema a la competencia, témale a la incompetencia!*****Bogotá**. Editorial Norma.

Taylor, G. 2009. ***Introduction to Logistics Engineering.*** Boca Raton, Florida: CRC Press.

Turhan, S. N., & Vayvay, Ö. 2009. **Modeling of VMI implementation via SOA in a HEALTHCARE SUPPLY CHAIN.** ***European and Mediterranean Conference on Information Systems***, (pp. 1-2). Izmir.





DOI:10.6814/NCCU202101735