Chapter 1

Introduction

1.1 Inventory problem

Inventory, or 'stock' as it is more commonly called, is defined as the stored accumulation of material resources in a transformation system. The material resources can be raw materials, work in progress, finished goods, spare parts or consumable products. The *transformation system* includes a system such as processing raw materials to a finished product, or assembling some of products into a final product and etc.

Stocks are formed whenever an organization acquires materials that it does not use immediately. *Organization* here represents all types of company such as warehouse, retailer, factory, and etc. No matter what is being stored as inventory, or where it is positioned in the operation, it will be there because there is a difference in the timing or rate of supply and demand. If the supply of any item occurred exactly when it was demanded, the item would never be stored. In the production system, the common inventory problem arises whenever products need to be delivered to a buyer by a vendor. Vendors face problems in distributing the inventory in the right amount and at the right time in order to meet their buyer's requirements. On the other hand, the buyer will be facing problems in determining the size of each order.

The main purpose of inventory is to give a buffer between supply and demand. Buffer inventory is also called *safety inventory.* Its purpose is to compensate for any unexpected fluctuation in supply and demand. In other words, it allows for variation and uncertainty in both supply and demand. Keeping too much stock on hand may satisfied the customer's demand but it may increases cost capital and storage. However, holding too little stock disrupts production because the customer's demand may not be satisfied and the replenishment orders will be more frequent. Therefore the correct amount of stock and the correct time to deliver or replenish stock must be balanced in order to satisfy the demand and at the same time stockholding cost can be minimized.

There are five reasons for keeping inventory :

1. To cope with random or unexpected interruptions in supply or demand

(buffer inventory).

2. To cope with an operation's liability to make all products simultaneously.

3. To allow different stages of processing to operate at different speeds and with different schedules.

4. To cope with planned fluctuations in supply or demand.

5. To cope with transportation delays in the supply network.

However, holding inventory also has the disadvantages where

1. Inventory is often a major part of working capital, tying up money which could be used more productively elsewhere.

2. If inventory is not used quickly, there is an increasing risk of damage, loss, deterioration, or obsolescence.

3. Inventory invariably takes up space (for example, in a warehouse) and has to be managed, stored in appropriate conditions, insured, and physically handled when transactions occur. It therefore contributes to overhead costs.

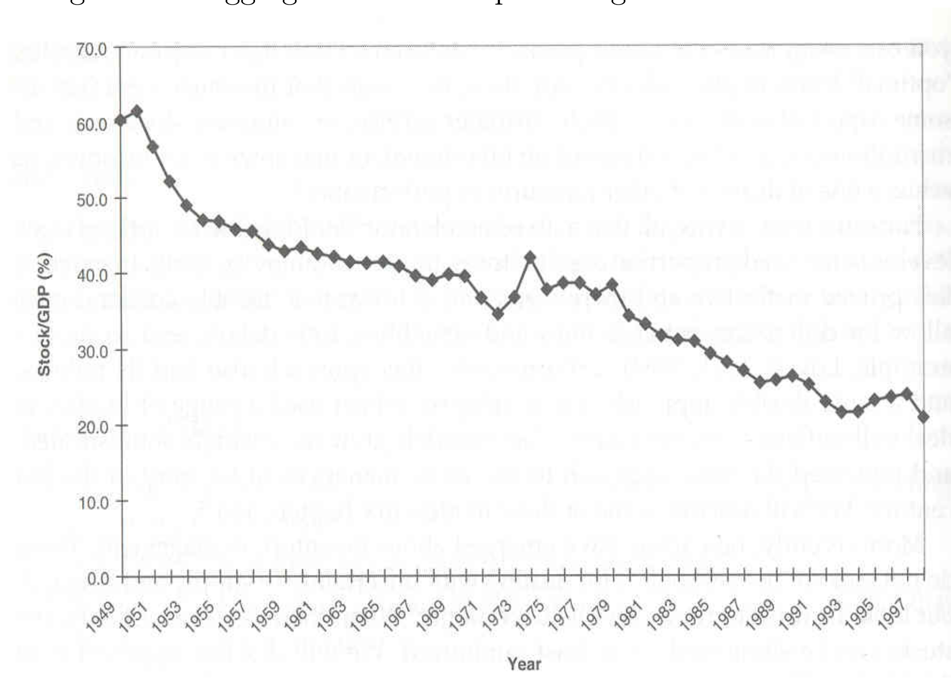
From the previous explanation, we can classify the inventory as one of the current assets of an organization. Therefore, it must be accurately counted and valued at the end of each accounting period to determine a company's profit or loss. Hence, we need to manage inventory in order to balance the costs incurred and the cost saved by holding inventories.

1.2 Inventory management

Throughout history, stocks have been considered as a measure of wealth or well-being. Therefore most organizations have been working to lower stocks without affecting either their own efficiency or customer service. Surveys give some evidence for success, with the Institute of Grocery Distribution finding that stock levels in retail distribution centers fell by 8.5 percent in the year 1995 to 1998 and the Institute of Logistics finding that some United Kingdom companies had managed to almost halve the stockholding requirements since the 1995 survey [51]. In Canada, the total inventories held by a typical Canadian manufacturer represents on average 34 percent of his current assets and 90 percent of his working capital, [47].

In the UK aggregate stock holdings are about 100,000 million pounds, divided roughly equally between raw materials, work in progress and finished goods. If we consider the aggregate national stock as a proportion of gross domestic product, we get the useful measure on the changes which are positively planned. Figure 1.1 shows this result for the second half of the last century [51].

Figure 1.1: Aggregate stock as a percentage of GDP for the UK



Source : Central Statistics Office (1966-1983)- National Income and Expenditure, London and Central Statistics Office (1984-1996)- United Kingdom National Accounts, London.

However, by the turn of twentieth century the uncertainty in supply was greatly reduced, and this brought a new attitude towards stock. Organizations buy material when needed rather than when they are available. They looked for more rational ways of controlling stock levels.

Klein and Popkin [33] suggest that controlling 75 percent of the variation in stock levels in the United States between World Wars would have avoided all recessions.

We conclude that the optimal policy in managing stocks should be defined as it gives the greatest benefits where the aims are to minimize the relevant cost, maximize the profit and at same time the demand are satisfied. Therefore in this thesis we are focussing on the modeling of the inventory problem with considering some policies.

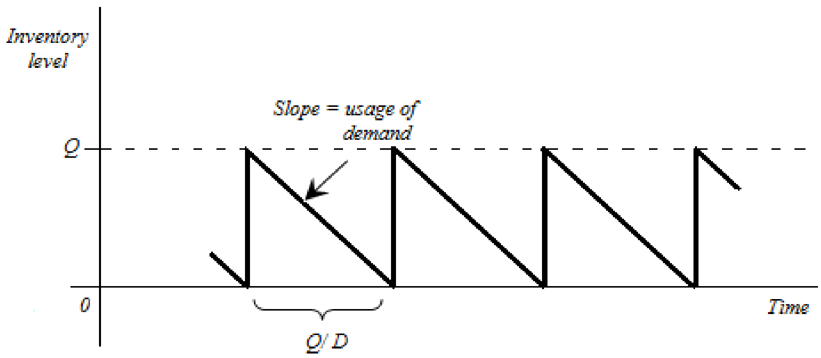
1.3 Inventory model

Inventory model has three principal tasks. These are constructing the mathematical model, specifying the values of the model parameters and finding the optimal solution. The inventory model may has a variation of the important aspects such as single or multiple buyer or vendor, shortages are allowed to occur, finite or infinite time horizon and etc.

The inventory model helps organizations in determining the optimal solution in the frequency of ordering or delivering to keep the best services to the customer without interruption or delay and in the same time their relevant cost can be minimized. In most cases, minimizing costs will result in the same control policy as that obtained by maximizing profits.

The complexity of the model depends on the assumptions that one makes about the demand, cost structure and physical characteristics of the system. The simplest assumption is that the demand is constant and known. A simple inventory model initiated based on constant and known demand is the classical Economic Order Quantity (EOQ) model. Sometimes it is referred as the *economic lot-size model* [28] and also known as *Wilson Lot Sizing model* [22]. The first reference to this model is by Harris [25], but the calculation is often credited to Wilson [52] who independently duplicated the work and marketed the results. The production rate and delivery time considered in this model are also constant and deterministic. The formula in EOQ model is known as a *squareroot equation* where the optimal ordering sizes and the ordering times can be calculated easily from this formula. The diagram for this model is shown in Figure 1.2 where the demand and the replenishment quantity are represents by D and Q. We can see that the inventory level forms the repeating sawtooth pattern.

Figure 1.2: The behavior of inventory level with time



The parameters involved in this model are assumed not to change with time, therefore it is reasonable to think in terms of same order quantity each time that a replenishment is made. Furthermore, because the demand is deterministic, the replenishment lead time is zero and the shortages is not allowed, it is clear that each replenishment will be made when inventory level is exactly zero.

When the demand rate varies with time, we can no longer assume that the best strategy is always the same replenishment quantity. An exact analysis becomes very complicated because the diagram of the inventory level versus time, even for a constant replenishment quantity, is no longer the simple repeating sawtooth pattern as in EOQ model.

In this thesis, we will consider the inventory models where the demand rate is varying with time. The objective function will be the total cost of the system which includes the vendor's and buyer's holding cost, shipment cost and set up cost. Some constraint will be put into consideration in order to assure the demand and the production or delivery time are satisfied.

1.4 Research objective

The objective of this research are listed as follows:

1. To develop the integrated inventory models which consider :

    (a) Final production batch

        i. Case 1 : $h_1 < h_2$: Vendor's holding cost is less than the buyer's

            - Policy 1 : Equal shipment sizes
            - Policy 2 : Equal shipment periods
            - Policy 3 : Unequal shipment sizes and unequal shipment periods

        ii. Case 2 : $h_1 > h_2$: Vendor's holding cost is greater than the buyer's

            - Policy 1 : Equal shipment sizes
            - Policy 2 : Equal shipment periods
            - Policy 3 : Unequal shipment sizes and unequal shipment periods

    (b) n production batches

        i. Case 1 : $h_1 < h_2$: Vendor's holding cost is less than the buyer's

- Policy 1 : Equal cycle times
  - Policy 1(a) : Equal shipment sizes
  - Policy 1(b) : Unequal shipment sizes and unequal shipment periods
- Policy 2 : Unequal cycle times
  - Policy 2(a) : Equal shipment sizes
  - Policy 2(b) : Unequal shipment sizes and unequal shipment periods

ii. Case 2 : $h_1 > h_2$: Vendor's holding cost is greater than the buyer's

- Policy 1 : Equal cycle times
  - Policy 1(a) : Equal shipment sizes
  - Policy 1(b) : Unequal shipment sizes and unequal shipment periods
- Policy 2 : Unequal cycle times
  - Policy 2(a) : Equal shipment sizes
  - Policy 2(b) : Unequal shipment sizes and unequal shipment periods

2. To solve and to find the optimal solution for each model in 1 using Microsoft Excel Solver.

1.5 Outline of study

In this research, we will present an inventory model which considers a single-vendor single-buyer system under time varying demand process. We assume that the vendor and the buyer collaborate, and find a way of sharing the consequent benefit. The main objective is to determine the number of shipments and the sizes of those shipments which minimize the total cost of each model considered in this thesis.

This thesis is organized as follows. We start by introducing the problem in inventory, the definition and research scope. Chapter 2 is the literature review of the integrated inventory model for constant and varied demand. It is followed by Chapter 3 which is discusses the integrated inventory model with single-vendor single-buyer system for shipping the final production batch. We consider three cases : (i) equal shipment sizes, (ii) equal shipment periods, and (iii) unequal shipment sizes and unequal shipment periods. We propose a consignment policy in which the vendor's holding cost is bigger than the buyer's. Next, in Chapter 4, we develop the integrated inventory model with n-manufacturing batches. We consider the case where the vendor's holding cost is less than the buyer's and vice versa. Each cases will discuss the equal and unequal cycle time with considering the equal and unequal shipments sizes policies. Some numerical examples and sensitivity analysis will be presented for every cases to see the effectiveness of the proposed policies. We end the thesis with some conclusions and recommendations for further research in Chapter 5.

1.6 Contribution of research

1. Paper

   (a) M. Omar and S.S. Supadi (2012). "The Integrated Models For Shipping a Vendor's Final Production Batch to a Single Buyer Under Linearly Decreasing Demand For Consignment Policy", *Sains Malaysiana Vol 41 (3) 367-370* (ISI journal).

   (b) M. Omar and S.S. Supadi (2012). "Single-vendor single-buyer under time varying demand processes for n production batch with equal cycle time (in process).

   (c) M. Omar and S.S. Supadi (2012). "Single-vendor single-buyer under time varying demand processes for n production batch with unequal cycle time (in process).

   (d) M. Omar and S.S. Supadi (2012). "The integrated inventory model with CS policy for a single-vendor single-buyer under time varying demand processes and equal cycle time for n production batch (in process).

   (e) M. Omar and S.S. Supadi (2012). "The integrated inventory model with CS policy for a single-vendor single-buyer under time varying demand processes and unequal cycle time for n production batch (in process).

2. Presentation :

   (a) A just-in-time production-inventory model for single-vendor single-buyer under time-varying demand processes, Applied Mathematics international Conference 2010 (AMIC 2010) and The 6th East Asia SIAM Conference 2010 (EASIAM 2010), 22-24 June 2010, PNB Darby Park Executive Suites, Kuala Lumpur, MALAYSIA.

   (b) Single-vendor single-buyer model under linearly decreasing demand, 5th International Conference On Mathematics, 9-11 June 2009, Andalas University, The Hills Hotel Bukit Tinggi, Sumatera, INDONESIA.

   (c) An optimal integrated policy for shipping a vendor's final production batch to a single buyer under linearly decreasing demand, 7th Annual Seminar on Science and Technology, 29-30 October 2008, Universiti Malaysia Sabah, Grand Dorset Hotel Labuan, Sabah, MALAYSIA.