MBA-DE(Second Year)
Semester-III

IM 311
INVENTORY MANAGEMENT

Lesson No. 1

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STRUCTURE

1.0 OBJECTIVES

After reading this chapter, the student should be able to:

- Understand the important concepts of inventory management.
- Gain an insight into the objectives of holding inventory by an organization.

1.1 INTRODUCTION

A truly effective inventory management system will minimize the complexities involved in planning, executing and controlling a supply chain network which is critical to business success. The opportunities available by improving a company's inventory management can significantly improve bottom line business performance.

From a financial perspective, inventory management is no small matter. Oftentimes, inventory is the largest asset item on a manufacturer's or distributor's balance sheet. As a result, there is a lot of management emphasis on keeping inventories down so they do not consume too much cash. The objectives of inventory reduction and minimization are more easily accomplished with modern inventory management processes that are working effectively.

1.2 DEFINITIONS OF INVENTORY

Inventory means all the materials, parts, supplies, expense tools and in-process or finished products recorded on the books by an organization and kept in stocks, warehouses or plant for some period of time.

Inventory is an essential part of an organization. Every business or manufacturing organization, however big or small has to maintain some inventory. Different definitions of inventory explain different aspects of inventory analysis. Some of the definitions are:

i. Inventories are the piles of raw materials and finished goods in the warehouse.
ii. All the material, parts, and in-process or finished products recorded on the books by an organization and kept in its stores, warehouses, and plants are known as inventories.
iii. Inventory is a list of names, quantities, and /or monetary values of all or any group of items.
iv. Inventory is a detailed list of those movable items that are necessary to manufacture a product and to maintain the equipment and machinery in good working order. The quantity and value of every item is also mentioned in the list.

1.3 CHARACTERISTICS OF INVENTORY

The concept of inventory and its relation with the performance of any system can be very well explained by the following statements:

i. Inventories serve as cushions to absorb shocks: An organization has to deal with several customers and vendors who are not necessarily close to these works. However, due to their unpredictable behavior, there are always fluctuations in demand and supply of the items which disturbs the schedule of an organization. Inventories absorb these fluctuations and help in maintaining undisturbed production and stable employment rates.
ii. Inventory for any organization is a necessary evil: Inventories require valuable space and consume taxation and insurance charges. This leads to considerable investment and causes considerable opportunity loss. The capital invested in inventories remains idle till items present in stocks are not used. On the other hand, no organization can work without maintaining some inventory i.e., it is a necessity. The costs of not having inventories are usually greater than the costs of having them. Thus, inventories are a necessary evil.
iii. Inventories are the result of many interrelated decisions and policies within an organization. The behavior of inventories is the direct result of diverse policies and decisions within a company. Marketing, production, finance, and purchasing decisions directly influence the level of inventory.
iv. The inventory provides production economies: Stock brings economy in the purchase of various inputs due to discounts on bulk purchases. This also minimizes ordering, transportation, and other costs. It also reduces the number of setups.

1.4 CONCEPTS OF INVENTORY MANAGEMENT

Safety Stock: Remaining inventory between the times that an order is placed and when new stock is received. If there are not enough inventories then a shortage may occur.

Safety stock is a hedge against running out of inventory. It is an extra inventory to take care on unexpected events. It is often called buffer stock. The absence of inventory is called a shortage.

Lead Time: The time from the point a requisition for material is raised by the user or the inventory control section has raised a purchase requisition after review of stock level and future requirements, to the point when material is received, inspected and are ready for use is known as the lead time.

Delivery Time: The time taken by the supplier to complete certain order. This includes: time for uncrating goods, time for inspection of goods, time for movement of goods to store and time for entering goods in stocks.

Reorder Point: The inventory level R in which an order is placed where R ® D.L, D = demand rate (demand rate period (day, week, etc.), and L = lead time.

Inventory Costs: Inventories cost money. The cost factor must be considered whenmaking any decision regarding inventories. Inventory costs include: ordering costs, carrying costs, out-of-stock or shortage costs, and capacity costs. The components of each of these costs are listed as:

1. **Ordering costs**
   - A. **Cost of placing an order with a vendor of materials:**
     - a) Preparing a purchase order
     - b) Processing payments
     - c) Receiving and inspecting the material
   - B. **Ordering from the plant:** a) Machine set-up

   b) Start-up scarp generated from getting a production run started
2. **Carrying Costs**
   - A. **Costs connected directly with materials:**
     - a) Obsolescence
     - b) Deterioration
     - c) Pilferage
   - B. **Financial costs:**
     - a) Taxes
     - b) Insurance
     - c) Storage
     - d) Interest (as the cost of capital borrowed to acquire and maintain the inventories)
3. **Out-of-stock Costs**
   - A. Back ordering
   - B. Lost sales
4. **Capacity Costs**
   - A. Overtime payments when capacity is too small
   - B. Lay-offs and idle time when capacity is too large

SELF CHECK EXERCISE - I

1. Inventories are the detailed list of raw materials and_________________in the warehouse.

2.The time taken by supplier for completing order, encompassing uncrating, inspection, movement to storage and stock entry is known as _________________?

1.5 OBJECTIVES OF INVENTORY MANAGEMENT

The main objectives of inventory management are as follows:

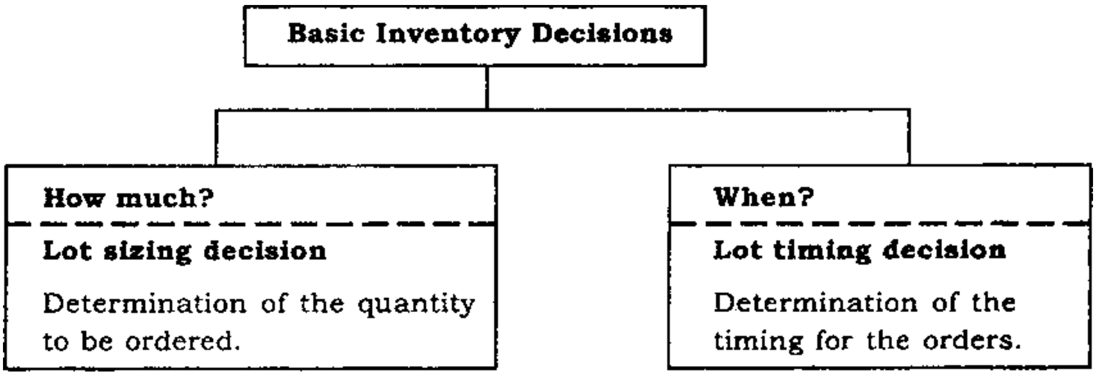
- a. **Provide the desired level of customer service:** Customer service refers to a company's ability to satisfy the needs of its customers. There are several ways to measure the level of customer service, such as: (1) percentage of orders that are shipped on schedule, (2) the percentage of line items that are shipped on schedule, (3) the percentage of dollar volume that is shipped on schedule, and (4) idle time due to material and component shortage. The first three measures focus on service to external customers, while the fourth applies to internal customer service.
- b. **Achieve cost-efficient operations:** Inventories can facilitate cost-efficient operations in several ways. Inventories can provide a buffer between operations so that each phase of the transformation process can continue to operate even when output rates differ. Inventories also allow a company to maintain a level workforce throughout the year even when there is seasonal demand for the company's output.

By building large production lots of items, companies can spread some fixed costs over a larger number of units, thereby decreasing the unit cost of each item. Finally, large purchases of inventory might qualify for quantity discounts, which will also reduce the unit cost of each item,

c. **Minimize inventory investment**: As a company achieves lower amounts of money tied up in inventory, a company's overall cost structure will improve, as will its profitability. A common measure used to determine how well a company is managing its inventory investment (i.e., how quickly it is getting its inventories out of the system and into the hands of the customers) is the inventory turnover ratio, which is a ratio of the annual cost of goods sold to the average inventory level in dollars.

1.6 BASIC INVENTORY DECISIONS

Two basic decisions must be made for every item that is maintained in inventory. These decisions have to do with the timing of orders for the item and the size of orders for the item.



1.7 USES OF INVENTORY OR REASONS FOR MAINTAINING INVENTORY

i. **Anticipation Inventory or Seasonal Inventory:** Inventory are often built in anticipation of future demand, planned promotional programs, seasonal demand fluctuations, plant shutdowns, vacations, etc.

ii. **Fluctuation Inventory or Safety Stock:** Inventory is sometimes carried to protect against unpredictable or unexpected variations in demand.

iii. **Lot-Size Inventory or Cycle Stock:** Inventory is frequently bought or produced in excess of what is immediately needed in order to take advantage of lower unit costs or quantity discounts.

iv. **Transportation or Pipeline Inventory:** Inventory is used to fill the pipeline as products are in transit in the distribution network.

v. **Speculative or Hedge Inventory:** Inventory can be carried to protect against some future event, such as a scarcity in supply, price increase, disruption in supply, strike, etc.

vi. **Maintenance, Repair, and Operating (MRO) Inventory:** Inventories of some items (such as maintenance supplies, spare parts, lubricants, cleaning compounds, and office supplies) are used to support general operations and maintenance.

1.7.1 Importance of Inventory

The importance of inventory to an organization can be summarized as:

a) Provides and maintains good customer service.
b) Enables smooth flow of goods through the production process.
c) Protects against the uncertainties of demand and supply.
d) Various production operations can be performed economically and independently.
e) It allows temporary variations in operating rates.
f) Ensures a reasonable utilization of equipment and labor.
g) Bulk discounts can be availed on purchases.

1.8 INVENTORY MANAGEMENT PROBLEMS

In actual practice the vast majority of manufacturing and distribution companies suffer from lower customer service, higher costs, and excessive inventories than are necessary. Inventory control problems are usually the result of poor processes, practices, and antiquated support systems.

The inventory management process is much more complex than it seems to be. In fact, in many companies, the inventory control department is perceived as little more than a clerical function. When this is the case, the fact is the function is probably not very effective. The likely result of this approach to inventory management is lots of material shortages, excessive inventories, high costs, and poor customer service. For example, if a customer orders a product that requires a manufacturer to acquire 20-part numbers to assemble a product and then, only 19 of the 20-part numbers are available, you have nineteen-part numbers which are excess inventory. Worse, the product can't be shipped to create revenue and the customer is not serviced. It is a complex network to control and a set of inventory management tasks must be performed with precision.

1.8.1 What should be done?

Too much inventory and not high enough customer service are very common but unnecessary. There are proven methods that can help a manufacturer accurately project customer demand and calculate the inventory he will need to meet his defined level of customer service. Using the right techniques for sales forecasting and inventory management will allow him to monitor changes and respond to alerts when action needs to be taken. The right approach to inventory management can produce dramatic benefits in customer service with lower inventory, no matter how complex the network is.

Modem inventory management processes utilize new and more refined techniques that provide for dynamic optimization of inventories to maximize customer service with decreased inventory and lower costs. These improved approaches to inventory management are of major consequence to overall competitiveness where the highest level of customer service and delivered value can favorably impact market share and profits.

1.8.2 Understanding the Process of Inventory Management

The overall process of effective inventory management crosses a number of functions. The inventory management process can be divided into the following general categories:

1. Demand management which covers the processes for sales and operations planning, sales forecasting and finished goods inventory deployment planning.
2. Inventory planning and ordering which is often accomplished with material requirements planning, often referred to by its acronym MRP or in a lean manufacturing environment kanban ordering is used to affect deliveries of material.
3. Inventory optimization systems are being advocated by some as the supply chain management mechanism that should be used to mathematically calculate where inventory should be deployed to satisfy predetermined supply chain management objectives.
4. Physical inventory control is a phrase that describes the receiving, movement, stocking and overall physical control of inventories.

Inventory management is a vital function to help ensure the success of manufacturing and distribution companies. The effectiveness of inventory management is directly measurable by how successful a company is in providing high levels of customer service, low inventory investment, maximum throughput, and low costs.

SELF-CHECK EXERCISE II

3. Which inventory is carried to protect against unpredictable or unexpected variations in demand?

4. Inventory management provides protection against the uncertainties of ____________and ____________.

1.9 SUMMARY

The important concepts related to the management of inventory have been discussed in the chapter. An organization holds inventory to provide and maintain good customer service, enable the smooth flow of goods in the production process, protect against the uncertainties of demand and supply, ensure a reasonable utilization of equipment and labor, and get bulk discounts, etc.

1.10 KEYWORDS

Inventory, Lead time, Safety stock, Delivery time, Inventory cost

1.11 EXERCISES

1.11.1 SHORT QUESTIONS

1. Define Inventory.

2.Write a short note on the following: -

a. Delivery Time b. Safety Stock c. Inventory Costs

3.Explain various reasons for maintaining inventory.

1.11.2 LONG QUESTIONS

1. What do you mean by the phrase“Inventory is a necessary Evil”? Discuss the objectives of maintaining inventories by an organization.
2. What are the important decisions faced by an organization concerning inventories? How do inventories help an organization to run its operations smoothly?
3. Explain the process of Inventory Management.

1.12 GLOSSARY

- **Inventory:** the piles of raw materials and finished goods in the warehouse.
- **Safety Stock:** Remaining inventory between the times that an order is placed and when new stock is received.

1.13 ANSWERS TO SELF CHECK QUESTIONS

1.Finished Goods, 2. Delivery Time, 3. Fluctuation Inventory/Safety Stock, 4. Demand and Supply

1.14 SUGGESTED READINGS

- Goel, B.S., *Production Operations Management,*Pragati Prakashan, Meerut, 18th Edition, 2005.
- Chary S. N., Production *and Operations Management,*Tata Me Graw-Hill Publishing Company Limited, New Delhi, 2nd Edition, 2000

MBA-DE(Second Year) | **IM 311**

Semester-Ill | **INVENTORY MANAGEMENT**

Lesson No. 2 | **AUTHOR: SHILPI GOYAL**

TYPES OF INVENTORIES

STRUCTURE

2.0 OBJECTIVES

After reading this chapter, the student should be able to:

- Understand the different criteria for classifying inventories.
- Discuss the various types of inventories and the factors affecting inventory control.

2.1 INTRODUCTION

Inventory is needed for the definite consumption demand of materials, and to take care of the uncertainty involved in the usage of the materials. There are inventories for normal consumption requirements. Therefore, depending upon the average consumption rates and average lead times for procurement/manufacture of the material, inventories are kept at the appropriate times. The inventory taking care of this aspect of normal consumption is called the normal inventory and the inventory held to take care of the uncertainty is called the safety stock or buffer stock of inventory.

There are various other categories of inventories. They are discussed in the following chapter.

2.2 INVENTORY CLASSIFICATION

Some inventory items can be classified as independent demand items, and some can be classified as dependent demand items. While the timing and sizing decisions for all inventory items need to be made, a manufacturer must be careful in the manner in which he makes those decisions for these two types of items.

Independent demand inventory item: Inventory item whose demand is not related to (or dependent upon) some higher level item. Demand for such items is usually thought of as forecasted demand. Independent demand inventory items are usually thought of as finished products. **Dependent demand inventory item**: Inventory item whose demand is related to (or dependent upon) some higher level item. Demand for such items is usually thought of as derived demand. Dependent demand inventory items are usually thought of as the materials, parts, components, and assemblies that make up the finished product.

2.3 CLASSIFICATION ACCORDING TO THE FUNCTION

According to their function, the inventories may be classified as follows:

1. **Transit Inventories:** These are primarily pipeline inventories and their existence arises because of the need to transport inventories from one point to another. The larger the distance of the supply source, the larger the transit inventory. Work-in-process transit inventories are determined by process design and plant layout.
2. **Cycle Inventories:** These exist because management attempted to provide Economic Order Quantity. Here inventories tend to accumulate at various points in the system.
3. **Buffer Inventories**: In any organization, due to the uncertainties of demand and supply of units or due to price changes, some inventory is to be maintained. The size of the buffer inventory may be of significant financial consequence to a firm. These can be reduced by reducing uncertainties of demand and supply and price variations. In periods of shortages and rapidly rising prices, although the need to increase inventory in the form of buffer and anticipation stock is clear, the ability of the organization to commit the necessary funds may be severely taxed. These are also known as Safety Stocks.
4. **Decoupling Inventories**: The existence of inventories at major linkage points in a production process makes it possible to carry activities on either side of the point relatively independent of each other.

SELF CHECK EXERCISE I

1. Inventory item whose demand is not related to some higher-levelitem is known as__________.

2. Buffer Inventories are also known as__________.

2.4 CLASSIFICATION ACCORDING TO THE NATURE OF ITEMS STOCKED

Inventory can also be classified according to the nature of items stocked namely regular inventory items for production items, in-process inventories, and finished goods inventories.

2.4.1 Regular Inventory Items

In a production unit, regular inventories can further be divided into more categories for effective operations and control and they are:

a. Capital Equipment: production machinery and other machines that are either used in manufacturing activities or are supportive to the production functions.
b. Tools
c. Furniture
d. General stores (Spare parts and Consumables)
e. Chemicals and Inflammable stores
f. Raw materials
g. Packing materials
h. Scrap materials

a. Capital Items

All the capital equipment must be properly accounted for. Normally capital items are issued in the name of the nominated official(s). Each capital equipment should be properly recorded in a record referred to as an "Asset Register". The details should contain the name of the manufacturer, his address, telephone/fax/telex no., year of purchase of the equipment, nameplate details with the list of recommended spares, initial cost, present worth, etc. for future reference.

b. Tools

Tools play an important role in the efficiency and productivity of an organization. Without tools, it is impossible to repair, install, or dismantle equipment. It is not only the availability of the tool which is important but also the availability of proper tools for the job, that is essential. For example, a hydraulic puller for bearings may be much better than a mechanical puller for bearings. The same is true for other tools. Several special tools are stored to meet the requirements of special applications.

c. Furniture

Different types of furniture are used in an organization. Furniture is allotted to an individual who is normally the user. Some of the items of furniture are maintained for general purposes. These axesare under the control of the Administration Department. The new entrants are issued the furniture according to their functional requirements. Company norms are also established for different levels of officials.

Each item of furniture is numbered and its location is written on the furniture and a record of this is kept in a register. Annual verification of the inventory of furniture is essential. Broken furniture must be either repaired or condemned and removed from the inventory.

d. General Store

The general store has spare parts and consumables as inventory items. These inventory items are regularly in demand for maintenance and operational requirements of the process. The parts that are likely to fail and may need replacement are stocked to meet any eventuality and are called spare parts. Consumables like oils, lubricants, gases, etc. are essential for plant maintenance and operation, and efforts should be made to ensure that there are no stock outs.

e. Chemicals and Inflammable Store

Both these categories of inventory items are important for production activities. They should be in enough quantity to avoid any stock out. At the same time, excessive storage may result on deterioration of their quality and even may result in total loss. These materials are also safety hazards. Therefore, greater care is necessary in controlling their quantities.

f. Raw Materials

Raw materials are the most important of all the inventory items. Firstly, the production is directly affected due to the shortage of any raw material. Secondly, the consumption of raw material is so large that the cost of raw material directly affects the cost of the product. The top management controls the raw materials inventory.

g. Packing Materials

Packing materials are of great importance as they are required for packing the goods produced. Like raw materials, packing materials are controlled and monitored very meticulously. Any shortage of packing material directly affects the production process. Excess of packing materials increases the inventory. Packing materials are stocked in terms of a few weeks' requirements, say for six to eight weeks. Top Management should check the stock regularly to monitor the inventory of packing materials,

h. Scrap Materials

Scrap materials are generated during the process of production and/or from repair activities. They are termed as junk and normally stored in one place and are not accounted for as other items are. Some junk materials are useful for future repairs and should be segregated and kept aside. Other materials are usually disposed of in lots.

2.4.2 In-Process Inventories

Materials or semi-finished goods lying on the shop floor or in stores for temporary storage before being used in a production process are known as in-process inventories. For example, raw metal in a process plant like a cement plant is an in-process material, which has been produced by processing a mix of raw materials. Similarly, clinker is an in-process inventory for producing cement.

2.4.2.1 Reasons for the Existence of In-process Inventory

In-process inventories are always an integral part of any production process. They exist due to various reasons:

(1) There is a time- lag before a raw material or a semi-finished product can be used from one stage of production to the next stage of production. This results in in- process inventories. Efforts should be made in such a way that the in-process materials have to wait for a minimum period before their consumption. This requires strict management control.

(2) Lack of production and planning results in the accumulation of inventories at certain stages. This may be because the next stage may not be ready to use the in-processed inventory. Balancing of material processed with the available production capacity is important for balancing the production at every stage. The problem of imbalance in the production capacity of different sections may arise only in one or two stages. To control this and to ensure that the in-process inventory is kept at a minimum, each production operation should be carefully monitored so that each stage is efficient and balanced.

(3) In-process inventory may also result due to shortage of orie of the raw materials in the stock. This may be due to delayed procurement, delayed supply of material by the supplier or transportation delay/ failure. Shortage of material affects other proceeding operations and results in an increased in-process inventory.

(4) Faulty management decisions may also cause an excess of in-process inventories. A management decision to stop production of one product halfway to produce another important product results in an excess of in-process inventory of the earlier product.

(5) Delays in in-stage inspections of various in-process inventories do not allow continuous production and create more in-process inventories. At times, inspection is carried out by an external agency, like the surveyor or the customer's representative, who does not arrive in time for the inspection. The delay in inspection causes interruptions in production and results in an excess of in-process inventories.

(6) In certain complicated production processes, a large number of sub-assemblies may have to be kept for the production process. This cannot be avoided for certain processes. The in-process inventories are as important as raw materials and finished goods to avoid any loss.

2.4.2.2 Factors Influencing the Level of In-process Inventories

Some of the factors which should be considered in deciding the level of in-process inventories are:

(1) Realistic requirements of each item or semi-processed items for the production process should be worked out carefully to avoid any shortage or excess. The requirement should take into consideration various uncertainties like delay in customs clearance formalities in case of imported items or delay in the production process itself.

(2) Acquisition cost, inventory carrying cost, quantity discounts, and follow-up costs should be considered while deciding on the level of in-process inventories.

(3) Investment needed and availability of funds for the size of the inventory needed.

(4) Cost of maintaining and controlling the in-process inventory.

(5) Space availability for storing the in-process inventory is a very important aspect. In some of the plants, space restrictions do not permit storing of in-process inventory beyond a certain limit. Single or multiple handling of material is an important consideration. Double or multiple handling of materials should be avoided since handling cost becomes a part of the product cost.

(6) Other considerations, such as pollution control aspects, upkeep of factory premises, effect on sales etc., should also be considered.

2.4.3 Finished Goods Inventories

Finished goods occupy a substantial share of the total inventory in an organization. The Production Department and Marketing Department prefer to have large quantities of finished goods so that the market demands can be satisfied easily. However, the finance department always wants to reduce the stock of finished goods so that money is not blocked. Keeping optimum level of finished goods in very essential for the best utilization of funds. During recession in the market, demand is low. The competition among the suppliers forces them to sell their product(s) at rock bottom prices, which directly affects their profit margin. Stock level of finished goods of perishable nature or of goods having a limited shelf-life should be controlled very strictly. As the expiry date of perishable goods or goods with limited shelf-life such as food products and medicines approaches, they are sold at even lower prices than their cost. The objective is to recover the money to the maximum extent possible before their total rejection.

The size of the finished goods inventory greatly depends upon the nature of business. Individual items of inventory will have different levels of inventories. A marketing company may be able to sell an item in demand quickly after its receipt However in case of another item in low demand or unsteady demand, the company may have to stock the item for long to meet the requirements as and when they arise. Seasonal production or seasonal requirements also influence the inventory levels.

2.4.3.1 Factors Influencing Finished Goods Inventories

Various factors that are important and influence the finished goods level are:

(a) Demand
(b) Batch production
(c) Multiple Warehouses
(d) Imports
(e) Distribution Network

a) Demand

Market demand for each product depends upon the nature of the product. For example, the sale of cement may be at a low level during the rainy season as construction activities will not be at the same level as in other seasons. Refrigerators, air conditioners, and desert coolers have greater demand in the summer season as compared to other seasons. The demand for such items can be forecasted with accuracy to a great extent.

The level of inventory of items that undergo frequent changes in design and models should be monitored very closely. This applies to electronic goods, computer software, and hardware, where the design and features of each model undergo fast changes. If they are not properly monitored, such items may be lying in stores, thus blocking valuable money.

Certain items are linked with fashion, especially garments and jewelry items. However, the demand for certain garments is so stable that they withstand various changes in fashion.

There is yet another category of demand that is related to some unpredictable situations, such as earthquakes, floods, wars, accidents, or epidemics. These situations create sudden demands; both short-term and long term and influence the inventory levels as well as the strategy for stocking them.

Thus, demand plays a key role in the level of inventories. The changing economic health of the country, social system, and developmental works are all linked to the finished goods inventory level.

b) Batch Production

Certain products are more suitably produced in batches since they cannot be kept beyond a certain period. This is very common for medicines, which have an expiry date. Moreover, the production facilities have a limited capacity; hence one product is produced at one time in a batch. Only after producing a required/planned quantity, the second product is produced. Such items have to be in the stores for a long period at times. An economic batch size should therefore be worked out keeping in view all the related parameters, which directly affects the finished goods inventory level.

c) Multiple Warehouses

Big companies may have very large network of warehouses throughout the country or even spread out in a number of countries. Bach warehouse will have to meet different demands as each location would have a different market. This would depend upon the type of clientele, different weather conditions from one place to another, different levels of industrial activity in different regions and different social systems prevailing at each location of the warehouse. This would greatly influence the inventory level of finished goods in different warehouses. On the basis of market surveys in the region of each warehouse, appropriate inventory strategies could be developed.

d) Imports

Some industrial products require raw materials and also parts that have to be imported. This is because particular raw materials of acceptable grades are available in certain parts of the world only. For example, cement-grade bauxite, a raw material for making cement is available in a few countries only like Australia, India and Italy etc. In certain economies, the government imposes restrictions on imports and controls the import of goods. Companies producing the products involving imports manufacture the goods much ahead of the actual market demand. This results in the excessive stock of the finished goods inventories. A well-calculated strategic decision is called for while controlling such factors in the overall management of the finished goods inventory.

e) Distribution of the Finished Goods

There should be a balance between the production, storing, and sales of the finished products. The modes of distribution should commensurate to meet the requirements of the sales department. In some case, a road transport system is required for distribution. In other cases, rail, air or sea transportation is adopted. The adoption of a particular transportation mode or a combination of many depends upon the territory, transport facilities available, and volume of business. Any delay in transportation arrangement will cause the piling up of the finished goods inventory.

SELF CHECK EXERCISE Ⅱ

3. Classify Inventories according to the nature of items stocked?

4. Name different factors influencing Finished Goods Inventories.

2.5 FACTORS AFFECTING INVENTORY CONTROL POLICY

The inventory policy of an organization has an impact on the whole system. There are a number of factors which can affect the inventory decisions. They can be broadly divided in the following categories:

A. Characteristics of the Manufacturing System

The nature of the production process, the product design, and production planning and plant layout have significant effect on inventory policy. Some of these factors are:

i. **Degree of specialization and differentiation of the product at various stages:** The degree of changes in the nature of the product from raw material to final product at various stages of transformation viz., final assembly, assembly and packaging determines the nature of inventory control operation. For example, if nature of the product remains more or less the same at various stages of production then the economies can be achieved by keeping the right balance of stocks of semi-finished product.

ii. **Process Capability and Flexibility:** Process capability is characterized by processing time of various operations. For example, the replenishment lead time (length of delay in execution after issuance of a replenishment order) directly influences the size of the inventory. Similarly, how rapidly and economically a system can adjust its production rate, shift production facilities from one operation to another operation and change equipment from one product to another determines the magnitude of flexibility. Inventory policy should aim towards balancing the production flexibility, capability, inventory levels and customer service needs.

Iii. Production Capacity and Storage Facility: The capacity of the production system as well as the nature of storage facilities considerably affects the inventory policy of an organization. For example, capacity for heating oil in an oil refinery is governed in part by its through-put capacity and in part by its distribution system.

Similarly, if for any product the cost of storage facility ishigh, then it sets a limit on the storage capacity.

iv. **Quality requirements, Shelf-life and Obsolescence risks**

v. **The Nature of the Production System:**It is characterized by the number of manufacturing stages and the interrelationship between various production operations. For example, in product-line system, inventory control is simpler than in job-type system. Similarly, when there are many operational stages then the inventory control system must provide smooth adjustment of early operating stages.

B. Amount of Protection Against Shortages

There is always variation in demand and supply of the product. The protection against such unpredictable variations can be done by means of buffer stocks. The factors responsible for such variations are:

i. **Changes in Size and Frequency of Orders:**The amount of product sold in a large number of orders of small size can be operated with less inventory.

ii. **Unpredictability of Sales:**If there are too many fluctuations in the demand of a product then these can be handled only by flexible and large capacity of inventory operations.

iii. **Physical and economic Structure of Distribution pattern;**Longer the channel of distribution, the more is the inventory requirement. Field inventories basically improve service to retailers by removing some of the burden of keeping stocks.

iv. **Cost Associated with Failure to meet Demand:**When there is heavy penalty on any delay in fulfillment of any order then inventory should be large.

v. **Accuracy, Frequency and Detail of Demand Forecasts:**Fluctuation stock exists when forecasts are not exact. The responsibility of forecast errors for inventory needs should be clearly recognized.

vi. **Protection Against Breakdown or Other Interruptions in Production**

C. Organizational Factors

There are certain factors which are related to the policies, traditions and environment of any enterprise. Some of these are:

i. labour relation policies of the organization
ii. Amount of capital available for tock.
iii. Rate of return on capital available if invested elsewhere.

D. Other Factors

These are related to the overall business environment of the region viz.,

i. Inflation
ii. Strike situation in communication facilities
iii. Wars or some other natural calamities like famines, floods etc.
iv. Difference between input and output.

2.6 SUMMARY

The chapter focused on the different criterion for the classification of inventory. The inventories can be classified on the basis of their function and the nature of the items stocked. The factors that affect the inventory decisions include characteristics of the manufacturing system, the amount of protection against shortages, organizational factors and some miscellaneous factors such as inflation, natural calamities, problems in communication facilities etc.

2.7 KEY-WORDS

Capital Items, In-process Inventories, Finished Goods

2.8 GLOSSARY

- **Independent demand inventory item:** Inventory item whose demand is not related to (or dependent upon) some higher level item.
- **Dependent demand inventory item:** Inventory item whose demand is related to (or dependent upon) some higher level item
- **In-process inventories:** Materials or semi-finished goods lying on the shop floor or in stores for temporary storage before being used in a production process.

2.9 EXERCISES

2.9.1 SHORT QUESTIONS

1. Classify Inventories according to their functions.

2. Classify Inventories according to the nature of items stocked.

3. What are the various factors affecting Inventory Control Policies?

2.9.2 LONG QUESTIONS

1. What are the various types of inventories? Explain the importance of different types of inventories for an organization.
2. What are the important factors that affect the decisions related to inventory management?

2.10 ANSWER TO SELF CHECK EXERCISE

1. Independent demand inventory Item, **2**. Safety Stocks,

3. Regular Inventory Item, In-process, Finished Goods

4. Demand, Batch production, Multiple Warehouses, Import, Distribution Network

2.11 SUGGESTED READINGS

- Goel, B.S., *Production Operations Management*, Pragati Prakashan, Meerut, 18th Edition, 2005.
- Chary S. N., *Production and Operations Management*, Tata Me Graw-Hill Publishing Company Limited, New Delhi, 2nd Edition, 2000
- Saxena, J.P., *Warehouse Management*&*Inventory Control*, Vikas Publishing House Pvt. Ltd., New Delhi.

CODIFICATION OF INVENTORY

STRUCTURE

4. OBJECTIVES

After reading this chapter, the student should be able to:

- Understand the concepts of codification and standardization of inventory.
- Discuss the above learned concepts and understand their process and importance if the field of inventory management.

3.1 INTRODUCTION

3.1.0 Codification of inventory

Codification of materials can also be termed as the identification of materials. This deals with uniquely identifying each item in the inventory. It is useful

- In requisitioning items or the operational departments
- In placing of orders by the purchase department
- In receiving and expediting the items on receipt from the supplier
- In having a unique record of each of the items in stores and in work-in-process or in warehouse so as to facilitate the control over the inventory levels, and
- In having a good control over the loss, deterioration, obsolescence, nonmovement, or pilferage of the items in the inventory.

Unique identification of the materials - whether they are raw materials, work-in- process or finished goods - is the first step towards a good materials management system. Without it, the control over inventory by rigorous exercises is not very effective. Without it, confusion might prevail in the operational departments. Moreover, for a good quality control system a unique identification is a pre-requisite. There are many other advantages such as variety reduction and standardization etc.

It is amazing to find that in many of our large public and private sector corporations, a considerable amount of inventory lies in the stores or elsewhere because of a confused nomenclature and a lack of proper identification system. Many items in inventory such as pipes, rods, angles electrical switches, cables, valves, similar equipment's, spare parts and even nuts, bolts and such items in inventory are available under different names and codes thereby reducing the actual availability of the item for operational needs. An item may be called a 'nut and bolt' by one section of the *organization,* whereas another may call it a 'fastener' and because of this there are two separate requisitions made, two separate purchase orders sent out, and two separate inventory levels of the items built into the system. One section might call an item a 'pipe' whereas another might call it a 'conduit[1] in fact both sections using the same item. This increases the inventory level unnecessarily Prevention of duplication is one of the important benefits of a good materials coding system.

A good identification is of immense help for proper stock taking. Many cases have been observed in large corporations where the concerned people do not even know what materials have been lying in the inventory for a large duration of time. These materials could easily be eliminated from the list, salvage value recovered and the storage space freed. It is also not uncommon to observe that although a material is available with the stores in reality due to duplication of the identity it is often quoted as not available' and thus, many production programs suffer with consequent loss to the organization as a whole Proper identification of inventory items helps in simplification of all the processes such as storing, receiving, procuring, manufacturing, warehousing and this results in a multiplicity of benefits to the company. It is a simple concept. If followed it might produce results of proportions equivalent to that of a rigorous application of the inventory control principles with, perhaps much less effort,

3.1.1. Codification by Group Classification:

What do we mean by coding? By this, we give a unique number to a particular item in the inventory. For instance, 010237 might mean a specific item in inventory such as a particular kind of gasket, of a certain material, of a certain shape, and of certain dimensions. Of course, each of these numbers or groups of numbers (within the total identification number) should convey some unique information. For instance, the following numbers might be used to describe the first classification of materials in an inventory:

1 - Raw materials
2 - Purchased components
3 - Spare parts
4 - Tools
5 - Fixtures and Patterns
6 - Other supplies
7 - Work-in-process material
8 - Finished goods
9 - Capital Equipment

The next classification group may be based on, say, 'shape' of the items. For instance:

1 - Wire
2 - Tubing
3 - Rod
4 - Bar

5 - Sheet
6 - Strip

Further classification could be based on the material of construction. For instance:

1 ..... Mild Steel
2 ..... Stainless Steel - 304
3 ..... Stainless Steel - 316
4 ..... Stainless Steel - ...
5 ..... Stainless Steel - ...
6 ...... Copper
7 .....Brass
8 ..... Bronze
9 ..... Aluminum
10 ..... Special alloy
11 ..... PVC
12 ..... Polypropylene

To this, one more classification in terms of the composition, use, characteristics, etc. may be added.

For instance, for metals we could have a group of classification as follows:

1 ..... Cold rolled,
2 ….. Tempered
3 ..... Normalized
4 ..... Annealed,
5 ..... Hardened etc.

If the material is a wire, then the next group of classification could be in terms of the 'use' characteristics such as:

1 ..... 5 amps
2 …. 15 amps
3 .....*25* amps

Thus, an item could be coded as:

8 1 06 03 01

This nine-digit code uniquely identifies the item as a Finished' Product, Wire made of copper, Normalized for 5 amps performance.

Codification as done above is called Codification by group classification where the identification is done by reserving a number of characters (spaces) for each ’group’ of classification. In each group the relevant 'details are sequentially numbered.

3.2 STANDARDIZATION

Standardization means uniformity and reduction in variety. Standardization can be attempted in many areas. Standardization of procedures, standardization of specifications, say size, shape, color, standardization of design, standardization of machines, standardization of factory layout, if similar plants are to be repeated; standardization in building construction, standardization of test procedures etc. are some of the areas where standardization has been attempted successfully.

Standardization helps in quality assurance. Today, Total Quality Management (TQM) or Total Quality Control (TQC) is aiming at improving the quality in every activity through standardization. Standardization of office procedures, stationery, furniture, uniforms etc. is necessary for uniformity, orderliness and creating a common understanding in office functioning. Similarly, standard sizes have revolutionized the manufacturing process where interchangeability of parts has a great importance. Standardization of material specifications has two aspects: first being variety reduction and second simplification.

3.2.1 Variety Reduction

Frequency of Use

Variety reduction is necessary to control inventory. Large number of sizes of nuts and bolts can be reduced to a select number of sizes. Similarly, large number of oils and lubricants can be studied from the point of view of their characteristics or services required from them. Some grades of oils and lubricants can be eliminated and can be substituted by others, which can perform the same function or even better than it. The usage pattern is studied and the items that are similar to each other in certain characteristics are combined in one quality, which can serve the function of all, so that variety is reduced.

Preferred Number System

Some sizes, weights and other characteristics are preferred over others to bring about reduction in variety. These sizes and weights are selected based on a preferred number system. For example, edible oil is sold in tins of 1 Kg, 2 kg, and 5 Kg capacities. Electric bulbs are available in 0, 10, 15,25,40,60,100,150,200,250 and 500 watts ratings.

The next size of these items by and large has a uniform increase or decrease. The sizes, in between the selected sizes, are left out and preferred numbers are selected based on the nearly uniform increase or decrease.

SELF CHECH EXERCISE I

1. Codification of Inventory is done to provide __________ to each item in the inventory.
2. Standardization can be attempted to provide ____________.
3. What is the full-form of TQM?

3.3 SITUATIONS WHERE STANDARDIZATION IS NOT

PREFERRED Shape

Standardization is not preferred in cases where the item is defined by shape, which differs from case to case. For example, glass tumblers of different shapes with different designs.

Novelty

In cases of decorative pieces or items of some specialty, standardization is not preferred. Each design should be unique. For example, jewelry is made with different designs to make it attractive thus sacrificing the concept of standardization.

Special Requirements

Some of the requirements are very typical and cannot be standardized. For example, new sizes or designs may be required in research applications.

Patented Items or Secret Designs

When a manufacturer wants to keep his product different from others for maintaining superiority, he may choose a non-standard item. Similarly, when the intention is to keep the design secret, non-standard items are preferred. This is true with industrial items, which are based on typical heat treatments where it is difficult to standardize the heat treatment,

3.4 ADVANTAGES OF STANDARDIZATION

1. Standardization helps in better understanding of the customer requirements.

2. The process of Standardization examines all aspects of the quality, both plus and minus points of the quality.
3. Standardization helps in maintaining steady prices.
4. Large quantity orders are processed for the standard items as compared to small orders for non-standard items.
5. Total processing time is reduced in purchases for standard items.
6. Less storage space is required for items of same specification as compared to a variety of items that have to be kept separately.
7. Rate of obsolescence reduces by standardization.
8. Inventory turnover is increased and results in lower inventory for slow moving items.
9. A standard item can be manufactured easily with an optimum operating time of machines.
10. Standardization reduces demand on drawing office and design staff as fewer drawings and a smaller number of designs are required.
11. Advance planning is possible for large scale activities with standardization.
12. Standardization reduces the requirements of spare parts through variety reduction.

3.5 STANDARDIZATION PROGRAM

Various organizations have a standardization program, which is normally undertaken by a committee. The Standardization Committee comprises of representatives of various departments concerned with the specifications such as Production, Maintenance, Sales, Marketing, and Materials. Every departmental representative makes a contribution to the whole issue of standardization. The materials department, which represents storekeeping as well as purchasing, plays an important role in the standardization program.

The objectives of the standardization program are:

1. Standardize the materials used in the industry.
2. To bring company standards as close to the industry standards as possible.
3. Variety reduction.
4. Establishing the specification of items to be purchased.

Normally the standardization committee meets once a month for discussing various issues that surface during production and maintenance, or complaints from the customers. These objectives are discussed with a view to improve material specifications, variety reduction, and rationalization. In case the issue is urgent, a meeting could be called at any time. Records of the discussion are kept for each meeting and action points identified for further action in the matter. In the basis of various issues discussed at the standardization committee meetings; a program is prepared with time targets for completing the actions on each item. Regular review of the progress, problems faced in implementation, targets achieved are some of the functions of the Committee, and this is an important part of the standardization program.

SELF CHECH EXERCISE Ⅱ

4. Name the situations where standardization is not preferred.

5. Who is responsible for standardization program in an organization.

3.6 SUMMARY

The chapter focused on the concepts of codification and standardization of inventory. The codification of inventory is giving a unique number to the item in the inventory so that it can be easily identified. The basis of codification of a material may be the characteristics or composition of the material, the shape of the material, the use of the material etc. Standardization means uniformity and reduction in variety. Standardization could be done for procedures, specifications, machines, designs, factory layout, building construction etc. the two important aspects of standardization are variety reduction and simplification.

3.7 KEYWORDS

- **Codification**, **Standardization**

3.8 EXERCISE

3.8.1 SHORT QUESTIONS

1. Explain Codification of Inventories.
2. Explain Codification by Group Classification
3. What are the various advantages of Standardization of inventories.

3.8.2 LONG QUESTIONS

1. Giving examples, discuss the meaning of codification of inventory? How is the process of codification helpful for an organization?
2. Explain standardization of inventory, also discuss its importance.

3.9 ANSWERS TO SELF CHECK QUESTIONS

1. Unique identification, 2. Quality Assurance, 3. Total Quality Management

4. Preferred Shape, Novelty, Special Requirement, Patented Item/ Secret Design.

5. Standardization Committee

3.10 SUGGESTED READINGS

- Goel, B.S., *Production Operations Management* Pragati Prakashan, Meerut, 18th Edition, 2005.
- Chary S. N., *Production and Operations Management*,Tata Me Graw-Hill Publishing Company Limited, New Delhi, 2nd Edition, 2000
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MBA-DE(Second Year) **IM 311**
Semester-in **INVENTORY MANAGEMENT**

<u>Lesson No. 4AUTHOR: SHILPI GOYAL</u>

SELECTIVE INVENTORY CONTROL TECHNIQUES

STRUCTURE

4. OBJECTIVES

After reading this chapter, the student should be able to:

- Understand the importance of inventory control.
- Describe the important techniques used in selective inventory control.

4.1 INTRODUCTION

In any medium to large industry there are thousands of items in the inventory. The items may range from a spare generating set to cans of paint or small nuts and bolts. It is neither logical nor possible to exercise tight management control over these different items varying in their value, complexity, size or necessity. It will be too much of effort for little benefit.

The principle of management by Exception is better suited here. Controls exercised selectively contribute to better management, in most cases avoiding wastage of precious management time and, more importantly, avoiding the confusion resulting from excessive controls. The degree and character of the controls to be exercised by the management should depend upon:

(a) The necessity of the control
(b) The relative importance of the material to be placed under control
(c) The particular characteristics of the material.

Some of the methods used in the selective inventory control are discussed as follows

4.2 ABC ANALYSIS

ABC analysis stands for 'Always Better Control* analysis.

It is based on the concept: thick on the best and thin on the rest. The objective of ABC control is to vary the expenses associated with maintaining appropriate control according to the potential savings associated with proper level of such control. It is one of the widely used techniques of inventory control.

The ABC approach is a means of categorizing inventory items into 3 classes: A, B andC according to the potential amount to be controlled.

For this annual consumption value is calculated by

Annual Usage Value *= annual requirement * per unit coat.

The items of inventory are then categorized under

- Items functionally critical, no matter how small they are,
- , • Items important because their usage value is very high,
- Items having average usage value,
- Items having low usage value.

The following procedure is selected for developing an ABC analysis:

(1) List each item carried in inventory by number or some other designation,
(2) Determine the annual volume of usage and rupee value of each item,
(3) Multiple each items annual volume of usage by its rupee value,
(4) Compute each items percentage of the total inventory in terms of annual usage in rupees.
(5) Select the top 10% of all items which have the highest rupee percentages and classify them as 'A' items.
(6) Select the next 20% of all items with the next highest rupee value percentages and designate them as 'B' items.
(7) The next 70% of all items with the lowest rupee percentages are ’C items.

Inventory Item Number	Annual Usage	Value Per	Annual Dollar Usage
1	25,000	$3	75,000
2	5,000	$4	20,000
3	1,000	$10	10,000
4	10,000	$2	20,000
5	4,000	$5	20,000
6	70,000	$10	700,000
7	25,000	$5	125,000
8	5,000	$1	5,000
9	3,000	$5	15,000
10	2,000	$5	10,000

When classifying the items as A, B, or C items, it can be somewhat subjective as to where the lines are drawn. With the small demonstration above, the first 20% of the inventory items constitute 82.5% of the inventory value, so these items (Items 6 and 7) will be designated as A items. On the other extreme, 70% of the items constitute only 10% of the inventory value, so these items (Items 2, 4, 5, 9, 3, 10, and 8) will be designated as C items. Finally, 10% of the items constitute 7.5 % of the inventory value, so this item (Item 1) will be designated as a B item.

Item Number	Annual $ Usage	% of Items	Cumulative % of Items	% of Value	Cumulative % of Value	Category Assigned
6	$700,000	10%	10%	70	70	**A**
7	$125,000	10%	20%	12.5	82.5	A
1	$75,000	10%	30%	7.5	90	B
2	$20,000	10%	40%	2	92	C
4	$20,000	10%	50%	2	94	C
5	$20,000	10%	60%	2	96	c
9	$15,000	10%	70%	1.5	97.5	C
3	$10,000	10%	80%	1	98.5	C
10	$10,000	10%	90%	1	99.5	C
8	$5,000	10%	100%	.5	100	c
Total	$1,000,000					

SELF CHECK EXERCISE I

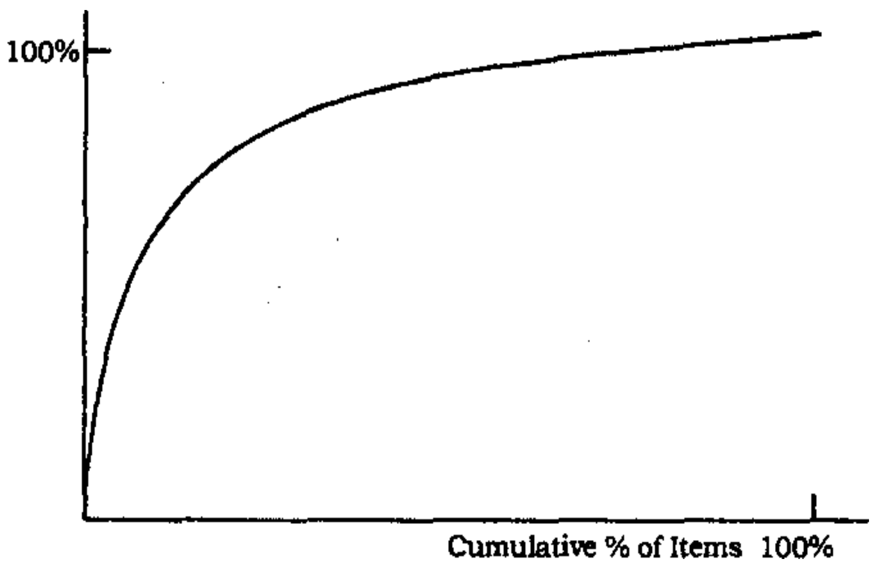
1. ABC Analysis stands for_________?

2. In ABC approach inventory items are classified into _________ classes.

The purpose of the ABC classification was to separate the "important few" from the "trivial many" so that the appropriate level of control can be assigned to each item. Items need the tightest degree of control, while C items do not need very close scrutiny.

ABC CLASSIFICATION OF ITEMS

Cumulative % of Value



4.3 VED ANALYSIS

In addition to the intrinsic or the market value of materials which is invested in the materials, there is sometimes a 'nuisance' value to the materials.

The nuisance value is the cost associated with the materials due to their absence. Certain materials are important by their absence and not necessarily by their presence.
If they are not available, they hold up production and, therefore, there are high costs of shut-down or slow-down of production. By themselves, these materials may not be priced high in the market. The investment in these materials may be small but for lack of any of them, the production process may come to a grinding halt. These are critical items which are required in adequate quantity.

Thus, there is another kind of classification of materials which has to deal with the critical nature of the items, i.e., whether they are 'vital' to the production process, or 'essential' or just 'desirable'. In addition to the conventional ABC analysis, the VED analysis is of great importance. Such VED ranking can be done on the basis of the shortage costs of materials which can be either quantified or qualitatively expressed.

The VED analysis is done to determine the criticality of an item and its effect on production and other services. It is specially used for classification of spare parts. If a part is vital it is given 'V' classification, if it is essential, then it is given 'E* classification and if it is not so essential, the part is given 'D' classification.

For 'V' items, a large stock of inventory is generally maintained in view of their extreme critical nature. The stock-out costs associated with such materials are very high and therefore, the service levels will be very high for this class of materials. The service levels for the subsequent E and D class materials will be lower and lowest respectively. The D class items are easily available in the market. They do not hold up production and can be substituted as well. Therefore, we can manage with small inventories of these items without drastic consequences on the running of the production line.

VED (Vital, Essential, Desirable) analysis examines the items from the importance of plant operations and is not related to the value of annual usage. Spares related to machinery on single line operations are very important. Their non-availability can result in stoppage of the plant. These spares may be of very low value but have great importance in plant operations. Spares therefore should also be examined from the point of view of vital, essential or desirable nature. The ideal decision for the quantity to be purchased would be based on a balanced, combined approach of ABC and VED analyses. The attention to each item in the inventory to be purchased would be determined on the consideration of the matrix of ABC and VED. For example, highest attention is to be given to 'A' category items in the category of 'Vital', next to be given to 'B' category items in the 'Essential' category and lowest attention is to be given to 'C' category items in the 'Desirable' category. For explaining this point, values of the inventory are given in the matrix as below:

	V	E	D
A	80	70	60
B	70	60	50
C	60	50	40

Such an analysis for inventory items would give optimum results with respect to availability of spares and also for the value of inventory investment.

4.4 FSN ANALYSIS

FSN stands for fast moving, slow moving and non- moving. By doing FSN analysis materials can be classified based on their movement from inventory for a specified period. Items are classified based on consumption and average stay in the inventory. Higher the stay of item in the inventory, the slower would be the movement of the material. To carry out FSN analysis, the date of receipt or the last date of issue, whichever is later, is taken to determine the number of months, which have lapsed since the last transaction. The items are usually grouped in periods of 12 months.

F - Fast Moving
S- Slow Moving
N- Non moving

The following steps are undertaken while doing the FSN analysis:

i. Calculation of average stay and the consumption rate of the material in warehouse
ii. FSN Classification of materials based on average stay in the inventory
iii. FSN Classification of the material based on consumption rate
iv. Finally classifying based on above FSN analysis.

Calculation of consumption rate and average stay of the material in the inventory

Consumption Rate - Total Issue Qty/Total Period Duration

Average stay of the material *» Cumulative No of Inventory Holding Days/ (Total quantity received + Opening Balance)

FSN Analysis is helpful in identifying active items which need to be reviewed regularly and surplus items which have to be examined further. Non-moving items may be examined further and their disposal can be considered.

4.5 HML ANALY8IS

The High, Medium and Low (HML) classification follows the same procedure as is adopted in ABC classification. Only difference is that in HML, the criterion of classification is the unit value and not the annual consumption value. The items of inventory should be listed in the descending order of unit value and it is up to the management to fix limits for the three categories. For example, the management may decide that all units with unit value of Rs.2000 and above will be H items, Rs.1000 to 2000 M items and less than Rs.1000, L items.

The HML analysis is useful for keeping control over consumption at departmental levels, for deciding the frequency of physical verification, and for controlling purchases.

4.6 SDE ANALYSIS

The SDE analysis is based upon the availability of items and is very useful in the context of scarcity of supply. In this analysis, 'S' refers to scarce items, generally imported, and those which are in short supply. 'D' refers to difficult items which are available indigenously but are difficult to procure. Items which have to come from distant places or for which reliable suppliers are difficult to come by fall into 'D' category. 'E' refers to items which are easy to acquire and which are available in the local markets.

The SDE classification, based on problems faced in procurement, is vital to the lead time analysis and in deciding on purchasing strategies.

SELF CHECK EXERCISE Ⅱ

3. FSN stands for____________________.

4. In FSN analysis material can be classified based on their_____________ from inventory for a specified period.

5. SDE analysis is based upon the________________.

4.7 INVENTORY CONTROL APPROACHES

Continuous Review System: This approach maintains a constant order size, but allows the time between the placements of orders to vary. This method of monitoring inventory is sometimes referred to as a perpetual review method, a fixed quantity system, and a two-bin system. When the inventory is depleted to the reorder point, a replenishment order is placed. The size of that order is the economic order quantity for that item. This type of system provides closer control over inventory items since the inventory levels are under perpetual scrutiny.

Periodic Review System: This approach maintains a constant time between the placements of orders, but allows the order size to vary. This method of monitoring inventory is sometimes referred to as a fixed interval system or fixed period system. It only requires that inventory levels be checked at fixed periods of time. The amount that is ordered at a particular time point is the difference between the current inventory level and a predetermined target inventory level (also called an order up to level). If demand has been low during the prior time interval, inventory levels will be relatively high, and the amount to be ordered will be relatively low. If demand has been high during the prior time interval, inventory levels will have been depleted to low levels, and the amount to be ordered will be higher.

Minimum-maximum System: This approach allows both the order size and the time between the placement of orders to vary. This method of monitoring inventory is sometimes referred to as an optional replenishment system. It is a hybrid system that combines elements of both the continuous review system and the periodic review system. It is similar to the periodic review system in that it only checks inventory levels at fixed intervals of time, and it has a target inventory level. However, when one of those review periods arises the system does not automatically place an order. An order is only placed if the size of the order would be sufficient to warrant placing the order. This determination is made by incorporating the reorder point concept from the continuous review system. At the review period the inventory level on hand is compared to a reorder point for the item. If inventory has not fallen below the reorder point, no order is placed. However, if the inventory level has dropped below the reorder point, an order is placed. The size of the order is the difference between the inventory on hand and the target inventory level.

4.8 SUMMARY

The chapter focused on the selective inventory control techniques. The degree and nature of the control exercised by the management depends upon the necessity of the control, the real importance of the material to be placed under control and typical characteristics of the material. Different inventory control techniques classify the materials on different bases. ABC analysis classifies the items according to the potential amount to be controlled. VED analysis classifies the items on the basis of the shortage costs of the material. FSN analysis makes a distinction on the basis of consumption and average stay in the inventory, HML on the basis of the unit value and SDE on the basis of the availability of the material.

4.9 KEYWORDS

The ABC approach, FSN Analysis, SDE Analysis, HML Analysis

4.10 EXERCISES

4.10.1 SHORT QUESTIONS

1. Write short notes on following:

a) FSN Analysis, b) HML Analysis, c) SDE Analysis

2) Explain VDE analysis.

4.10.2 LONG QUESTIONS

1. Discuss ABC analysis with an example.

2. What are the various techniques used in inventory control? Which one of the techniques do you think to be the best for an automobile industry?

4.11 ANSWERS TO SELF CHECK EXERCISE

1. Always Better Control, 2. Three, 3. Fast Moving, Slow Moving, Non-Moving

4. Movement, 5. Availability of items.

4.12SUGGESTED READINGS

- Goel, B.S., *Production Operations Management*, Pragati Prakashan, Meerut, 18th Edition, 2005.
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Lesson No. 5 **AUTHOR: DYAL BHATNAGAR**

MATERIAL REQUIREMENT PLANNING

STRUCTURE

5.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the Concept of MRP.
- Know the inputs and outputs of an MRP system.
- Know the problems and benefits of an MRP system.

5.1 INTRODUCTION

Companies need to control the types and quantities of materials they purchase, plan which products are to be produced and in what quantities and ensure that they are able to meet current and future customer demand, all at the lowest possible cost. Making a bad decision in any of these areas will make the company lose money. A few examples are given below:

- If a company purchases insufficient quantities of an item used in manufacturing, or the wrong item, they may be unable to meet contracts to supply products by the agreed date.
- If a company purchases excessive quantities of an item, money is being wasted - the excess quantity ties up cash while it remains as stock and. may never even be used at all. However, some purchased items will have a minimum quantity that must be met, therefore, purchasing excess is necessary.
- Beginning production of an order at the wrong time can cause customer deadlines to be missed.

MRP is a tool to deal with these problems. It provides answers for several questions:

- What items are required?
- How many are required?
- When are they required?

MRP can be applied both to items that are purchased from outside suppliers and to sub-assemblies, produced internally, that are components of more complex items.

5.1.1 DISAGGREGATION PROCESS OF INVENTORY MANAGEMENT

Aggregate Production Plan Specifies monthly or quarterly output requirements by major product groups either in labour hours required or units of production.

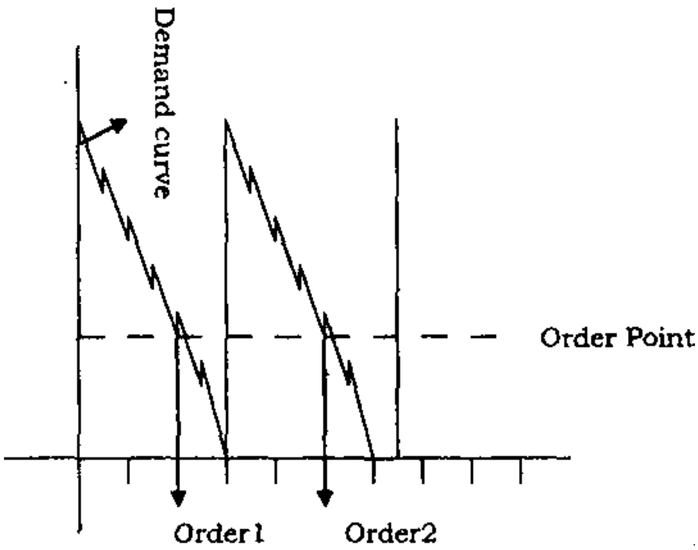
Master Production Schedule Specifies how many and when a company plans to build each specific end item.

Material Resource Planning or the Material Requirement Planning calculates and schedules all of the raw materials, parts and supplies needed to make each unit specified in MPS.

Thus, it is clear from the above that firstly an Aggregate Production Plan (APP) is framed, based on it a Master Production Schedule (MPS) is developed. On the basis of the requirement given by APP, the MPS give schedules of the production operations to be carried out for covering the target dates mentioned in the APP. Further, The MRP is obtained on the basis of MPS. It gives the exact amount of all raw materials required and the supplies needed by the production process, so that, the production process is not hindered in between.

5.1.2 INDEPENDENT AND DEPENDENT DEMAND INVENTORY MANAGEMENT SYSTEMS

Independent demand is the demand of the finished goods that will be consumed or used up by the ultimate consumers. This type of demand can also be stated in terms of the demand of a particular manufacturing department that will finally consume the units demanded by it or the input received by it. In contrast to the independent demand, the dependent demand is the demand for the items that are used in the manufacturing of the finished product.

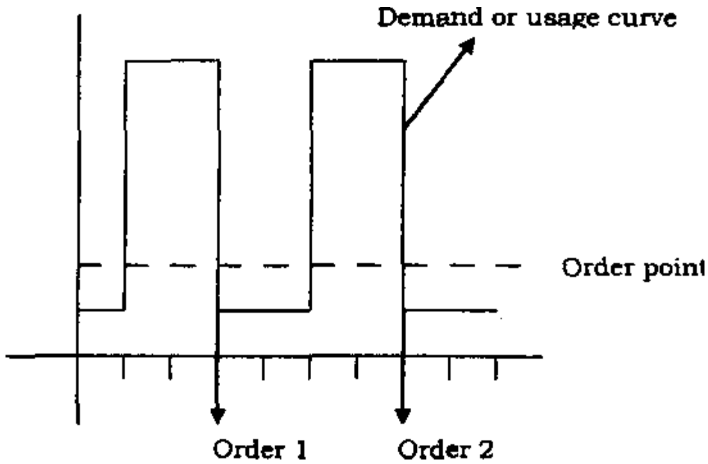


Time in weeks

Figure 1: Independent Demand Inventory Management System

Both the independent and dependent demand inventory management systems are shown in figure 1 and figure 2 respectively. Figure 1 shows continually downward sloping demand curves indicating independent demand. The lead time in this case is one week. When the demand curve reaches the order point an order is placed. As the order is received the next week the stock level goes up. The demand curve in figure 2 indicates a demand dependent upon other parts or items that are required for the process to go on. The lead time here is of two weeks. Here also, as the order point is reached an order is placed and as the order is received after two weeks the stock level goes up.

It is to be mentioned here that Material Requirement Planning is based upon the Dependent Demand Inventory Management System. This fact will be clearer after the example discussed below.

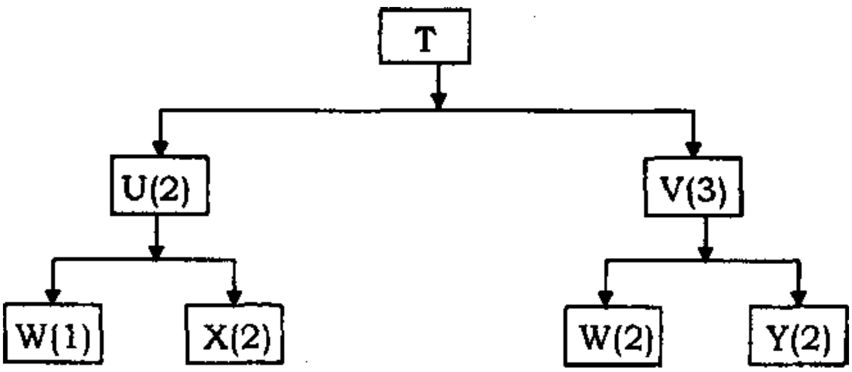


Time in weeks

Figure 2: Dependent Demand Inventory Management System

5.1.3 MATERIAL REQUIREMENT PLANNING; AN EXAMPLE

Example: Suppose we want to produce a product T which further needs the following:



The figures in the parenthesis are the units required for producing the parent product. Say, for producing one unit of product T we need two units of U and three units of V. Similarly, for producing one unit of product U we need one unit of W and two units of X and so on. Further, if we have to produce 100 units of product T, we have the following requirements of other sub products. The following table also indicates the lead time required by each part.

Parts	Units Required	Lead Time (Weeks)
Part T	100	1
Part U	200 (100 of T x 2)	2
Part V	300 (100 of T x 3)	2
Part W	800 (200 of U x 1) + (300 of V x 2)	3
Part X	400 (200 of U x 2)	1
Part Y	600 (300 of V x 2)	1

From the information given in the above example, a sample Material Requirement Plan can be developed, which is shown in the ensuing table. Table - 1 shows a detailed Material Requirement Plan. For each part the required date (in weeks) is given. With the help of lead time date for placing the order can be found. In this way firstly the order for product W is placed as it has the highest lead time in the lowest level of hierarchy. Then the orders for the products X and Y are placed as they have lesser lead time on the same hierarchy level as compared to W. After that Orders for U and V are placed as they are on the next upper level of product hierarchy. Lastly the order for final product T is placed. In this way the total schedule of orders and target dates is visible from the Material Requirement Plan.

Table 1: Material Requirement Plan

Parts	Dates	
T	REQUIRED DATE	
	ORDER PLACEMENT	
U	REQUIRED DATE	
	ORDER PLACEMENT	
V	REQUIRED DATE	
	ORDER PLACEMENT	
W	REQUIRED DATE	
	ORDER PLACEMENT	
X	REQUIRED DATE	
	ORDER PLACEMENT	
Y	REQUIRED DATE	
	ORDER PLACEMENT	

By now the meaning of Material Requirement Planning is clear. From the above discussion the theme of Material Requirement Planning should also be understood which is 'getting the right material to the right place at the right time.

SELF CHECK EXERCISE I

1. Write the steps involved in disaggregation process of inventory management.

2.________________ is the demand for the items that are used in the manufacturing of the finished products.

5.2 OBJECTIVES OP MATERIAL REQUIREMENT PLANNING

There are basically two objectives of Material Requirement Planning:

1. **To minimize inventory investment.** As the Material Requirement Plan gives a precise schedule of all the required dates, there is no need of placing orders before than required. This will lead to avoidance of overstocking and thus
„ Resulting in minimization of inventory cost.
2. **To maximize operating efficiency.** Again, as the Material Requirement Plan will give the precise requirement dates, there will also be no under-stocking which can lead to the stoppage of production process resulting in maximization of operating efficiency.

5.3 MATERIAL REQUIREMENT PLAN STRUCTURE

The structure of Material Requirement Plan consists of inputs and outputs to the MRP system, which is depicted in the figure 3 shown below:

INPUTS

1. **Master Production Schedule** is the first input to an MRP system which contains information such as orders placed by the customers of the firm and future forecasts of the demand
2. **Bills of Materials Pile** contains the complete product description, listing not only the materials, parts and components but also the sequence in which the product has been created. It is also called product tree as it shows how product has been put together. The products can be listed in two different formats shown below:

Parts list in indented format

A
    B (2)
        D(1)
        E(4)
    C(3)
        F(2)
        C(5)
        H(4)

Parts listed in single level format

A
    B(2)
    C(3)
B
    D(1)
    E(4)
C
    F(2)
    C(5)
    H(4)

3. **Inventory Records file** keeps data about the projected use and receipts of each item and to determine the amount of inventory that will be available in each time bucket.

If the projected available inventory is not adequate, the Material Requirement Planning System will recommend ordering the item. There are basically two types of inventory record file i.e., Inventory Master File and Inventory Transaction File. Inventory Transaction File is further segregated into Issue Transaction File and Receipt Transaction File. Inventory Master File tells the actual balance of an item on a particular date and is updated repeatedly through the transaction files.

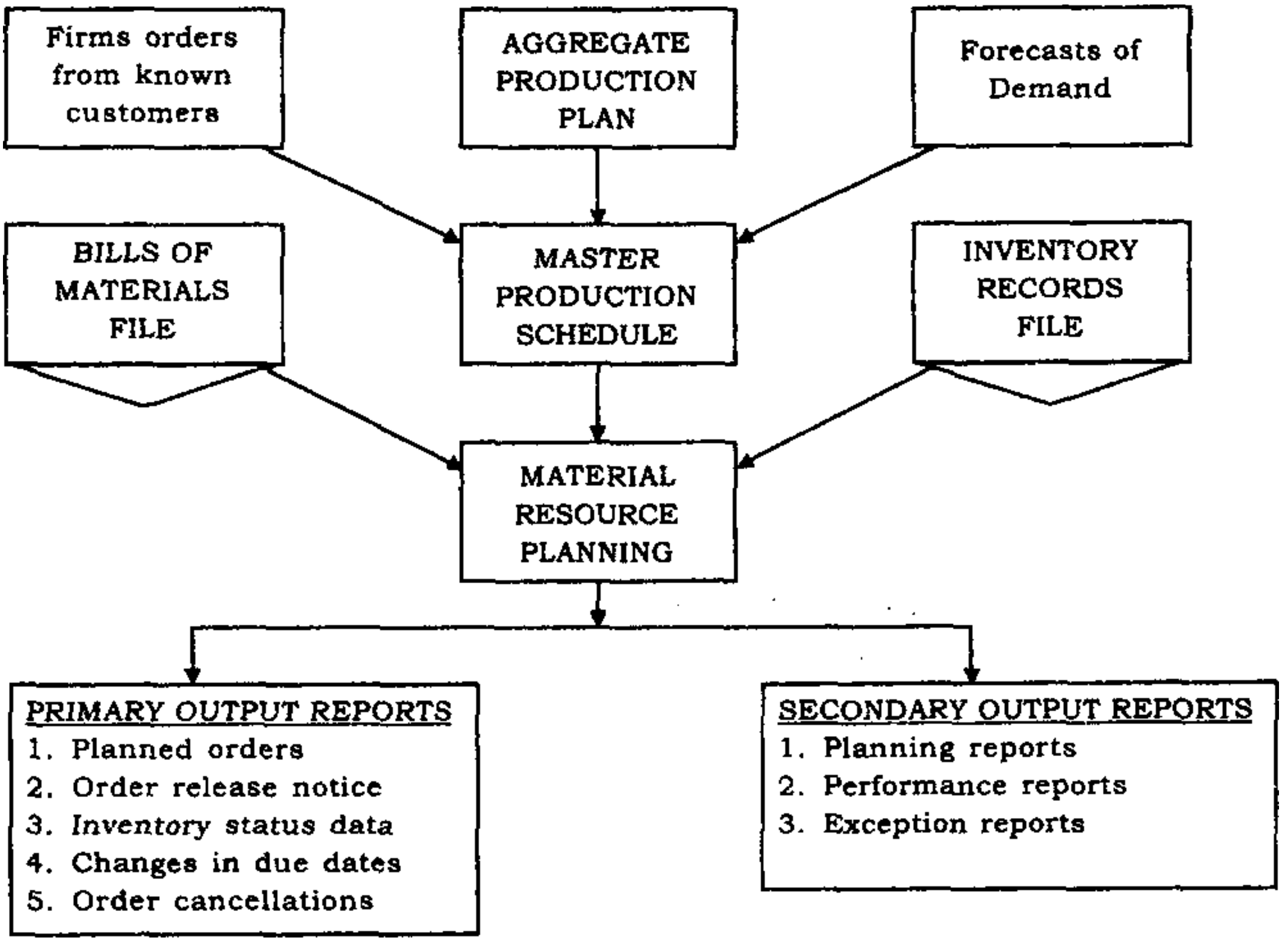
OUTPUTS 1. Primary Reports

- 'Planned orders' to be released at a future time
- 'Order release notice' to execute the planned orders
- Changes in due dates due to rescheduling
- Cancellations due to cancellation in orders of MPS
- Inventory status data

2. Secondary Reports

- 'Planning reports' are used in forecasting inventory and specifying requirements

Figure 3: Material Requirement Planning Structure



- 'Performance reports' are used for determining agreement between actual and programmed lead times, usage and cost
- 'Exception reports' point out serious discrepancies, such as, errors, out of range situations, late orders, excessive scrap, etc.

SELF CHECK EXERCISE Ⅱ

3. Which reports are used in forecasting inventory and specifying requirements?

4. Performance reports are used for determining agreements between actual and programmed ____________, ___________and_____________.

5.4 PROBLEMS WITH MRP SYSTEMS

The major problem with MRP systems is the integrity of the data. If there are any errors in the inventory data, the bill of materials (commonly referred to as ’BOM') data, or the master production schedule, then the outputted data will also be incorrect. Most vendors of this type of system recommend at least 99% data integrity for the system to give useful results.

Another major problem with MRP systems is the requirement that the user specify how long it will take a factory to make a product from its component parts (assuming they are all available). Additionally, the system design also assumes that this "lead time" in manufacturing will be the same each time the item is made, without regard to quantity being made, or other items being made simultaneously in the factory.

A manufacturer may have factories in different cities or even countries. It is no good for an MRP system to say that we do not need to order some material because we have plenty thousands of miles away. The overall ERP system needs to be able to organize inventory and needs by individual factory, and intercommunicate needs in order to enable each factory to redistribute components in order to serve the overall enterprise.

This means that other systems in the enterprise need to work properly both before implementing an MRP system, and into the future. For example, systems like variety reduction and engineering which makes sure that product comes out right first time (without defects) must be in place.

Production may be in progress for some part, whose design gets changed, with customer orders in the system for both the old design, and the new one, concurrently. The overall ERP system needs to have a system of coding parts such that the MRP will correctly calculate needs and tracking for both versions. Parts must be booked into and out of stores more regularly than the MRP calculations take place. Note, these other systems can well be manual systems, but must interface to the MRP. For example, a 'walk around' stock take done just prior to the MRP calculations can be a practical solution for a small inventory (especially if it is an "open store").

The other major drawback of MRP is that takes no account of capacity in its calculations. This means it will give results that are impossible to implement due to manpower or machine or supplier capacity constraints. However.

Some other shortcomings of MRP

- MRP is a scheduling, not a stockage, algorithm
- MRP does not address how to determine lot size
- MRP systems do not inherently deal with uncertainty
- MRP assumes constant, known lead times
- MRP does not provide incentives for improvement

5.5 BENEFITS OF MRP SYSTEM

MRP systems can provide

- Better control of inventories
- Improved scheduling
- Productive relationships with suppliers

For Design / Engineering

- Improved design control
- Better quality and quality control

For Financial and Costing

- Reduced working capital for inventory
- Improved cash flow through quicker deliveries
- Accurate inventory records
- Timely and valid cost and profitability information

Some other Benefits of MRP

- Lower Inventory Levels
- Able to better manage components
- Fewer Stock outs
- Relationships are defined and explicit
- Allows for coordination with MPS
- Less Expediting required
- Fewer Production Disruptions
- Input needs are explicitly modeled
- Plans are integrated

5.6 MRP: EVOLUTION OF CONCEPTS

The following discussion helps in understanding some recent concepts which are evolving, using MRP as their basis.

Simple MRP

- Focus on "order launching"
- Used within production -not believed outside

Closed Loop MRP

- Focus on production scheduling
- Interacts with the MPS to create feasible plans

MRP II [Manufacturing Resource Planning]

- Focus on integrated financial planning
- Treats the MPS as a decision variable
- Capacity is considered (Capacity Resource Planning)

Enterprise Resource Planning Systems

- Common, centralized data for all areas
- Implementation is costly and effort intensive
- Forces business rules on companies

5.7 SUMMARY

Material Requirement Planning (MRP) as a crucial tool for companies to manage materials, production planning, and customer demand efficiently. MRP addresses issues such as insufficient or excessive purchases and untimely production. The disaggregation process involves an Aggregate Production Plan (APP) leading to a Master Production Schedule (MPS) and eventually MRP. Independent and dependent demand in inventory management systems is explained, with MRP based on the latter. The chapter details the MRP process through an example. Objectives include minimizing inventory investment and maximizing operating efficiency. The MRP structure involves inputs like MPS, Bills of Materials, and Inventory Records, generating primary and secondary reports. Challenges with MRP systems, such as data integrity and capacity constraints, are discussed. Despite drawbacks, MRP systems offer benefits like better inventory control and improved relationships with suppliers. The evolution of MRP concepts includes Simple MRP, Closed Loop MRP, MRP II, and Enterprise Resource Planning Systems.

5.8KEYWORDS

Material Requirements Planning (MRP), Bill of Materials (BOM**),** Master Production Schedule (MPS), Purchase Order (PO), Enterprise Resource Planning (ERP), Manufacturing Resource Planning (MRP II), Capacity Planning

5.9 EXERCISES

5.9.1 SHORT QUESTIONS

1. Explain disaggregation process of Inventory Management.
2. What is Independent and Dependent demand inventory management system.
3. Illustrate Material Requirement Planningstructure.
4. Discuss major problems with an MRP system

5.9.2 LONG QUESTIONS

l. What is 'Material Requirement Planning'? Elaborate with examples.
2. What are the inputs to and outputs of an MRP system?
3. What are the merits and demerits of an MRP system?

5.10 ANSWERS TO SELF CHECK EXERCISE

1. Aggregate production plan> Master production schedule> Material Resource Planning

2. Dependent Demand**, 3.** Planning Reports, **4.** Lead time, usage and cost.

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Lesson No. 6AUTHOR: PR. PARMOD KUMAR AGGARWAL

INVENTORY CONTROL MODEL-I

STRUCTURE

6.1 COSTS INVOLVED IN INVENTORY PROBLEMS

Various costs involved in inventory problems may be generally classified as follows:

1. Set-up Cost/Ordering Cost (C_0)

These include the fixed cost associated with obtaining goods through placing in orders or purchasing or manufacturing or setting up a machinery before starting production. The costs include ordering of raw materials for production purposes, advertisements, postage, telephone charges, travel expenditure and so on. These are also called order costs or replenishment costs per production run. These are assumed to be independent of the quantity ordered or produced. Ordering cost may be calculated as:

Order cost - (Cost per order) * (Number of orders)

2. Purchase or Production Cost

The cost of purchasing (or producing) a unit of item is known as purchase (or production) cost. Purchase cost per unit item is affected by the quantity purchased due to *quantity discounts or price breaks.*

Purchase cost = (Price per unit item) * (Demand per unit item)

When price break or quantity discounts are available for bulk purchase of a specified quantity, the unit price becomes smaller as size of order Q exceeds a specified quantity level. In such cases the purchase cost becomes variable and depends on the size of the order. In this purchase cost is given by

Purchase cost * Price per unit when order size is Q * Demand per unit time

3. Carrying or Holding Cost (C_c)

The cost associated with carrying or holding goods in stock is called holding or carrying cost per unit of item for a unit of time. It is assumed to vary directly with the size of inventory as well as the time the item is held in stock. This cost generally includes:

(i) **Invested Capital Cost:** This is the interest charged on the capital investment.
(ii) **Record-keeping and Administrative Cost:** This shows that there is a need of funds for maintaining the records and necessary administration.
(iii) **Handling Costs:** These include all costs associated with movement of stock, cost of labour, and so on.
(iv) **Storage Costs:** These involve the rent for storage space or depreciation and interest even if own space is used.
(v) **Depreciation, Deterioration, Obsolescence Costs:** These costs arise due to the items in stock being out of fashion or the items undergoing chemical changes

during storage, date expiring and so on.

(vi) Taxes and Insurance Costs: These costs require careful study and generally amount to 1 percent to 2 percent of the invested capital.

4. Shortage (or Stock out) Cost

The shortage of items occurs when actual demand cannot be fulfilled from the existing stock. These costs arise due to shortage of goods, and may cause loss of sales. Goodwill may be lost either by a delay in meeting the demand or being unable to meet the demand. The shortage can be looked at in two different ways:

(i) The supply of items is awaited by the customers, that is, the items are back ordered and therefore there is no loss in sale.

(ii) Customers are not ready to wait and, therefore, there, is loss of sale. In the case of shortage, cost shall be measured in terms of goodwill lost and lost profit on the unit which were demanded but were not available.

5. Salvage Cost (or Selling Price)

When the demand for commodity is affected by the quantity stocked, the decision model of the problem depends upon the profit maximization criterion and includes revenue from selling. Generally, salvage value may be combined with the cost of storage and not considered independently.

6. Revenue Cost

When it is assumed that both the price and the demand of the product are not under the control of the organization, the revenue from the sales is independent of the company's inventory policy. It may be neglected expect when the organization cannot meet the demand and the sale is lost. The revenue cost may or may not be included in the study of inventory.

7. Total Inventory Cost

If the unit price of an item depends on the quantity purchased, that is, price discount is available, then we formulate an inventory policy that considers the purchase cost of the items held in stock. The total inventory cost is given as:

Total inventory cost = Ordering cost + Carrying cost + Shortage cost

8. Total Variable Inventory Cost

When price discounts are not offered, the purchase cost remains constant and is independent of the quantity purchased. Hence, $TVC = C_Q + C_c + S_c$

SELF CHECK EXERCISE I

1. Order Cost=_______________*__________________.

2. Price per unit item* Demand per unit item=__________________.

3. Which cost include all costs associated with movement of stock, cost of stock, cost of labor, etc.?

4. Total Inventory Cost=____________+________________+___________________.

6.3 OTHER FACTORS IN INVENTORY ANALYSIS

The factors which play an important role in the study of inventory problems are:

1. Demand

Demand is the number of units required per period and may be known exactly or in terms of probabilities or be completely unknown. If demand is known, it may be either fixed or variable per unit time. Problems in which the demand is known and fixed are called *deterministic* problems. If the demand is assumed to be a random variable, then those problems are called *stochastic* or *probabilistic problems.*

2.Lead Time

The time gap between placing of an order and its actual arrival in the inventory is known as lead time. The Longer the lead time, the higher is the average inventory. Lead time has two components, namely *administrative lead* time-time from the initiation of procurement action to the placing of an order, and *delivery lead* time-time from placing of an order to the delivery of the ordered material.

3.Order Cycle

The time period between placements of two successive orders is referred to as an order cycle. The order may be placed on the basis of following two types of inventory review systems.

- **(a) Continuous review:** The record of the inventory level is checked continuously until a specified point is reached where a new order is placed.
- **(b) Periodic review:** The inventory levels are viewed at equal time intervals and orders are placed at such intervals. The quantity ordered each time depends on the available inventory level at the time of review.

4.Stock Replenishment

Actually, the replacement of stock may occur instantaneously or uniformly. Instantaneous replenishment occurs in case the stock is purchased from outside sources whereas uniform replenishment occurs when the product is manufactured by the company.

5.Time Horizon

The time period over which the inventory level will be controlled is called the time horizon.

6.Reorder Level

The level between maximum and minimum stock, at which purchasing (or production) activities start for replenishment is called reorder level.

Variables in Inventory Problem: The variables used in any inventory model are of two types:

- (a) Controlled variables
- (b) Uncontrolled variables
- **(a) Controlled variables:** The following variables are controlled separately or in combination.
  - (i) How much quantity to buy (purchase, production, so on)
  - (ii) The frequency or timing of acquisition-how often or when to replenish the inventory?
  - (iii) The completion stage of stocked items.
- **(b) Uncontrolled Variables:** These include the holding costs, shortage or penalty costs, set up costs, demand, lead time, and supply of goods.

SELF CHECK EXERCISE Ⅱ

5. Problems in which the demand is known and fixed are called as____________.

6. Time gap between placing of an order and its actual arrival in the inventory is known as___________.

7.The time period between placements of two successive orders is known as an____________.

6.3 SELECTING THE REORDER POINT WHEN DEMAND IS UNCERTAIN

In reality, demand and lead times are not always predictable. For instance, the museum's buyer knows that average demand is 18 feeders per week and that the average lead time is two weeks. That is, a variable number of feeders may be purchased during the lead time, with an average demand during lead time of 36 feeders (assuming that each week's demand is identically distributed. This situation gives rise to the need for safety stocks. Suppose that she sets R at 46 units, thereby placing orders before they typically are needed. This approach will create a safety stock, or stock held in excess of expected demand, of 10 units (46 - 36) to buffer against uncertain demand. In

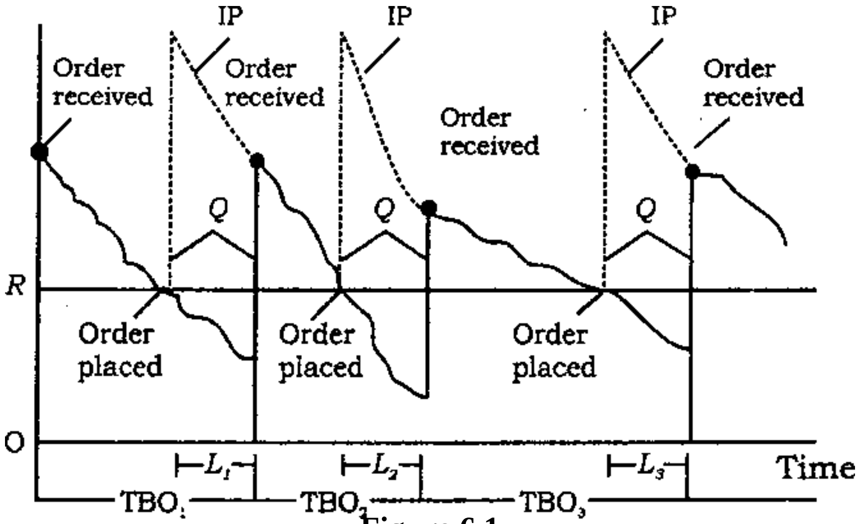

Figure 6.1

Figure 6.1 shows how the Q system operates when demand is variable and uncertain. We assume that the variability in lead times is negligible and, therefore, can be treated as a constant, as we did in the development of the EOQ model. The wavy downward-sloping line indicates that demand varies from day to day. Its slope is steeper in the second cycle, which means that the demand rate is higher during this time period. The changing demand rate means that the time between orders changes. Because of uncertain demand, sales during lead time are unpredictable, and safety stock is added to hedge against lost sales. It also explains why the on-hand inventory usually doesn't drop to 0 by the time a replenishment order arrives. The greater the safety stock and thus the higher reorder point R, the less likely a stockout.

Because the average demand during lead time is variable and uncertain, the real decision to be made when selecting R concerns the safety stock level. Deciding on a small or large safety stock is a trade-off between customer service and inventory holding costs. Cost minimization models can be used to find the best safety stock, but they require estimates of stockout and backorder costs, which are usually difficult to make with any precision. The usual approach for determining R is for management-based on judgment-to set a reasonable service-level policy for the inventory and then determine the safety stock level that satisfies this policy.

6.3.1 Choosing an Appropriate Service-Level Policy

Managers must weigh the benefits of holding safety stock against the cost of holding it. One way to determine the safety stock is to set a service level, or cycle-service level-the desired probability of not running out of stock in anyone ordering cycle, which begins at the time an order is placed and ends when it arrives in stock. In a bookstore, the manager may select a 90 percent cycle-service level for a book. In other words, the probability is 90 percent that demand will not exceed the supply during the lead time. The probability of running short during the lead time, creating a stockout or backorder, is only 10 percent (100 - 90). This stockout risk, which occurs only during the lead time in the Q system, is greater than the overall risk of stockout because the risk is nonexistent outside the ordering cycle.

To translate this policy into a specific safety stock level, we must know how demand during the lead time is distributed. If demand varies little around its average, safety stock can be small. Conversely, if demand during lead time varies greatly from one order cycle to the next, the safety stock must be large. Variability is measured with probability distributions, which are specified by a mean and a variance.

6.3.2 Finding the Safety Stock

When selecting the safety stock, the inventory planner often assumes that demand during lead time is normally distributed, as shown in Figure 6.2. The average demand during the lead time is the centerline of the graph, with 50 percent of the area under the curve to the left and 50 percent to the right. Thus, if a cycle-service level of 50 percent were chosen, reorder point R would be the quantity represented by this centerline. As R equals demand during the lead time plus the safety stock, the safety stock is a when R equals this average demand. Demand is less than average 50 percent of the time, and thus having no safety stock will be sufficient only 50 percent of the time.

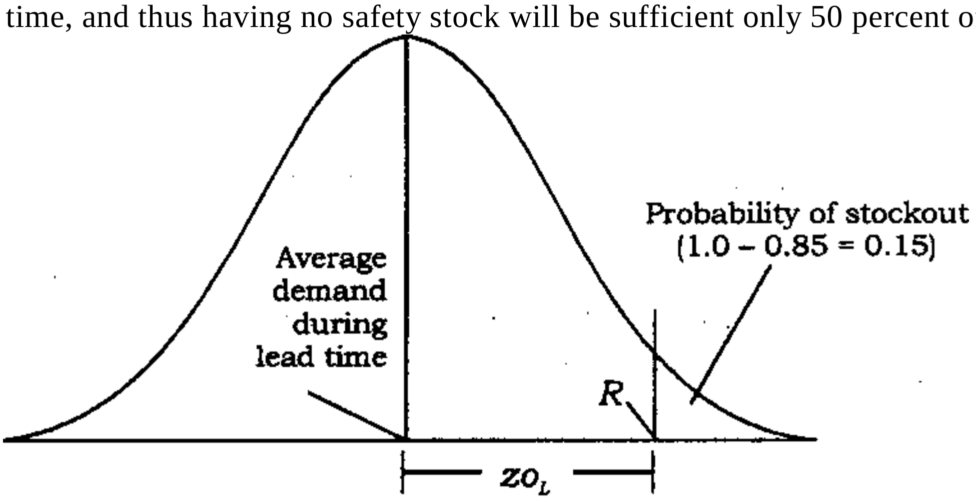

Figure 6.2

To provide a service level above 50 percent, the reorder point must be greater than average demand during the lead time. In Figure 6.2, that requires moving the reorder point to the right of the centerline so that more than 50 percent of the area under the curve is to the left of R. An 85 percent cycle-service level is achieved in Figure 6.2, with 85 percent of the area under the curve to the left of R and only 15 percent to the right. We compute the safety stock by multiplying the number of standard deviations from the mean needed to implement the cycle-service level, z, by the standard deviation of demand during lead time probability distribution, o.

Safety stock = z o

The higher the value of z, the higher the safety stock and the cycle-service level should be. If z = 0, there is no safety stock, and stock outs will occur during 50 percent of the order' cycles.

Example

Records show that the demand for dishwasher detergent during the lead time is normally distributed, with an average of 250 boxes and o = 22. What safety stock should be carried for a 99 percent cycle-service level? What is R?

Solution: The first step is to find z, the number of standard deviations to the right of average demand during the lead time that places 99 percent of the area under the curve to the left of that point (0.9900 in the body of the table in the Normal Distribution appendix).

Safety stock = z Σ= 2.33(22) = 51.3, or 51 boxes

Reorder point = Average demand during lead time + Safety stock = 250 + 51 = 301boxes

We rounded the safely stock to the nearest whole number. In this case, the theoretical cycle service level will be less than 99 percent. Raising the safety stock to 52 boxes will yield a cycle service level greater than 99 percent.

Management can control the quantity of safety stock by choosing a service level. Another approach to reducing safety stock is to reduce the standard deviation of demand during the lead time, which can he accomplished by closer coordination with major customers through information technology.

6.4 SUMMARY

The chapter discusses various costs associated with inventory problems, categorizing them into set-up/ordering costs, purchase/production costs, carrying/holding costs, shortage/stock-out costs, salvage costs, and revenue costs. It emphasizes the importance of considering these costs in inventory management decisions. The concept of total inventory cost and total variable inventory cost is introduced. Factors such as demand, lead time, order cycle, stock replenishment, time horizon, reorder level, controlled and uncontrolled variables are explored in inventory analysis. The chapter also delves into selecting the reorder point when demand is uncertain, highlighting the role of safety stock and service-level policies.

6.5 KEYWORDS

Set-up Cost/Ordering Cost (C_o), Total Inventory Cost, Total Variable Inventory Cost, Order Cycle

6.6 EXERCISES

6.6.1 SHORT QUESTIONS

1. Explain various costs involved in inventory problem.

2. Write short notes on the following:

Lead time, Order cycle, Reorder level

3. Discuss thedifferent approaches to determine the safety stock.

6.6.2 LONG QUESTIONS

1.Petromax Enterprises uses a continuous review inventory system for one of its items. The following information is available on the item. The firm operates 50 weeks in a year:

Demand ** 50,000 units per year Ordering cost = $35
per order Holding cost - $2 per unit per year Average
lead time - 3 weeks
Standard deviation of weekly demand - 125 units

(a) What is the economic order quantity for this item?

(b) If company wants to provide a 90 percent cycle-service level, what should be the safety stock and the reorder point?

Lesson No. 7

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INVENTORY CONTROL MODELS-II

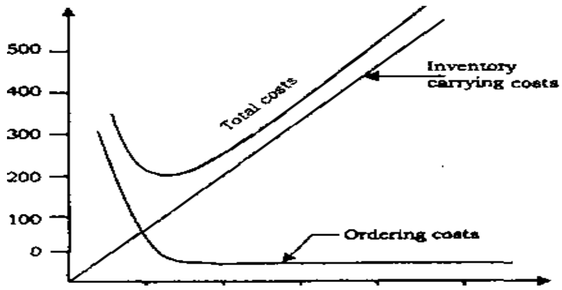
STRUCTURE

7.1 ECONOMIC ORDER QUANTITY (EOQ)

The concept of economic ordering quantity was first developed by F. Harries in 1916. The inventory problems in which the demand is assumed to be fixed and completely predetermined as usually referred to as economic order quantity (EOQ). When the size of order increases, the ordering costs (cost of purchase, etc.) will decrease, whereas the carrying charges {cost of storage, insurance etc.) will increase. Hence, there are two opposite costs in the production process, one encourages increase in the order size and the other discourages.

7.1.1 Determination of EOQ by Graphical Method

The data calculated in tabular method can be graphed as below:



1,0002,0003,0004,0005,000

Number of units

Figure 7.1

The minimum total cost occurs at the point where the ordering costs and inventory carrying costs are equal. A disadvantage of the graphical method is that without specific costs and values, an accurate plotting of the carrying costs, ordering costs, and total costs is not feasible.

7.1.2 Determination of EOQ by Algebraic Method

It is based on following assumptions:

(i) Demand is known and uniform
(ii) Lead time is zero
(iii) Production rate is infinite i.e., production is instantaneous
(iv) Shortage is not allowed
(v) Set-up cost per production is given
(vi) Holding cost/Carrying cost can be expressed as a percentage of the value of average inventory.

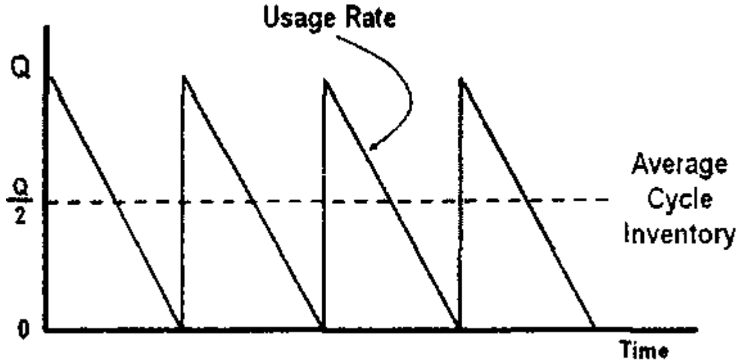


Figure 7.2

This method overcomes the problems of tabular and graphic method and is widely used. It is based on the fact that total cost would be minimum when carrying costs and ordering costs are equal. The step-by-step procedure to determine EOQ can written as:

(i) Annual Ordering Cost (C_0)

= No. of orders place/year * Ordering cost period

= (Annual Demand)/ (No. of units in each order) * Ordering cost per period

$=(DC_0)/Q$

(ii) Annual Carrying or holding cost *

= Average Inventory Level * Carrying Cost/Unit/Year

= (Ordered Quantity/2) * Carrying cost/unit/year

$= (Q/2).\ C_c$

(iii) Economic/Optimal Order Quantity is determined when ordering cost = Carrying Cost

i.e. $(DC_0/Q = (Q/2).\ C_c$

$DC_0=Q^2.C_c$

$Q^2 = 2DCO/C_c$

$Q = [(2DC_0)/C_c]^{1/2}$

(iv) Total inventory cost or Total variable cost

$= (DC_0/Q + (Q/2).\ C_c$

$TVC = (2DC_0.C_c)^{1/2}$

(v) Number of orders (N) = Total Demand/EOQ

(vi) Procurement Period/Time between Orders = EOQ/Demand per Annum

(vii) Ordering Cycle = (Time in no. of days/months/years)/No. of orders

For Example

A company purchases raw material from outside suppliers for annual requirement. During the coming year, the company plans to manufacture at a constant 1,00,000 units of its products. The cost of placing each order is Rs. 160 for any item in inventory, the company incurs an carrying cost annually equal to 20% of the item cost. Find the following:

(i) What is EOQ?

(ii) What is the total inventory cost?

(iii) How many orders will be placed in next year?

Solution:

C_0 = 160; Co = Ordering Cost; C_{PU} = Cost per unit = Rs. 20;

C_c = 20% of inventory item; C_c = Carrying cost

= 20/100 x 20 * Rs. 4 per unit annum

(i) EOQ $=((2DC_0)/C_c)^{1/2}$ = 2828 units.

(ii) Total inventory cost

= Material Cost + Total Material cost = D * CPU + $(2DC_0.C_c)^{1/2}$

=200000 + 11314 = Rs. 2011314

(iii) Number of Orders (N)

= D/Q

= 100,000/2828 = 35.36 Orders = 35 Orders.

SELF CHECK EXERCISE I

1. What does EOQ stands for?

2. Who first developed the concept of Economic Order Quantity?

3.In the EOQ formula $[(2DC_0)/C_c]$ ^ (1/2), what do 'D,' 'C_0 ,' and 'Cc' represent?

7.2 ECONOMIC ORDER QUANTITY MODEL WHEN DEMAND IS UNIFORM AND SHORTAGES ARE PERMITTED

When demand or consumption is in excess of supply or production, it will result in shortages. Such situations affect the goodwill of concern and may lead to permanent decline in sales and profit. In this case following formulas can be used:

(i) EOQ = $[(2DC_0)/C_c]^{1/2}$ * f $(C_s + C_c)/ C_s]^{1/2}$

C_s = Shortage Cost, D = Annual Demand

C_0 = Ordering Cost C_c = Carrying Cost

(ii) Back-order units or shortage quantity (S) * EOQ * $C_c/ (C_S + C_c)$

(iii) Total Shortage Cost = S * C_s

(iv) Total Variable Cost (TVC) = $(2DC_0C_c)^{1/2}$ * $[(C_S/ (C_S + C_c)]^{1/2}$

(v) Maximum Inventory Level = EOQ - S

For **Example**

Oswal Sugar Ltd. has demand for 18,000 tonnes sugarcane per year. The sugarcane price is Rs. 1200 per tonne. The holding cost is 0.1 percent of sugarcane price and cost of shortage is Rs. 5 per tonne. The production set-up is Rs. 400 calculate.

Solution:

Demand (D) = 18,000 tonnes

Inventory price C_{pu} = 1200 per tonne

Carrying cost C_c = 0.1 % of 1200 = 1.2

Shortage cost C_s = Rs. 5 per tonne

EOQ (Q) = $[(2DC_0)/C_c]^{1/2} * [(C_s + C_c)/ C_s]^{1/2}$ = 3857 tonnes

Shortage quantity (S)= EOQ * C_c/ $(C_S + C_c)$ = 746 tonnes

Shortage Cost » S * C_s = 746 x 5 = 3730 Rs.

TVC = $(2DC_0*C_c)^{1/2} * [(C_S/ (C_S + C_c)]^{1/2}$ = Rs. 20785

7.3 EOQ PRODUCTION MODEL

In this model, supply is finite i.e., inventory is not replenished immediately rather it builds up over time period because production rate (p) is greater than demand rate (d) i.e., p > d. It is based on following assumptions.

(a) Demand is exactly known and uniform

(b) Shortages are not permitted

(c) Inventory is building up at constant (p - d) units per annum (tl)

(d) There is no replenishment during time t2 following formulas are used to determine various parameters:

For Example

If the production rate is 100 units per day and the demand is 5 units per day, the buildup is 95 (or 100-5) units each day. This buildup continues until the lot size Q, has been produced, after which the inventory depletes at a rate of 5 units per day. Just as the inventory reaches zero, the next production interval begins. The p-d buildup continues for Q/p days because Q is the lot size and p units are produced each day. For the given rate of buildup over the production interval, the maximum cycle inventory, I_{max}, is

$$I_{max} = (Q/P)\ (P-d) = Q\ (P-d)/P$$

Cycle inventory is no longer Q/2, as it was with the basic EOQ method instead it is $I_{max}/2$.

Total cost = Annual holding cost + Annual ordering cost

$$C = (I_{max}/2)\ (H) + (D/Q)\ (S)$$

$$= (Q/2)\ (p-d/p)\ (H) + (D/Q)\ (S)$$

Based on this cost function, the optimal lot size often called the economic production lot size (ELS) is

$$ELS = (2DS/H)^{1/2}.\ [p/(p-d)]^{1/2}$$

Inventory level

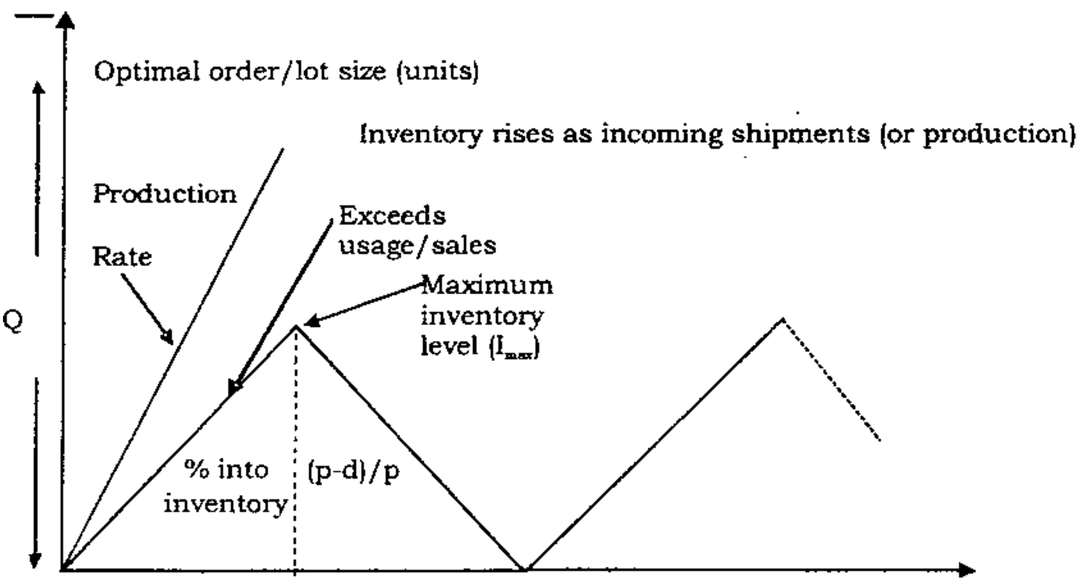


Figure 7.3

Example

A plant manager of a chemical plant must determine the lot size for a particular chemical that has a steady demand of 30 barrels per day. The production rate is 190 barrels per day, annual demand is 10,500 barrels, set up cost is $200, annual holding cost is $0.21 per barrel, and the plant operates 350 days per year. Determine

a. The economic production lot size (ELS)

b. The total annual cost for this item

c. The time between order (TBO) or cycle length

d. The production time per lot

Solution

ELS = $(2DS/H)^{1/2}. [p/(p-d)]^{1/2}$

= $(2*10,500*200/0.21)^{1/2} * \{190/(190-30)\}^{1/2}$ = 4,873.4 barrels

b. The annual total cost is C = (Q/2) (p-d/p) (H) + (D/Q) (S)

= (4873.4/2) * (160/190) (0.21) + (10500/4873.4) (200)

= $861.82

c. TBO = ELS/D

= (4873.4/10500) * 350 days/year = 162.4 or 162 days

d. the production time during each cycle

= ELS/p = 4873.4/190 = 25.6 or 26 days.

7.4 QUANTITY DISCOUNTS

Quantity discounts, which are price incentives to purchase large quantities, create pressure to maintain a large inventory. For example, a supplier may offer a price of $4 per unit for orders between 1 and 999 units, a price of $3.50 per unit for orders between 1000 and 1999 units and a price of $3.00 per units for orders of more than 2000 units. The item's price is not fixed as assumed in EOQ derivation; instead, if the order quantity is increased enough the price is discounted. In such cases, the total annual cost includes:

Holding Cost = (Q/2) (H)
Ordering Cost » (D/Q) (S)
Cost of purchased materials = PD
Where,
Q-lot size
H-holding cost of one unit D-demand S-set up cost P-price per unit
Total Cost = (Q/2) (H) + (D/Q) (S) + PD

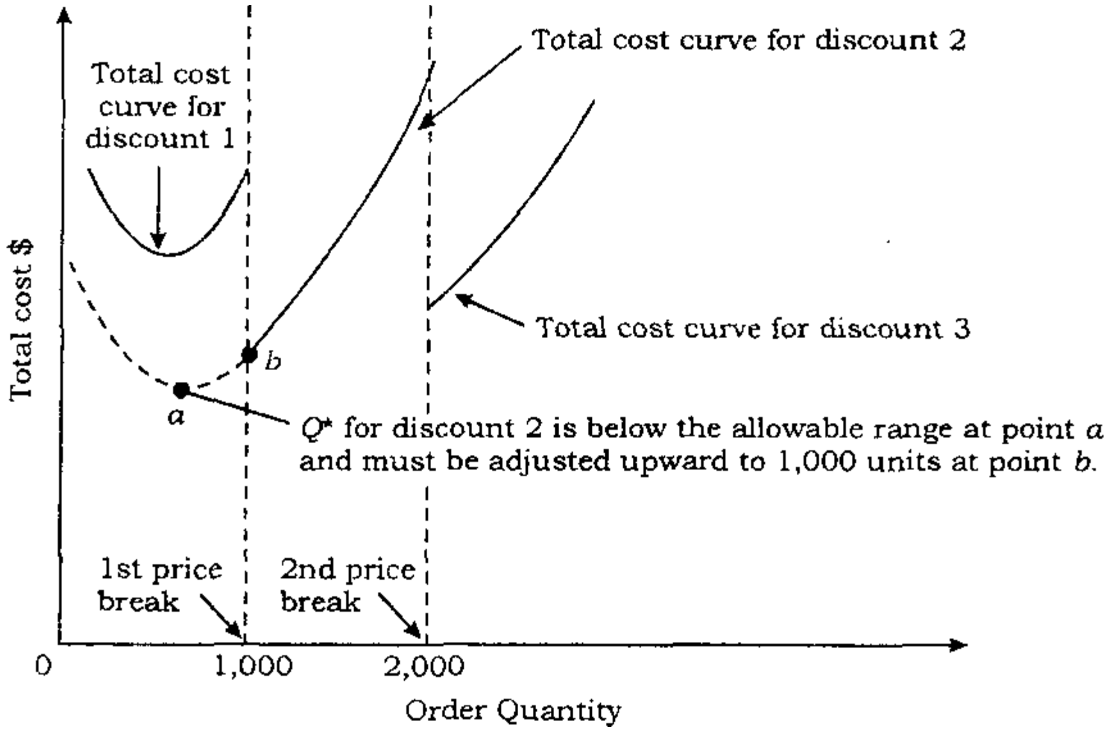


Figure 7.4

The total cost equation yields U-shaped curve and adding the annual cost of materials to the total cost equation raises each total cost curve by a fixed amount as shown in the Figure 8.2. There are three cost curves-one for each price level. The relevant or feasible total cost begins with the top curve, then drops down curve by curve at the price breaks which occur at Q=*1000 and Q=2000. The result is a total cost curve, with steps at the price breaks. The EOQs shown in the Figure 7.4 do not necessarily produce the best lot size for two reasons:

1. The EOQ at a particular price level may not be feasible- the lot size may not lie in the range corresponding to its per-unit price. For example, the $4.00 price level is greater than the first price break, so the price charged would be only $3.50.
2. The EOQ at a particular price level may be feasible but may not be the best lot size i.e., the feasible EOQ may have a higher cost than is achieved by the EOQ or price break quantity on a lower price curve. For example, 1750 units is the feasible EOQ for $3.50 curve as shown in the figure, but its total cost is higher than the 2000-unit price break quantity for the $3.00 price level.

Thus, the following two-step procedure may be used to find the best lot size.

Step 1: Beginning with the lowest price, calculate the EOQ for each price level until a feasible EOQ is found. It is feasible if it lies in the range corresponding to its price.

Step 2: If the first feasible EOQ found is for the lowest price level, this quantity is the best lot size. Otherwise calculate the total cost for the feasible EOQ and for the larger price break quantity at each lower price level. The quantity with the lowest cost is optimal.

Example

A supplier has introduced quantity discounts to encourage larger order quantities of an item. The price schedule is

Order Quantity	Price per Unit
0-299	$60.00
300-499	$58.80
500 or more	$57.00

The supplier estimates that its annual demand for the item is 936 units, its ordering cost is $45 per order, and its annual holding cost is 25 percent of the item's unit price. What quantity of the item should the company order to minimize total Costs?

Solution

Step 1: Find the first feasible EOQ, starting -with the lowest price level:

EOQ ($57.00) = $\{(2DS)/(H)\}^{1/2}$ = $\{\{2*936*45)/ (0.25*57)\}^{1/2}$ = 77 units

A 77-unit order actually costs $60.00 per unit, instead of the $57 per unit used in the EOQ calculation, so this EOQ is not feasible. Now,

EOQ ($58.80) = $\{(2DS)/(H)\}^{1/2}$ - $f(2*93b*45)/ (0.25*58.80)\}^{1/2}$ = 76 units

This quantity also is infeasible because a 76-unit order actually costs $60.00 per unit. So, try the highest price level:

EOQ ($60.00) = $f(2DS)/(H)\}^{1/2}$ = $((2*936*45)/ (0.25*60.00)\}^{1/2}$ = 75 units

This quantity is feasible, because it lies in the range corresponding to its price, P = $60.00

Step 2: The first feasible EOQ of 75 does not correspond to the lowest price level.

Hence, we must compare its total cost with the price break quantities (300 and 500 units) at the lower price levels ($58.80 and &57.00):

C = (Q/2) (H) + (D/Q) (S) + PD

C (75) = (75/2) (0.25*60.00) + (936/75) (4S) + 60*936 = $57,284 C (300) = (300/2) (0.25*58.80) + (936/300) (45) + 58.80*936 = $57,382 C (500) = (500/2) (0.25*57.00) + (936/500) (45) + 57*936 = $56,999

The best purchase quantity is 500 units, which qualifies for the deepest discount.

7.5 INVENTORY CONTROL SYSTEMS

The EOQ and other lot-sizing methods answer the important question: How much to order? An inventory control system also answers the question: When to place an order? In selecting an inventory control system for a particular application, the nature of the demands imposed on the inventory items is crucial. An important distinction between types of inventories is whether an item is subject to dependent or independent demand. This chapter discusses inventory control systems for independent demand items which is influenced by market conditions and is not related to the inventory decisions for any other item held in stock. The two inventory control systems: continuous review system and the periodic review system have been discussed below.

7.6.1 Continuous Review (Q) System

This system also known as fixed order-quantity system, tracks the remaining inventory of an item each time a withdrawal is made to determine whether it is time to reorder. In practice, these reviews are done frequently and often continuously (after each withdrawal). At each review a decision is made about an item's inventory position. When the inventory position reaches a predetermined minimum level, called the reorder point (R)> a fixed quantity Q of the item is ordered. In a continuous review system, although the order quantity Q is fixed, the time between orders can vary.

7.6.1.1 When demand is certain:

Suppose that the demand for cards at a gift shop is always 18 per week, the lead time is constant two weeks and the supplier always ships on time the exact amount ordered. With both demand and lead time certain, the buyer can wait until the inventory drops to 36 units, to place a new order. Thus, in this case, the reorder point,

R = demand during lead time,
with no added allowance for safety stock.

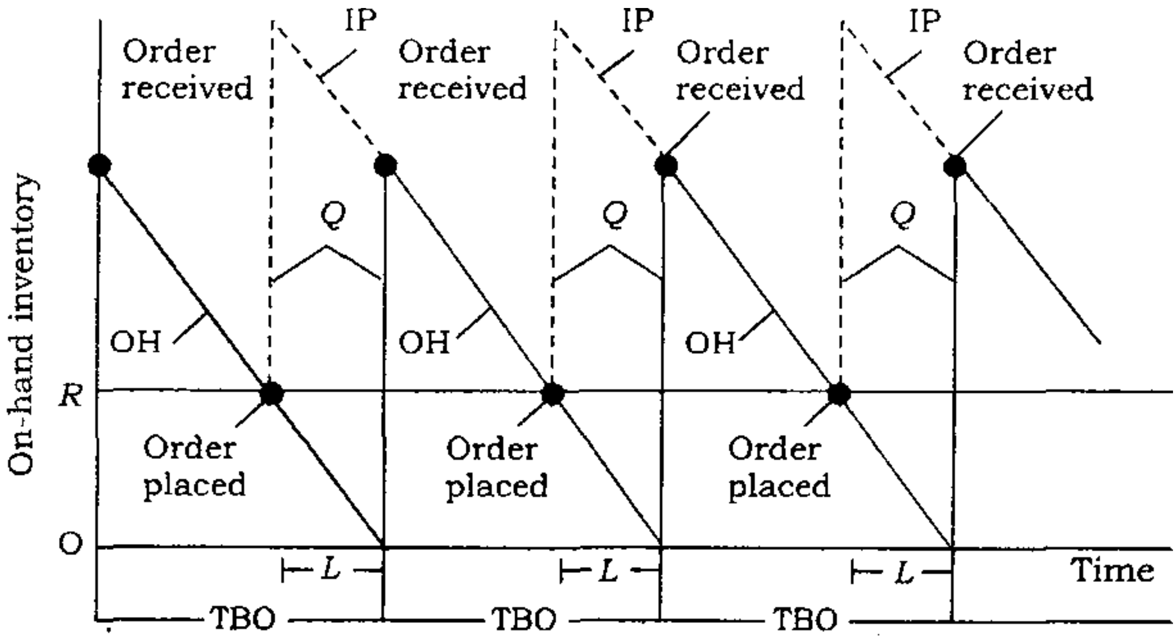


Figure 7.5

The Figure 8.3 shows how the system operates when demand and lead time are constant. The downward sloping line represents the on-hand inventory which is being depleted at a constant rate. When it reaches reorder point R, a new order for Q units is placed. The on-hand inventory continues to drop throughout lead time L until the order is received. At that time, which marks the end of the lead time, on-hand inventory jumps by Q units. A new order arrives just when inventory drops to zero. The time between orders (TBO) is the same for each cycle. The inventory position, IP, shown in the Figure 8.3 corresponds to the on-hand inventory, except during the lead time. Just after a new order is placed, at the start of the lead time, IP increases by Q, as shown in the dashed line.

7.6.1.2 When demand is uncertain

In reality, demand and lead times are not always predictable. For instance, the buyer of gift shop knows that average demand is cards per week and that the average lead time is two weeks i.e. a variable number of cards may be purchased during the lead time, with an average demand during lead time of 36 cards. This situation gives rise to the need for safety stocks. Suppose that reorder point R is set at 46 units, thereby placing orders before they are needed. This approach will create a safety stock, or stock held in excess of expected demand of 10 units to buffer against uncertain demand. Thus,

Reorder point = Average demand during lead time + Safety stock

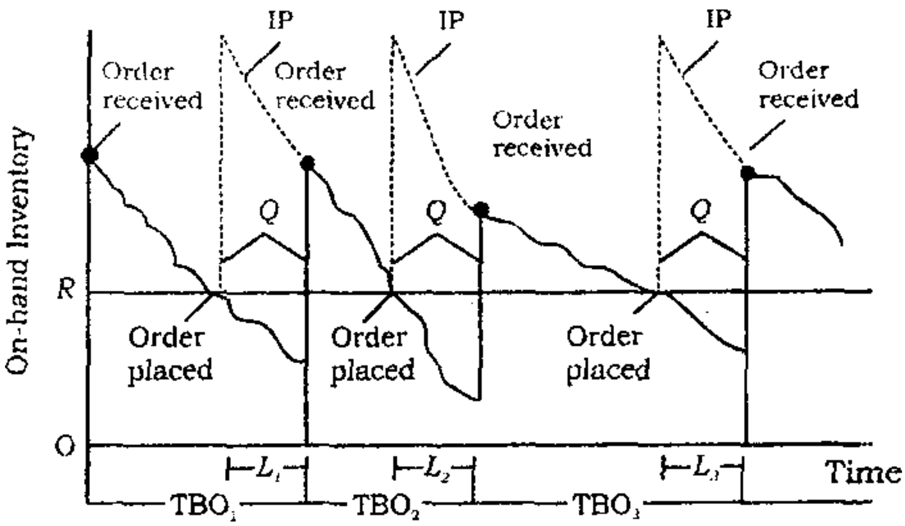


Figure 7.6

Figure 7.6 shows how the Q system operates when demand is variable and uncertain. The wavy downward-sloping line indicates that demand varies from day to day. The changing demand rate means that the time between orders changes so TB0l? TB02? TB03. Because of uncertain demand sales during lead time are unpredictable, and safety stock is added to hedge against lost sales. It explains why on-hand inventory usually does not drop to zero by the time replenishment arrives. The greater the safety stock, and thus the higher the reorder point R, the less likely a stockout.

7.6.1.3 Advantages of Continuous Review (Q) System

- The review frequency of each item may be individualized. Tailoring the review frequency to the item can reduce total ordering and holding costs.

- Fixed lot sizes, if large enough, may result in quantity discounts.
- Lower safety stocks result in savings.

7.6.1.4 Two-Bin System

The concept of Q system can be incorporated in a visual system i.e., a system that allows employees to place orders when inventory visibly reaches a certain marker. A visual system version of the Q system is the two-bin system in which an item's inventory is stored at two different locations. Inventory is first withdrawn from one bin. If the first bin is empty, the second bin provides backup to cover demand until a replenishment order arrives. An empty first bin signals the need to place a new order. When the new order arrives, the second bin is restored to its normal level and the rest is put in the first bin. The two-bin system operates like a Q system, with the normal level in the second bin being the reorder point R.

7.6.2 Periodic Review (P) System

In this system, also known as fixed interval reorder system, an item's inventory position is reviewed periodically rather than continuously. A new order is always placed at the end of each review, and the time between orders (TBO) is fixed. Demand being a random variable, varies between reviews. In this system, the lot size Q may change from one order to the next but the time between orders is fixed. For example, a soft drink supplier making weekly rounds of grocery stores. Each week, the supplier reviews the store's inventory of soft drinks and restocks the store with enough items to meet demand and safety stock requirements until the next week. The assumptions of periodic review system are as:

- no constraints on the size of the lot
- holding and ordering costs are the only relevant costs
- decisions of one item are independent of decisions for other items
- there is no uncertainty in lead times or supply.

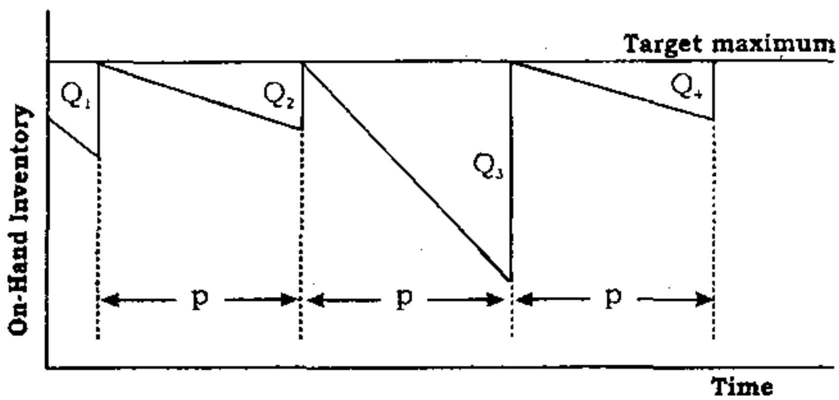


Figure 7.7

Figure 7.7 shows the periodic review system when demand is uncertain. The downward-sloping line represents on-hand inventory. When the predetermined time, P, has elapsed since last review an order is placed to bring the inventory position, up to target inventory level. The lot size for the first review is Ql, for second review is Q2 and for third review the lot size is Q3. Figure 7.7 shows that lot sizes vary from one order cycle to the next. Because the inventory position is lower at the third review, a greater quantity is needed to achieve the target inventory level.

7.6.2.1 Advantages of Periodic Review (P) System:

- Administration of the system is convenient because replenishments are made at fixed intervals. Fixed replenishment intervals also allow for standardized pickup and delivery times.
- Orders for multiple items from the same supplier may be combined into a single purchase order. This approach reduces ordering and transportation costs.
- The inventory position needs to be known only when a review is made whereas in Q system it is to be known continuously.

SELF CHECK EXERCISE Ⅱ

4. According to the Continuous Review (Q) system, at which point, a fixed quantity of the item is ordered?

5. Periodic Review System (P) is also known as__________.

7.6.3 Probabilistic Inventory Control Models

One of the dilemmas facing retailers is how to handle seasonal goods such as winter coats. Often, they can't be sold at full markup next year because of changes in styles. Furthermore, the lead time can be longer than the selling Season, allowing no second chance to rush through another order to cover unexpectedly high demand. This type of situation is often called the newsboy problem. If the newspaper seller does not buy enough papers to resell on the street corner, sales opportunities are lost. If the seller buys too many, the overage cannot be sold because nobody wants yesterday's newspaper.

The following process is a straightforward way to analyze such problems and decide on the best order quantity.

1. List the different levels of demand that are possible, along with the estimated probability of each.
2. Develop a payoff table that shows the profit for each purchase quantity, Q, at each assumed demand level, D. each row in the table represents a different order quantity and each column represents a different demand level. The payoff for a given quantity-demand combination depends on whether all units are sold at the regular profit margin during the regular season. There are two possible cases:
   (a) If demand is high enough (Q<=D) that all units are sold at the full profit margin, *p*, during the regular season,
   Payoff = (profit per unit) (purchase quantity)
   = PQ
   (b) If the purchase quantity exceeds the demand (Q>D), only D units are sold at the full profit margin, and the remaining units purchased must be disposed of at a loss, 1, after the season. In this case,
   Payoff = (profit per unit sold during season) (demand) - (loss per unit) (amount disposed of after season)
   = pD - I(Q-D)
3. Calculate the expected payoff for each Q by using the expected value decision rule. For a specific Q, first multiply each payoff in the row by the demand probability associated and then add these products.
4. Choose the order quantity Q with the highest expected payoff.

Example

Swell Productions is sponsoring an outdoor conclave for owners of collectible and classic Fords. The concession stand will sell T-shirts and other souvenirs of the 1950s. These T-shorts are bought from a company for $40 each and are sold during the event for & 75 each. If any T-shirts are leftover, they can be returned to the company for a refund of $30 each. The following table shows the probability of various sales quantities. How many T- shirts should Swell order from the company for the event?

Sales Quantity	Probability
100	0.05
200	0.11
300	0.34
400	0.34
500	0.11
600	0.05

Solution

The payoff table is shown below. The upper-right portion of the table shows the payoffs when the demand D is greater than or equal to the order quantity Q. For example, when the order quantity is 100 and the demand is 200,

Payoff = (75-40) *100 = $3500 The lower left portion of the payoff table shows the payoffs when the order quantity exceeds the demand. For, example when the order quantity is 500 and the demand is 200 Payoff = (75-40) * 200 - (40 - 30) * (500-200) =■ $4,000

Demand							
Q	**100**	**200**	**300**	**400**	**500**	**600**	**Expected payoff**
100	3500	3500	3500	3500	3500	3500	3500
200	2500	7000	7000	7000	7000	7000	6775
300	1500	6000	10500	10500	10500	10500	9555
400	500	5000	9500	14000	14000	14000	10805
500	500	4000	8500	13000	17500	17500	10525
600	1500	3000	7500	12000	16500	21000	9750
Probability	0.05	0.11	0.34	0.34	0.11	0.05	

The highest expected payoff occurs when 400 T-shirts are ordered:

Expected payoff = 500 * 0.05 + 5000 * 0.11 + 9500 * 0.34 + 14000 * 0.34 + 14000 * 0.05 « $10,805

7.7 SUMMARY

The chapter discusses Economic Order Quantity (EOQ) models for inventory management, covering both graphical and algebraic methods. It introduces EOQ models for fixed and uncertain demand, including scenarios with permitted shortages. The production models, quantity discounts, and inventory control systems (continuous and periodic review) are also explained. The chapter concludes with probabilistic inventory control models, illustrated with the newsboy problem.

7.8 KEYWORDS

Economic Order Quantity, Quantity Discounts, Inventory Control Systems

7.9 EXERCISES

7.9.1 SHORT QUESTIONS

1. Explain the concept of Economic Order Quantity.
2. Explain EPQ Model.
3. What are Quantity Discounts**.**
4. Explain Inventory Control System

7.9.2 LONG QUESTIONS

1. Yellow Press Inc., buys slick paper in 1500-pound rolls for textbook printing. Annual demand is 2500 rolls. The cost per roll is $800 and the annual holding cost is 15 percent of the cost. Each order costs $50.
   (a) How many rolls should the company order at a time?
   (b) What is the time between orders?
2. A company buys 400 blank cassette tapes per month for use in producing foreign film course. The ordering cost is $12.50. Holding cost is $0.12 per cassette per year.
   (a) How many rolls should the company order at a time?
   (b) What is the time between orders?
3. The demand of books at a large retailer is constant at 32,000 books per year. The cost of placing an order to replenish stock is $10, and the annual cost of holding is $4 per book. Stock is received 5 working days after an order has been placed. Assume 300 working days a year.
   (a) What is the retailer's optimal ordering quantity?
   (b) What is the optimal number of orders per year?
   (c) What is demand during lead time?
   (d) What is the reorder point?

7.10 ANSWERS TO SELF CHECK EXERCISE

1.Economic Order Quantity, 2. F. Harries, 3. D is the annual demand, C_0 is the ordering cost, and Cc is the carrying cost. 4. At Reorder point, 5. Fixed interval order system.

7.11 SUGGESTED READINGS

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MBA-DE(Second Year) **IM 311**
Semester-Ill **INVENTORY MANAGEMENT**
Lesson No. 8 **AUTHOR: DR. DYAL BHATNAGAR**

INVENTORY CHECKING AND ACCOUNTING

STRUCTURE

8.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the fundamentals of inventory accounting
- Learn various methods of accounting for inventory
- Understand the concept and ways of physical inventory verification.

8.1 INTRODUCTION

There are three basic reasons for keeping an inventory:

1. Time: The time lags present in the supply chain, from supplier to user at every stage, requires that you maintain certain amount of inventory to use in this "lead time"
2. Uncertainty: Inventories are maintained as buffers to meet uncertainties in demand, supply and movements of goods.
3. Economies of scale: Ideal condition of "one unit at a time at a place where user needs it, when he needs it" principle tends to incur lots of costs in terms of logistics. So bulk buying, movement and storing brings in economies of scale, thus inventory.

8.2 HIGH LEVEL INVENTORY MANAGEMENT

It seems that around about 1880 there was a change in manufacturing practice from companies with relatively homogeneous lines of products to vertically integrated companies with unprecedented diversity in processes and products. Those companies (especially in metalworking) attempted to achieve success through economies of scope - the gains of jointly producing two or more products in one facility. The managers now needed information on the effect of product mix decisions on overall profits and therefore needed accurate product cost information. A variety of attempts to achieve this were unsuccessful due to the huge overhead of the information processing of the time. However, the burgeoning need for financial reporting after 1900 created unavoidable pressure for financial accounting of stock and the management need to cost manage products became overshadowed. In particular it was the need for audited accounts that sealed the fate of managerial cost accounting. The dominance of financial reporting accounting over management accounting remains to this day with few exceptions and the financial reporting definitions of 'cost' have distorted effective management 'cost' accounting since that time. This is particularly true of inventory.

Hence high-level financial inventory has these two basic formulas which relate to the accounting period:

1. **Cost of Goods**= Cost of Beginning Inventory at the start of the period + inventory purchases within the period + cost of production within the period

2. **Cost of Goods Sold**=Cost of goods ─ Cost of ending inventory at the end of the period

The benefit of these formulae is that the first absorbs all overheads of production and raw material costs in to a value of inventory for reporting. The second formula then creates the new start point for the next period and gives a figure to be subtracted from sales price to determine some form of sales margin figure.

Manufacturing management is more interested in inventory turnover ratio or average days to sell inventory since it tells them something about relative inventory levels.

Inventory turnover ratio(also known as inventory turns) = cost of goods sold / Average Inventory = Cost of Goods Sold / ((Beginning Inventory + Ending Inventory) / 2) and its inverse

Average Days to SellInventory= Number of Days a Year / Inventory Turnover Ratio = 365 days a year / Inventory Turnover Ratio

This ratio estimates how many times the inventory turns over a year. This number tells us how much cash/goods are tied up waiting for the process and is a critical measure of process reliability and effectiveness. So, a factory with two inventory turns has six months stock on hand which generally not a good figure (depending upon industry) whereas a factory that moves from six turns to twelve turns has probably improved effectiveness by 100%. This improvement will have some negative results in the financial reporting since the ’value' now stored in the factory as inventory is reduced.

Whilst the simplicity of these accounting measures of inventory are very useful, they are in the end fraught with the danger of their own assumptions. There are in fact so many things which can vary hidden under this appearance of simplicity that a variety of ’adjusting' assumptions may be used. These include:

8.2.1 ASSUMPTIONS

1. **Specific identification**is a method of finding out ending inventory cost. It requires a very detailed physical count, so that the company knows exactly how many of each goods brought on specific dates remained at year-end inventory. When this information is found

the amount of goods are multiplied by their purchase cost at their purchase date, to get a number for the ending inventory cost.

On theory, this method is the best method, since it relates the ending inventory goods directly to the specific price they were brought. However, this method allows management to easily manipulate ending inventory cost, since they can choose to report that the cheaper goods were sold first, hence increasing ending inventory cost and lowering Cost of Goods Sold. This will increase the income. Alternatively, management can choose to report lower income, to reduce the taxes they needed to pay.

2. **Weighted average cost**is a method of calculating Ending Inventory cost. It takes Cost of Goods Available for Sale and divides it by the total amount of goods from Beginning Inventory and Purchases. This gives a Weighted Average Cost per Unit. A physical count is then performed on the ending inventory to determine the amount of goods left. Finally, this amount is multiplied by Weighted Average Cost per Unit to give an estimate of ending inventory cost.
3. **Moving-average cost**is a method of calculating Ending Inventory cost. Assume that both Beginning Inventory and beginning inventory cost are known. From them the Cost per Unit of Beginning Inventory can be calculated. During the year, multiple purchases were made. Each time, purchase costs Eire added to beginning inventory cost to get Cost of Current Inventory. Similarly, the number of units bought is added to beginning inventory to get Current Goods Available for Sale. After each purchase. Cost of Current Inventory is divided by Current Goods Available for Sale to get Current Cost per Unit on Goods. Also during the year, multiple sales happened. The Current Goods Available for Sale is deducted by the amount of goods sold, and the Cost of Current Inventory is deducted by the amount of goods sold times the latest (before this sale) Current Cost per Unit on Goods. This deducted amount is added to Cost of Goods Sold. At the end of the year, the last Cost per Unit on Goods, along with a physical count, is used to determine ending inventory cost.
4. **FIFO and LIFO accounting methods**are means of managing inventory and financial matters involving the money a company ties up within inventory of produced goods, raw materials, parts, components, or feed stocks. FIFO stands for first-in, first-out, meaning that the oldest inventory items are recorded as sold first. LIFO stands for last-in, first-out, meaning that the most recently purchased items are recorded as sold first. Since the 1970s, U.S. companies have tended to use LIFO, which reduces their income taxes in times of inflation.

8.3 ACCOUNTING FOR INVENTORY

The internal costing/valuation of inventory can be complex. Whereas in the past most enterprises ran simple one process factories, this is quite probably in the minority in the 21st century. Where ’one process' factories exist then there is a market for the goods created which establishes an independent market value for the good. Today with multi-stage process companies there is much inventory that would once have been finished goods which is now held as 'work-in-process' (WIP). This needs to be valued in the accounts but the valuation is a management decision since there is no market for the partially finished product. This somewhat arbitrary 'valuation' of WIP combined with the allocation of overheads to it has led to some unintended and undesirable results.

8.3.1 THE BASIS OF INVENTORY ACCOUNTING

Inventory needs to be accounted where it is held across accounting period boundaries since generally expenses should be matched against the results of that expense within the same period. When processes were simple and short then inventories were small but with more complex processes then inventories became larger and significant valued items on the balance sheet. This needs to value unsold and incomplete goods has driven many new behaviours into management practise. Perhaps most significant of these are the complexities of fixed cost recovery, transfer pricing, and the separation of direct from indirect costs. This, supposedly, precluded "anticipating income" or "declaring dividends out of capital".

8.3.2 FINANCIAL ACCOUNTING

An organization's inventory can appear a mixed blessing, since it counts as an asset on the balance sheet, but it also ties up money that could serve for other purposes and requires additional expense for its protection. Inventory may also cause significant tax expenses, depending on particular countries' laws regarding depreciation of inventory.

Inventory appears as a current asset on an organization's balance sheet because the organization can, in principle, turn it into cash by selling it. Some organizations hold larger inventories than their operations require in order to inflate their apparent asset value and their perceived profitability.

In addition to the money tied up by acquiring inventory, inventory also brings associated costs for warehouse space, for utilities, and for insurance to cover staff to handle and protect it, fire and other disasters, obsolescence, shrinkage (theft and errors), and others. Such holding costs can mount up: between a third and a half of its acquisition value per year.

Businesses that stock too little inventory cannot take advantage of large orders from customers if they cannot deliver. The conflicting objectives of cost control and customer service often pit an organization's financial and operating managers against its sales and marketing departments. Sales people, in particular, often receive sales commission payments, so unavailable goods may reduce their potential personal income. This conflict can be minimised by reducing production time to being near or less than customer expected delivery time. This effort, known as "Lean production" will significantly reduce working capital tied up in inventory and reduce manufacturing costs.

8.3.3 STANDARD COST ACCOUNTING

Standard cost accounting uses ratios called efficiencies that compare the labour and materials actually used to produce a good with those that the same goods would have required under ''standard" conditions. As long as similar actual and standard conditions obtain, few problems arise. Unfortunately, standard cost accounting methods developed about 100 years ago, when labor comprised the most important cost in manufactured goods. Standard methods continue to emphasize labor efficiency even though that resource now constitutes a (very) small part of cost in most cases.

Standard cost accounting can hurt managers, workers, and firms in several ways. For example, a policy decision to increase inventory can harm a manufacturing managers' performance evaluation. Increasing inventory requires increased production, which means that processes must operate at higher rates. When (not if) something goes wrong, the process takes longer and uses more than the standard labor time. The manager appears responsible for the excess, even though she/he has no control over the production requirement or the problem.

In adverse economic times, firms use the same efficiencies to downsize, right size, or otherwise reduce their labor force. Workers laid off under those circumstances have even less control over excess inventory and cost efficiencies than their managers.

Many financial and cost accountants have agreed for many years on the desirability of replacing standard cost accounting. They have not, however, found a successor.

SELF-CHECK EXERCISE – I

1. What is the method in which cost of goods available for sale is taken and divided by the total amount of goods from beginning inventory and purchases?
2. ________ accounting uses ratios called efficiencies that compare the labour and materials used to produce a good with those that the same goods would have required under 'standard' conditions.

8.4 FIFO AND LIFO ACCOUNTING

8.4.1 LIFO ACCOUNTING

LIFO is an acronym for "last in, first out." (Sometimes the term FILO {"first in, last out"} is used synonymously.) In LIFO accounting, a historical method of recording the value of inventory, a firm records the last units purchased as the first units sold. LIFO accounting is in contrast to the method FIFO accounting covered below.

Since prices generally rise over time because of inflation, this method records the sale of the most expensive inventory first and thereby decreases profit and reduces taxes. However, this method rarely reflects the physical flow of indistinguishable items.

LIFO valuation is permitted in the belief that an ongoing business does not realize an economic profit solely from inflation. When prices are increasing, they must replace inventory currently being sold with higher priced goods. LIFO better matches current cost against current revenue. It also defers paying taxes on phantom income arising solely from inflation. LIFO is attractive to business in that it delays a major detrimental effect of inflation, namely higher taxes. However, in a very long run, both methods converge.

8.4.2 FIFO ACCOUNTING

FIFO accounting is a common method for recording the value of inventory. It is appropriate where there are many different batches of similar products. The method presumes that the next item to be shipped will be the oldest of that type in the warehouse. In practice, this usually reflects the underlying commercial substance of the transaction, since many companies rotate their inventory (especially of perishable goods). This is still not in contrast to LIFO because FIFO and LIFO are cost flow assumptions not product flow assumptions.

In an economy of rising prices (during inflation), it is common for beginning companies to use FIFO for reporting the value of merchandise to bolster their balance sheet. As the older and cheaper goods are sold, the newer and more expensive goods remain as assets on the company's books. Having the higher valued inventory and the lower cost of goods sold on the company's financial statements may increase the chances of getting a loan. However, as it prospers the company may switch to LIFO to reduce the amount of taxes it pays to the government.

8.4.3 LIFO LIQUIDATION

Notwithstanding its deferred tax advantage, a LIFO inventory system can lead to LIFO liquidation, a situation where in the absence of new replacement inventory or a search for increased profits, older inventory is increasingly liquidated (or sold). If prices have been rising, for example through inflation, this older inventory will have a lower cost, and its liquidation will lead to the recognition of higher net income and the payment of higher taxes, thus reversing the deferred tax advantage that initially encouraged the adoption of a LIFO system.

Some companies who use LIFO have decades-old inventory recorded on their books at a very low cost. For these companies a LIFO liquidation would result in an inflated net income and higher tax payments. This situation is usually undesirable; on rare occasions a company in financial stress could abuse this method to temporarily increase income.

8.4.4 AVERAGE COSTING

Under the average-cost method, it is assumed that the cost of inventory is based on the average cost of the goods available for sale during the period. Average cost is computed by dividing the total cost of goods available for sale by the total units available for sale. This gives a weighted-average unit cost that is applied to the units in the ending inventory.

Average-Cost Method Illustration

Date	Transaction	Number of Items	Unit Cost	Total Coat
June 1	Beginning Inventory	50	1.00	50.00
June 6	Purchased	50	1.10	55.00
June 13	Purchased	150	1.20	180.00
June 20	Purchased	100	1.30	130.00
June 25	Purchased	150	1.40	210.00
	Total	**800**		**625.00**

Average Unit cost: Rs.625/500 = Rs.1.25

Ending inventory: 220 units @ Rs.1.25 = Rs.275

Cost of Goods Available for SaleRs.625

Less: June 30 InventoryRs.275

Cost of Goods SoldRs.350

The average-cost method tends to level out the effects of cost increases and decreases because the cost for the ending inventory calculated under the method is influenced by all the prices paid during the year and by the beginning inventory price. The criticism for this method is that the more recent costs are more relevant for income measurement and decision-making.

8.4.5 DISTINCTION BETWEEN LIFO AND FIFO

The LIFO method of inventory costing uses both unit-base and cost-base methods of inventory valuation, in which the latest unit acquisition cost is matched with current sales revenue. Therefore, under LIFO, the order of cost outflow recognized is the inverse of the order of cost inflow. The units remaining in ending inventory are costed at the oldest unit costs available; the units in cost of sales are costed at the most recent unit costs available.

Company administrators who have elected to use the LIFO approach generally believe that costs will either remain stable or increase. Companies that commonly use the LIFO valuation approach are those whose costs predominantly increase each year and whose inventory is generally quite large.

It is often desirable for a company to use LIFO for tax purposes to obtain a cash flow advantage (resulting from decreased tax payments) when inventory costs are rising. However, owing to a congressional income tax rule, a company that adopts the LIFO valuation method for income tax purposes also automatically adopts LIFO for financial reporting purposes.

Therefore, accounting for inventory under LIFO includes complexities relating to federal tax regulations. And it may reflect less favorable financial results owing to earnings reductions and negative effects on the balance sheet as a company reports its financial position.

The LIFO costing method contrasts with the first in, first out (FIFO) inventory method, which assumes that the cost of items sold in a period reflects the oldest cost in inventory just before sale. As a consequence, remaining inventory valued at FIFO more closely represents current or replacement cost.

As a practical matter, FIFO more closely depicts the physical movement of goods. Companies generally use the oldest items in inventory first so they can continually roll the stock and prevent deterioration or obsolescence. In times of stable prices, FIFO has been widely used and accepted.

However, in an inflationary environment, FIFO results in "inventory profits"—profits that arise merely from holding inventory—and fails to provide the best matching of costs and revenues.

Comparability

The financial statements of a company using the LIFO approach as opposed to FIFO generally reflect:

- Conservative profits, because LIFO buffers the effects of inflation.
- Better matching of current costs with current revenues.
- Lower liquidity, that is, a lower current ratio.
- Lower equity position, that is, a higher debt-to-worth ratio.

To clarify the primary differences between LIFO and FIFO, consider the hypothetical example of the ABC Company:

ABC produces gadgets that sell for Rs. 1,000 each. At start-up, ABC's cost to produce each gadget was Rs.500. During the year, ABC sold 10 gadgets for a total of Rs. 10,000 (10 at Rs. 1,000 per gadget). As ABC replenished its inventory, inflation increased the production cost to Rs.600 per gadget. Total cost to ABC to replenish the inventory was Rs.6,000 (10 at Rs.600 per gadget).

ABC uses the FIFO evaluation method, and it is assumed that the cost of each gadget produced will be Rs.500 (oldest cost). Conversely, if ABC were to use the LIFO valuation method, each gadget's production cost would be Rs.600 (most recent cost). The effect of each valuation method is shown as follows:

	LIFO	**FIFO**
Sales	Rs. 10,000	Rs. 10,000
Cost of sales	(6,000)	(5,000)
Gross profit	4,000	5,000
Operating expenses	(1,500)	(1,500)
Income before taxes	2,500	3,500
Taxes *	(875)	(1,225)
Net income	1,625	2,275

* An assumed 35% income tax rate.

The gross profit differential between the LIFO and FIFO approaches is Rs. 1,000. The difference can be attributed to the increased cost of sales (10 at Rs.100 per gadget), resulting in illusory inventory profits when FIFO is used to value ending inventory.

As a result of ABC's replenishing its inventory at the higher cost, the Rs.1000 of "inventory profits" under FIFO would not be available for stockholder distribution. Under LIFO, current costs are matched against sales, and therefore inventory profits are not recorded.

The cash flow effect. If ABC were to use LIFO as opposed to FIFO, the cash flow effect would be as shown:

	LIFO	**FIFO**
Cash from gadgetsales Cost	Rs.10,000	Rs.10,000
of new inventory Operating	**(6,000)**	(6,000)
expenses Income taxes	(1,500)	(1,500)
Net income	(875)	(1,225)
	1,625	2,275

Owing to reduced taxes under the LIFO method, greater cash flow results. With lower taxes, ABC has increased amounts of cash for operations, which in turn reduces the need to borrow and incur additional financing costs.

8.4.6 LIFO ADVANTAGES AND DISADVANTAGES

The LIFO valuation method has certain advantages, namely elimination of inventory profits, reduction of federal income taxes, and improved cash flow. Likewise, it has disadvantages:

- LIFO cost could exceed market value if costs were to decline.
- The LIFO valuation method is complex and costly to apply.
- LIFO distorts crucial ratios, such as the current and debt-to-worth ratios and inventory turnover.
- LIFO is an end-of-year calculation. Therefore, reliability of interim statements is questionable because a company must forecast prices for the remaining accounting year and estimate year-end inventory quantities.
- Balance sheet inventory is costed at noncurrent unit costs.

The LIFO inventory valuation methods can have a dramatic impact on financial reports. Therefore, LIFO must be recognized and the necessary adjustments made to applicable financial reports to achieve valid credit analysis conclusions. FIFO tends to be a complex technique, and therefore it requires a great deal of study and understanding.

8.5 INVENTORY CHECKING AND VERIFICATION

1. **Physical verification:**Control over inventory is exercised through a series of reports and records that provide information on recipes, usages and balances. For this, there is the necessity to ensure against embezzlement, spoilage, damage, obsolescence and errors. It is necessary, therefore, that inventories must be physically verified with records, which may be done by an agency having no interest in the actual operation of stores.
2. **Periodic verification:**The inventory records may be manually posted, machine operated or fully Computerized. But due to the possibilities of errors, there should be a thorough verification of accuracy of the records with physical balance. This is done over a short time, say, once during a year which coincides with the financial year or on a half yearly basis, when actual counting is done for all inventories to check that they are physically correct as per records. If any discrepancy is found, big or small, the causes must be investigated and the records reconciled.
3. **Continuous verification:** This method requires continuous stock taking during the whole year. A limited number of items are checked every day or at specific time intervals. The

items may be selected at random or on a pre-planned basis. The cycle continues for the whole year and it does not necessitate stoppage of work, or operation of the stores. This also acts as a deterrent to personal working in the stores which ensures the records integrity. It pre supposes that perpetual inventory records be maintained so that reconciliation may be done easily.

8.6 PRACTICE QUESTION

Mr. Ram began a business of buying and selling shirts at the beginning of Year 1. During the year he bought 1,000 shirts at Rs.10 each and sold 900 shirts for Rs. 15 each.

*Note****: When Mr. Ram buys these shirts, he is not allowed to claim a deduction, even though he is selling shirts at the same time. Instead, their cost is treated as a "cost" and added to the inventory account, which is a type of capital account.***

At the end of the year, Mr. Ram counts the shirts on hand. If there has been no pilferage or other loss, he will have 100 shirts on hand. To summarize, his opening inventory {at the beginning of the year) is 0; his purchases are 1,000 shirts at Rs.10 each, for a total of Rs. 10,000; his closing inventory is 100 shirts at Rs.10 each, or Rs. 1,000; so, his cost of goods sold is Rs.9 000. At the beginning of Year 2, Mr. Ram's opening inventory is 100 shirts at Rs. 10 each, or Rs. 1,000. Suppose that during the year Mr. Ram buys 1,000 shirts at Rs. 11 each and sells 1,000 shirts at Rs. 16 each. At the end of the year, Mr. Ram counts the shirts on hand. Again, assume no losses, so there are 100 shirts on hand.

*Note****: If Mr. Ram identifies each shirt on hand and*** its ***cost, that cost is used. (Or the lower market price is used if he uses lower of cost or market and the market price has in fact fallen.)***

If he cannot identify which shirts were bought when, he may use either LIFO or FIFO to figure out the value of the inventory on hand. The results are set forth below.

*Note****: If there had been pilferage, the number of shirts on hand would be reduced, so the cost of goods sold figure would increase. The result would be a deduction for the cost of the pilfered shirts*** in ***the year stolen.***

Purchase and Sale of Shirts

Year 1: Shirt Business

1	Beginning number of shirts	0
2	Shirts bought	1,000
3	Cost per unit	Rs.10
4	Total cost (line 2 × line 3)	Rs. 10,000
5	Number sold	900
6	On hand at end of year (by count)	100
7	Closing inventory (line 6 × line 3)	Rs. 1,000
8	Cost of goods sold (line 4 - line 7)	Rs.9,000
9	Sales (Rs.15 × line 5)	Rs. 13,500
10	Profits (line 9 - line 8)	Rs.4,500

*Note****: Under these facts, it does not matter in the first year whether we use LIFO or FIFO because there was only one purchase of shirts - that is, the last purchase and the first purchase are the same.***

How the accounting of inventory will be carried out under FIFO and LIFO inventory systems in the year 2? What will be the effect of these systems on the profit figure?

Solution:

Tear 2: Shirt business

		LIFO	FIFO
1	Beginning number of shirts	100	100
2	Cost per unit	Rs.10	Rs.10
3	Total cost, opening	Rs. 1,000	Rs. 1,000
4	Shirts bought (no. of units)	1,000	1,000
5	Cost per unit	Rs.11	Rs.11
6	Total cost of purchases (line 4 × line 5)	Rs. 11,000	Rs.11,000
7	Total cost, beginning and purchased (line 3 + line 6)	Rs. 12,000	Rs. 12,000
8	Ending number of shirts	100	100
9	Ending cost per unit	Rs.10	Rs.11
10	Ending total value	Rs. 1,000	Rs. 1,100
11	Cost of goods sold (line 7 - line 10)	Rs. 11,000	Rs. 10,900
12	Sales	Rs. 16,000	Rs. 16,000
13	Profits	Rs.5,000	Rs.5,100

Note: The profits under FIFO are higher because FIFO assumes that the higher-priced shirts ***bought in year 1 remain on hand, whereas LIFO assumes that the lower-priced shirts bought*** m ***year 1 remain on hand. Certain expenses may be deductible from profits in calculating taxable income, but these deductions are independent of the choice of FIFO or LIFO.***

SELF-CHECK EXERCISE – II

3. ________ is a historical method of recording the value of inventory, a firm records the last units purchased as the first units sold.

4. What do we call a situation where in the absence of new replacement inventory or a search for increased profits, older inventory in increasingly liquidated?

8.7 GLOSSARY

- **LIFO Accounting**: It is a historical method of recording the value of inventory, where, a firm records the last units purchased as the first units sold
- **FIFO Accounting**: The method presumes that the next item to be recorded will be the oldest of that type in the store.
- **Average-cost method**: Under this method, it is assumed that the cost of inventory is based on the average cost of the goods available for recording during the period.
- **Financial Accounting**: It is the field of accountancy concerned with the preparation of financial statements for decision makers, such as stockholders, suppliers, banks, employees, government agencies, owners, and other stakeholders.
- **Standard Cost Accounting**: It is a method of accounting to control costs, by comparing standard and actual costs, and take corrective action in case of deviation between the two.

8.8 KEYWORDS

Inventory Management, LIFO Accounting, FIFO Accounting, Standard Costing, Average Costing.

8.9 EXERCISES

8.9.1 SHORT QUESTIONS

1. What are the assumptions of High-Level Inventory Management?

2. What is the difference between LIFO and FIFO?

3. What do you mean by LIFO liquidation?
4. Explain the treatment of inventory in financial accounting.

8.9.2 LONG QUESTIONS

1. Elaborate the methods of accounting for inventory.
2. What is the process of FIFO accounting?
3. Explain the process of LIFO accounting in detail.
4. Explain the difference between average costing and standard costing.

8.10 ANSWERS TO SELF-CHECK EXERCISES

1. Weighted Average Cost; 2. Standard Cost; 3. LIFO Accounting; 4. LIFO Liquidation

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MBA-DE(Second Year) **IM 311**
Semester-Ill **INVENTORY MANAGEMENT**
Lesson No. 9 **AUTHOR: DR. DYAL BHATNAGAR**

MATERIAL HANDLING AND WAREHOUSE MANAGEMENT

STRUCTURE

9.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the principles of material handling
- Know about various materials handling equipment.
- Understand the concept of warehouse management system.

9.1 MATERIAL HANDLING

Material Handling is the movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal. The focus is on the methods, mechanical equipment, systems and related controls used to achieve these functions. The material handling industry manufactures and distributes the equipment and services required to implement material handling systems. Material handling systems range from simple pallet rack and shelving projects, to complex conveyor belt and Automated Storage and Retrieval Systems (AS/RS).

Inventory management is responsible for materials flow from the moment a product is conceived or customer order is received till the moment the material reaches the production shop floor and, then again from the time the finished product leaves the production pipeline and is delivered to the ultimate consumer. It, therefore, covers an activity that goes on in a storage place, warehouse or the construction site of a project, where materials and equipment are picked up and moved. This applies equally to raw materials and supplies in process inventories, maintenance and materials for repair operations and equipment and finished goods. In short, every operation requiring raising, lowering or moving an item may be termed as material handling. But movement of materials from one place of operation to another does not add to the value of the material in question and/or perform a value addition operation.

According to the British Institute of Material Handling, inventory management is a broad term covering a wide range of activities but, in general terms, it can be subdivided into two separate but closely interlinked disciplines. - Material Handling Management and Material Handling Technology and Engineering. The former is applied to systems covering such matters as production planning and control, buying, storage and distribution and the second applies to the technological aspects, e.g., technical and mechanical means of handling and movement of a commodity, be it either solid, liquid or gaseous.

9.2 MATERIAL HANDLING SYSTEM

Management strategy is concerned with coordination of the movement and storage of materials and supplies from the acquisition to the distribution of finished products. It pays particular attention to the form in which they are handled and quantities in which they are moved. It also stresses the need for communication and team work between a company's different departments and the line and staff managers who run them. This means that the management of materials handling activities draws upon a whole range of specialist disciplines and responsibilities including mechanical, electrical, hydraulic means and electronic devices as also management and work study.

The other, providing advice to line management, generally the province of the service department, requires a wide range of specialist knowledge particularly in the field of work study and engineering, covering purchase and design, installation and maintenance of material handling equipment and discrete systems.

Between the poles of theses definitions are blurred areas where material handling is envisaged as a management function in its own right, both a 'science' and an 'art'. The lack of credence given to these definitions by managements at large may serve as an indication of their weakness. However, in these blurred areas it becomes increasingly hard to distinguish material handling from materials management, logistic and physical distribution management, etc., and in fact, from the general responsibilities of industrial management. At any rate, it is agreed that material handling is an activity concerned with systems and management of materials through the production/distribution cycle and that the way in which material handling responsibilities are shared between line and staff managers is one of the major problems of industry. However, this depends upon the company strategy.

9.3 BASIC MATERIAL HANDLING PRINCIPLES

While material handling practices vary from industry to industry, the basic principles remain the same and they are as under

1. **Least handling is Best Handling:** It is best to keep the handling cost to the minimum because handling does not add value to the product or material
2. **Standardization of Equipment:** Material handling equipment should be selected in such a manner as to afford flexibility and be capable of performing multiple operations, but standardized. This will result in reduction of cost of operations, maintenance and repair and also costs to storage.
3. **Specialized equipments kept to a minimum:** It may be desirable to have specialized equipments but the first cost, cost of operation maintenance and repair are generally more than those of standardized equipment. Present worth and lifespan value should be evaluated.
4. **Volume dictates the method:** Volumetric consideration determines the method of handling, regardless of size, shape and value. Therefore, the most important criterion is the volume.
5. **Planning ahead:** Simultaneously with other planning activities selection and procurement of material handling equipment should be conducted in advance to

take care of all aspects of handling and storage, particularly of standardized equipment and combining methods.

6. **Length and number of moves:** Movement must be studied in detail to reduce 'back tracking' of materials. The extent of movement must also be studied so as to afford better utilization of men and equipment.
7. **Equipment capacity:** The capacity of rates should be carefully examined and never exceeded, as overloading causes undue wear, entails excessive maintenance and repair cost. It also creates potential accident hazard, violating the safety first principle in material handling.
8. **Analysis of operations:** To determine combination of handling activities, all operations must be analyzed. This will result in simplification and possibly, reduction in handling cost.
9. **Payload:** The selection of equipment must be made after careful consideration of the cost of moving, and economics can be measured by studying the cost of operation involved in handling in each move. The physical state of material is a determining factor in the selection process.
10. **Straight flow line:** The shortest distance between two given points is the straight line. This line provides guidance for the path to follow.
11. **Standardization of methods:**The line, method of picking, carrying and settling down of material varies. This does not call for an analysis like micro-motion analysis, but calls for forming a basis for material handling in the minimum length with the available equipment. When the method is standardized, the time could be fixed and wastage in time, labour and equipment could be eliminated.
12. **Short irregular moves:**Some material handling operations are not repetitive in nature. In such cases, deployment of equipment may be costlier than manpower. If the load capacity does not exceed the manpower, it is economical to use manual labour for short and irregular moves.
13. **Pre-positioning of material:**Wherever, practicable materials (viz. containers after determination of unit-loads) should be moved on a horizontal plane. When loading and unloading, excessive work can be reduced if the work layout is properly planned.
14. **Loading and unloading:** Since a major portion of material handling activity lies in loading and unloading, this function must be given a great deal of attention. Wherever, economical loading, arid unloading should be done mechanical devices such as, industrial trucks, cranes, conveyers, etc. When this principle is followed, not only is the possibility of loss and damage reduced, but accident hazards are also reduced and safety and protection are increased.

A large number of pickups and delivery points will increase loading and unloading requirements affecting manpower and equipment. Therefore, several pickup points should be combined into one central point. Further, by segregating materials at source or destination will eliminate double handling of material.

SELF-CHECK EXERCISE – I

1. The movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal is known as what?

2. Material handling is envisaged as a management function in its own right, both a 'science' and an 'art'. (True or False)

9.4 MATERIAL HANDLING EQUIPMENT

Material handling equipment is all equipment that relates to the movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal.

Material handling equipment is the mechanical equipment involved in the complete system. Material handling equipment is generally separated into four main categories; Storage and Handling Equipment, Engineered Systems, Industrial Trucks and Bulk Material Handling.

9.4.1 WAYS IN WHICH MATERIAL HANDLING EQUIPMENT CAN IMPROVE EFFICIENCY

Material handling equipment is used to increase throughput, control costs, and maximize productivity. There are several ways to determine if the material handling equipment is achieving peak efficiency. These include capturing all relevant data related to the warehouse's operation (such as SKUs), measuring how many times an item is "touched" from the time it is ordered until it leaves the building, making sure you are using the proper picking technology, and keeping system downtime to a minimum.

9.4.2 TYPES OF MATERIAL HANDLING EQUIPMENT

9.4.2.1 Storage and Handling Equipment

Storage and handling equipment is a category within the material handling industry. The equipment that falls under this description is usually non-automated storage equipment. Products such as Pallet rack, shelving, carts, etc. belong to storage and handling. Many of these products are often referred to as "catalog" items because they generally have globally accepted standards and are often sold as stock materials out of Material handling catalogs.

9.4.2.2 Engineered Systems

Engineered systems are typically custom engineered material handling systems. Conveyors, AS/RS, and most other automated material handling systems fall into this category. Engineered systems are often a combination of products integrated to one system. Many distribution centers will optimize storage and picking by utilizing engineered systems such as pick modules and sortation systems.

Equipment and utensils used for processing or otherwise handling edible product or ingredients must be of such material and construction to facilitate thorough cleaning and to ensure that their use will not cause the adulteration of product during processing, handling, or storage. Equipment and utensils must be maintained in sanitary condition so as not to adulterate product.

9.4.2.3 Industrial Trucks

Industrial trucks usually refer to operator driven motorized warehouse vehicles. Industrial trucks assist the material handling system with versatility; they can go where engineered systems cannot. Forklift trucks are the most common example of industrial trucks but certainly aren't the extent of the category. Tow tractors and stock chasers are additional examples of industrial trucks.

9.4.2.4 Bulk Material Handling

Bulk material handling equipment is used to move and store bulk materials such as ore, liquids, and cereals. This equipment is often seen on farms, mines, shipyards and refineries. This category is also explained in Bulk material handling.

9.5 WAREHOUSE MANAGEMENT SYSTEM

A warehouse management system, or WMS, is a key part of the supply chain and primarily aims to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, putaway and picking. The systems also direct and optimize stock putaway based on real-time information about the status of bin utilization.

Warehouse management systems often utilize Auto ID Data Capture (AIDC) technology, such asbarcode scanners, mobile computers, wireless LANs and potentially Radio Frequency Identification (RFID) to efficiently monitor the flow of products. Once data has been collected, there is either a batch synchronization with, or a real-time wireless transmission to a central database. The database can then provide useful reports about the status of goods in the warehouse

The objective of a warehouse management system is to provide a set of computerized procedures to handle the receipt of stock and returns into a warehouse facility, model and manage the logical representation of the physical storage facilities (e.g. racking etc.), manage the stock within the facility and enable a seamless link to order processing and logistics management in order to pick, pack and ship product out of the facility.

Warehouse management systems can be standalone systems, or modules of an ERP system or supply chain execution suite.

The primary purpose of a WMS is to control the movement and storage of materials within a warehouse - you might even describe it as the legs at the end-of-the line which automates the store, traffic and shipping management.

In its simplest form, the WMS can data track products during the production process and act as an interpreter and message buffer between existing ERP and WMS systems. Warehouse Management is not just managing within the boundaries of a warehouse today, it is much wider and goes beyond the physical boundaries. Inventory management,inventory planning, cost management, IT applications & communication technology to be used are all related to warehouse management. The container storage, loading and unloading are also covered by warehouse management today.Warehouse management today is part of SCM and demand management. Even production management is to a great extent dependent on warehouse management. Efficient warehouse management gives a cutting edge to a retail chain distribution company. Warehouse management does not just start with receipt of material but it actually starts with actual initial planning when container design is made for a product. Warehouse design is also part of warehouse management. Warehouse management is part of Logistics and SCM.

Warehouse Management monitors the progress of products through the warehouse. It involves the physical warehouse infrastructure, tracking systems, and communication between product stations.

Warehouse management deals with receipt, storage and movement of goods, normally finished goods, to intermediate storage locations or to final customer. In the multi-echelon model for distribution, there are levels of warehouses, starting with the Central Warehouse(s), regional warehouses services by the central warehouses and retail warehouses at the third level services by the regional warehouses and so on. The objective of warehousing management is to help in optimal cost of timely order fulfillment by managing the resources economically.

SELF-CHECK EXERCISE – II

3. Give an example of engineered systems.

4. _______ system primarily aims to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, putaway and picking.

9.6 GLOSSARY

- **Warehouse Management System:** It is a key part of the supply chain and primarilyaims to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, putaway and picking.
- **Automatic Identification and Data Capture (AIDC):** It refers to the methods of automatically identifying objects, collecting data about them, and entering that data directly into computer systems (i.e. without human involvement).

- **Barcode Reader (or Barcode Scanner):** It is an electronic device for reading printed barcodes. Like a flatbed scanner, it consists of a light source, a lens and a light sensor translating optical impulses into electrical ones.
- **Wireless LAN (WLAN):** It is a wireless local area network that links two or more computers or devices using spread-spectrum or OFDM modulation technology based to enable communication between devices in a limited area.
- **Radio-frequency Identification (RFID):** It is the use of an object (typically referred to as an RFID tag) applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves.
- **Pallet Rack:** It is also referred to as "pallet racking," is a material handling storage aid system designed to store materials on pallets (or "skids").
- **Belt Conveyor:** It consists of two or more pulleys, with a continuous loop of material - the conveyor belt - that rotates about them.One or both of the pulleys are powered, moving the belt and the material on the belt forward.
- **Forklift:** (also called a lift truck, a high/low, a stacker-truck, or a side loader) It is a powered industrial truck used to lift and transport materials.
- **Bulk Material Handling:** It is an engineering field that is centered around the design of equipment used for the transportation of materials such as ores and cereals in loose bulk form.

9.7 KEYWORDS

Material Handling, Material Handling Equipment, Engineered Systems, Warehouse Management system

9.8 EXERCISES

9.8.1 SHORT QUESTIONS

1. What do you mean by material handling system?
2. Elaborate the ways in which material handling equipment can improve efficiency.
3. Explain the warehouse management system.

9.8.2 LONG QUESTIONS

1. What are the principles of basic material handling?
2. Explain the different types of material handling equipments.

9.9 ANSWERS TO SELF-CHECK EXERCISE

1. Material Handling; 2. True; 3. Conveyors; 4. Warehouse Management System

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JUST IN TIME INVENTORY MANAGEMENT

STRUCTURE

10.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the evolution of the concept of JIT.
- Know the benefits and problems of JIT.
- Know various similar business models.

10.1 INTRODUCTION

Just-in-time (JIT)is an inventory strategy implemented to improve the return on investment of a business by reducing in-process inventory and its associated carrying costs. In order to achieve JIT the process must have signals of what is going on elsewhere within the process. This means that the process is often driven by a series of signals, which can be Kanban {Kanban is a signaling system to trigger action) that tell production processes when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. When implemented correctly, JIT can lead to dramatic improvements in a manufacturing organization's return on investment, quality, and efficiency.

Quick communication of the consumption of old stock which triggers new stock to be ordered is key to JIT and inventory reduction. This saves warehouse space and costs. However, since stock levels are determined by historicaldemand, any sudden demand rises above the historical average demand, the firm will deplete inventory faster than usual and cause customer service issues. Some have suggested that recycling Kanban faster can also help flex the system by as much as 10-30%. In recent years manufacturers have touted a trailing 13-week average as a better predictor for JIT planning than most forecasters could provide.

10.2 HISTORY

The technique was first used by the Ford Motor Company as described explicitly by Henry Ford's *My Life and Work* (1923): "We have found in buying materials that it is not worthwhile to buy for other than immediate needs. We buy only enough to fit into the plan of production, taking into consideration the state of transportation at the time. If transportation were perfect and an even flow of materials could be assured, it would not be necessary to carry any stock whatsoever. The carloads of raw materials would arrive on schedule and in the planned order and amounts, and go from the railway cars into production. That would save a great deal of money, for it would give a very rapid turnover and thus decrease the amount of money tied up in materials. With bad transportation one has to carry larger stocks." This statement also describes the concept of "dock to factory floor" in which incoming materials are not even stored or warehoused before going into production. The concept needed an effective freight management system (FMS); Ford's *Today and Tomorrow* (1926) describes one.

The technique was subsequently adopted and publicized by Toyota Motor Corporation of Japan as part of its Toyota Production System (TPS). However, Toyota famously did not adopt the procedure from Ford, but from Piggly Wiggly. Although Toyota visited Ford as part of its tour of American businesses, Ford had not fully adopted the Just-In-Time system, and Toyota executives were appalled at the piles of inventory laying around and the uneven work schedule of the employees of Ford. Toyota also visited Piggly Wiggly, and it was there that Toyota executives first observed a fully functioning and successful Just-In-Time system, and modeled TPS after it.

It is hard for Japanese corporations to warehouse finished products and parts, due to the limited amount of land available for them. Before the 1950s, this was thought to be a disadvantage because it forced the production lot size below the economic lot size. (An economic lot size is the number of identical products that should be produced, given the cost of changing the production process over to another product.) The undesirable result was poor return on investment for a factory.

The chief engineer at Toyota in the 1950s, examined accounting assumptions and realized that another method was possible. The factory could implement JIT which would require it to be made more flexible and reduce the overhead costs of retooling and thereby reduce the economic lot size to fit the available warehouse space, JIT is now regarded by Ohno as one of the two 'pillars' of the Toyota Production System.

Therefore, over a period of several years, Toyota engineers redesigned car models for commonality of tooling for such production processes as paint-spraying and welding. Toyota was one of the first to apply flexible robotic systems for these tasks. Some of the changes were as simple as standardizing the hole sizes used to hang parts on hooks. The number and types of fasteners were reduced in order to standardize assembly steps and tools. In some cases, identical sub-assemblies could be used in several models.

Toyota engineers then determined that the remaining critical bottleneck in the retooling process was the time required to change the stamping dies used for body parts. These were adjusted by hand, using crowbars and wrenches. It sometimes took as long as several days to install a large, multi-ton die set and adjust it for acceptable quality. Further, these were usually installed one at a time by a team of experts, so that the line was down for several weeks.

So, Toyota implemented a strategy now called Single Minute Exchange of Die (SMED), developed with Shigeo Shingo. With very simple fixtures, measurements were substituted for adjustments. Almost immediately, die change times fell to hours instead of days. At the same time, quality of the stampings became controlled by a written recipe, reducing the skill level required for the change. Further analysis showed that a lot of the remaining time was used to search for hand tools and move dies. Procedural changes (such as moving the new die in place with the line in operation) and dedicated tool-racks reduced the die-change times to as little as 40 seconds. Today dies are changed in a ripple through the factory as a new product begins flowing.

After SMED, economic lot sizes fell to as little as one vehicle in some Toyota plants.

Carrying the process into parts-storage made it possible to store as little as one part in each assembly station. When a part disappeared, that was used as a signal (Kanban) to produce or order a replacement.

10.3 PHILOSOPHY

The philosophy of JIT is simple - inventory is defined to be waste. JIT inventory systems expose the hidden causes of inventory keeping and are therefore not a simple solution a company can adopt; there is a wh working come from many different disciplines including statistics, industrial engineering, production management and behavioral science. In the JIT inventory philosophy, there are views with respect to how inventory is looked Upon, what it says about the management within the company, and the main principle behind JIT.

Inventory is seen as incurring costs, or waste, instead of adding and storing value, contrary to traditional accounting. This does not mean to say JIT is implemented without an awareness that removing inventory exposes pre-existing manufacturing issues. With this way of working, businesses are encouraged to eliminate inventory that does not compensate for manufacturing process issues, and then to constantly improve those processes so that less inventory can be kept. Secondly, allowing any stock habituates the management to stock keeping and it can then be a bit like a narcotic. Management is then tempted to keep stock there to hide problems within the production system. These problems include backups at work centers, machine reliability, process variability, lack of flexibility of employees and equipment, and inadequate capacity among other things.

In short, the just-in-time inventory system is all about having "the right material, at the right time, at the right place, and in the exact amount", without the safety net of inventory. The JIT system has implications of which are broad for the implementers.

Transaction Cost Approach

JIT reduces inventory in a firm. However, unless it is used throughout the supply chain, it can be hypothesized that firms are simply outsourcing their input inventory to suppliers (Naj 1993). This effect was investigated by Newman (1993), who found, on average, suppliers in Japan charged JIT customers a 5% price premium.

Environmental Concerns

During the birth of JIT, multiple daily deliveries were often made by bicycle; with increases in scale has come the adoption of vans and lorries (trucks) for these deliveries. Cusumano (1994) has highlighted the potential and actual problems this causes with regard to gridlock and the burning offossil fuels. This violates three JIT wastes:

1. Time; wasted in traffic jams
2. Inventory; specifically, pipeline (in transport) inventory and
3. Scrap; with respect to petrol or diesel burned while not physically moving.

Price Volatility

JIT implicitly assumes a level of input price stability such that it is desirable to inventory inputs at today's prices. Where input prices are expected to rise storing inputs may be desirable.

Quality Volatility

JIT implicitly assumes the quality of available inputs remains constant over time. If not, firms may benefit from hoarding high-quality inputs.

Demand Stability

Karmarker (1989) highlights the importance of relatively stable demand which can help ensure efficient capital utilization rates. Karmarker argues without a significant stable component of demand, JIT becomes untenable in high capital cost production. In the U.S., the 1992 railway strikes resulted in General Motors having to idle a 75,000-worker plant because they had no supplies coming in.

SELF-CHECK EXERCISE – I

1. An inventory strategy implemented to improve the return on investment of a business by reducing in-process inventory and its associated carrying costs is known as ___________.

2. According to JIT philosophy, inventory is defined as a _________.

10.4 EFFECTS OF JIT

Some of the initial results at Toyota were horrible, but in contrast to that a huge amount of cash appeared, apparently from nowhere, as in-process inventory was built out and sold. This by itself generated tremendous enthusiasm in upper management. Another surprising effect was that the response time of the factory fell to about a day. This improved customer satisfaction by providing vehicles usually within a day or two of the minimum economic shipping delay.

Also, many vehicles began to bebuilt to order, completely eliminating the risk they would not be sold. This dramatically improved the company's return on equity by eliminating a major source of risk.

Since assemblers no longer had a choice of which part to use, every part had to fit perfectly. The result was a severe quality assurance crisis, and a dramatic improvement in product quality. Eventually, Toyota redesigned every part of its vehicles to eliminate or widen tolerances, while simultaneously implementing careful statistical controls for quality control. Toyota had to test and train suppliers of parts in order to assure quality and delivery. In some cases, the company eliminated multiple suppliers.

When a process problem or bad parts surfaced on the production line, the entire production line had to be slowed or even stopped. No inventory meant that a line could not operate from in-process inventory while a production problem was fixed. Many people in Toyota confidently predicted that the initiative would be abandoned for this reason. In the first week, line stops occurred almost hourly. But by the end of the first month, the rate had fallen to a few line stops per day. After six months, line stops had so little economic effect that Toyota installed an overhead pull-line, similar to a bus bell-pull, that permitted any worker on the production line to order a line stop for a process or quality problem. Even with this, line stops fell to a few per week.

The result was a factory that eventually became the envy of the industrialized world, and has since been widely emulated.

The just-in-time philosophy was also applied to other segments of the supply chain in several types of industries. In the commercial sector, it meant eliminating one or all of the warehouses in the link between a factory and a retail establishment. Examples in the field of sales, marketing and customer service involve applying information systems and mobile hardware to deliver customer information immediately, at the time it is needed, and reducing waste by applying video conferencing to cut travel time.

10.5 BENEFITS

As most companies use an inventory system best suited for their company, the Just- In-Time Inventory System (JIT) can have many benefits resulting from it. The main benefits of JIT are listed below.

1. **Set up times are significantly reduced in the factory.**Cutting down the setup time to be more productive will allow the company to improve their bottom line to look more efficient and focus time spent on other areas that may need improvement. This allows the reduction or elimination of the inventory held to cover the "changeover" time, the tool used here is SMED.
2. **The flows of goods from warehouse to shelves are improved.**Having employees focused on specific areas of the system will allow them to process goods faster instead of having them vulnerable to fatigue from doing too many jobs at once and simplifies the tasks at hand. Small or individual piece tot sizes reduce lot delay inventories which simplifies inventory flow and its management.
3. **Employees who possess multiple skills are utilized more efficiently.**Having employees trained to work on different parts of the inventory cycle system will allow companies to use workers in situations where they are needed when there is a shortage of workers and a high demand for a particular product.
4. **Better consistency of scheduling and consistency of employee work hours.**If there is no demand for a product at the time, workers don't have to be working. This can save the company money by not having to pay workers for a job not completed or could have them focus on other jobs around the warehouse that would not necessarily be done on a normal day.
5. **Increased emphasis on supplier relationships.**No company wants a break in their inventory system that would create a shortage of supplies while not having inventory sit on shelves. Having a trusting supplier relationship means that you can rely on goods being there when you need them in order to satisfy the company and keep the company name in good standing with the public.
6. **Supplies continue around the clock keeping workers productive and businesses focused on turnover.**Having management focused on meeting deadlines will make employees work hard to meet the company goals to see benefits in terms of job satisfaction, promotion or even higher pay.

10.6 PROBLEMS

10.6.1 WITHIN A JIT SYSTEM

The major problem with just-in-time operation is that it leaves the supplier and downstream consumers open to supply shocks and large supply or demand changes. For internal reasons, this was seen as a feature rather than a bug by Ohno, who used the analogy of lowering the level of water in a river in order to expose the rocks to explain how removing inventory showed where flow of production was interrupted. Once the barriers were exposed, they could be removed; since one of the main barriers was rework, lowering inventory forced each shop to improve its own quality or cause a holdup in the next downstream area. One of the other key tools to manage this weakness is production levelling to remove these variations. Just-in-time is a means to improving performance of the system, not an end.

With very low stock levels meaning that there are shipments of the same part coming in sometimes several times per day, Toyota is especially susceptible to an interruption in the flow. For that reason, Toyota is careful to use two suppliers for most assemblies. As noted in Liker (2003), there was an exception to this rule that put the entire company at risk by the 1997 Aisin fire. However, since Toyota also makes a point of maintaining high quality relations with its entire supplier network, several other suppliers immediately took up production of the Aisin-built parts by using existing capability and documentation. Thus, a strong, long-term relationship with a few suppliers is preferred to short-term, price-based relationships with competing suppliers. This long-term relationship has also been used by Toyota to send Toyota staff into their suppliers to improve their suppliers' processes. These interventions have now been going on for twenty years and result in improved margins for Toyota and the supplier as well as lower final customer costs and a more reliable supply chain. Toyota encourages their suppliers to duplicate this work with their own suppliers.

10.6.2 WITHIN A RAW MATERIAL STREAM

As noted by Liker (2003) and Womack and Jones (2003), it would ultimately be desirable to introduce synchronized flow and linked JIT all the way back through the supply stream. However, none followed this in detail all the way back through the processes to the raw materials. With present technology, for example, an ear of corn cannot be grown and delivered to order. The same is true of most raw materials, which must be discovered and/ or grown through natural processes that require time and must account for natural variability in weather and discovery. The part of this currently viewed as impossible is the synchronized part of flow and the linked part of JIT. It is for the reasons stated raw materials companies decouple their supply chain from their clients' demand by carrying large 'finished goods' stocks. Both flow and JIT can be implemented in isolated process islands within the raw materials stream. The challenge then becomes to achieve that isolation by some means other than the huge stocks they carry to achieve it today.

It is because of this almost all value chains are split into a part which makes-to- forecast and a part which could, by using JIT, become make-to-order. Often, historically, the make-to-order part has been within the retailer portion of the value chain. Toyota's revolutionary step has been to take Piggly Wiggly's supermarket replenishment system and drive it back to at least half way through their automobile factories. Their challenge today is to drive it all the way back to their goodsinwards dock. Of course, the mining of iron and making of steel is still not done specifically because somebody orders a particular car. Recognizing JIT could be driven back up the supply chain has reaped Toyota huge benefits and a world dominating position in the auto industry.

It should be noted that the advent of the mini mill steelmaking facility is starting to challenge how far back JIT can be implemented, as the electric arc furnaces at the heart of many mini-mills can be started and stopped quickly, and steel grades changed rapidly.

10.6.3 REGARDING OIL INDUSTRY

It has been frequently charged that the oil industry has been influenced by JIT. Besides the obvious point that prices went up because of the reduction in supply and not for anything to do with the practice of JIT, JIT students and even oil & gas industry analysts question whether JIT as it has been developed by Ohno, Goidratt, and others is used by the petroleum industry. Companies routinely shut down facilities for reasons other than the application of JIT. One of those reasons may be economic rationalization: when the benefits of operating no longer outweigh the costs, including opportunity costs, the plant may be economically inefficient. JIT has never subscribed to such considerations directly; following Waddel and Bodek (2005), this ROI-based thinking conforms more to Brown-style accounting and Sloan management. Further, and more significantly, JIT calls for a reduction in inventory capacity, not production capacity. From 1975 to 1990 to 2005, the annual average stocks of gasoline have fallen by only 8.5% from 228,331 to 222,903 bbls to 208,986 (Energy Information Administration data}. Stocks fluctuate seasonally by as much as 20,000 bbls. During the 2005 hurricane season, stocks never fell below 194,000 thousand bbls, while the low for the period 1990 to 2006 was 187,017 thousand bbls in 1997. This shows that while industry storage capacity has decreased in the last 30 years, it hasn't been drastically reduced as JIT practitioners would prefer,

Finally, as shown in a pair of articles in the Oil & Gas Journal, JIT does not seem to have been a goal of the industry. In Waguespack and Cantor (1996), the authors point out that JIT would require a significant change in the supplier/refiner relationship, but the changes in inventories in the oil industry exhibit none of those tendencies. Specifically, the relationships remain cost-driven among many competing suppliers rather than quality- based among a select few long-term relationships. They find that a large part of the shift came about because of the availability of short-haul crudes from Latin America. In the follow-up editorial, the Oil & Gas Journal claimed that "casually adopting popular business terminology that doesn’t apply” had provided a "rhetorical bogey" to industry critics. Confessing that they had been as guilty as other media sources, they confirmed that "It also happens not to be accurate."

10.7 BUSINESS MODELS FOLLOWING SIMILAR APPROACH

10.7.1 VENDOR MANAGED INVENTORY

Vendor Managed Inventory (VMI) employs the same principles as those of JIT inventory however the responsibilities of managing inventory are placed with the vendor in a vendor/customer relationship. Whether it’s a manufacturer who is managing inventory for a distributor, or a distributor managing inventory for their customers; the role of managing inventory is given to the vendor.

The primary advantage of this business model is that the vendor has industry experience and expertise which enables them to better anticipate demand and inventory needs. The inventory planning and controlling is facilitated by the use of applications that allow vendors to have access to the inventory picture of its customer.

Third party applications offer vendors the benefit afforded by a quick implementation time. Further, such companies hold valuable inventory management knowledge and expertise that helps organizations immensely.

10.7.2 CUSTOMER MANAGED INVENTORY

With Customer Managed Inventory (CMI), the customer as opposed to the vendor in a VMI model is given the responsibility of making all inventory decisions. This is similar to the concepts employed by JIT inventory. With a clear picture of their inventory and that of their supplier's, the customer is able to anticipate fluctuations in demand and make inventory replenishment decisions accordingly.

SELF-CHECK EXERCISE – II

3. The method of measuring the level of inventory that minimizes the total inventory holding and ordering costs is known as what?

4. _______ is an event that suddenly changes the price of a commodity or service. It may be caused by a sudden increase or decrease in the supply of a particular good.

10.8 GLOSSARY

- **Just-in-time (JIT):** It is an inventory strategy implemented to improve the return on investment of a business by reducing in-process inventory and its associated carrying costs.
- **Kanban:** Kanban is a signaling system to trigger action, that tells production processes when to make the next part.
- **Single Minute Exchange of Die (SMED):** It is one of the many lean production methods for reducing waste in a manufacturing process. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product.
- **Build to Order:** It is often abbreviated as BTO and sometimes referred to as make to order (MTO), is a production approach where once a confirmed order for products is received, products are built.
- **Vendor Managed Inventory (VMI):** It is a family of business models in which the buyer of a product provides certain information to a supplier of that product and the supplier takes full responsibility for maintaining an agreed inventory of the material, usually at the buyer's consumption location (usually a store).

10.9 KEYWORDS

Just-in-time, Vendor Managed Inventory, Kanban, Customer Managed Inventory, Economic lot size.

10.10 EXERCISES

10.10.1 SHORT QUESTIONS

1. What are the environmental concerns related to JIT?
2. What is transaction cost approach?
3. Explain the vendor managed inventory model.
4. Explain the process of determining the Economic Order Quantity.

10.10.2 LONG QUESTIONS

1. What is the history and philosophy of JIT?
2. What benefits and problems are associated with JIT?
3. What are the effects of JIT on inventory management?
4. Explain various models following the similar approach to JIT.

10.11 ANSWERS TO SELF-CHECK EXERCISES

1. Just-in-time; 2. Waste; 3. Economic Order Quantity; 4. Supply Shock.

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MBA-DE(Second Year) **IM 311**

Semester-III **INVENTORY MANAGEMENT**

Lesson No. 11 **AUTHOR: DR. DYAL BHATNAGAR**

ENTERPRISE RESOURCE PLANNING

STRUCTURE

11.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the evolution of concept of ERP
- Know the factors to be considered while implementing ERP
- Know the advantages and disadvantages of implementing ERP

11.1 INTRODUCTION

Enterprise resource planning (ERP)is a company-wide computer software system used to manage and coordinate all the resources, information, and functions of a business from shared data stores.

An ERP system has a service-oriented architecture with modular hardware and software units or "services" that communicate on a local area network. The modular design allows a business, to add or reconfigure modules (perhaps from different vendors) while preserving data integrity in one shared database that may be centralized or distributed.

MRP vs. ERP: Manufacturing management systems have evolved in stages over the past 30 years from a simple means of calculating materials requirements to the automation of an entire enterprise.

Around 1980, over-frequent changes in sales forecasts, entailing continual readjustments in production, as well as inflexible fixed system parameters, led MRP (Material Requirement Planning) to evolve into a new concept: Manufacturing Resource Planning (or MRPII) and finally the generic concept Enterprise Resource Planning (ERP).

To be considered an ERP system, a software package must provide the function of at least two systems. For example, a software package that provides both payroll and accounting functions could technically be considered an ERP software package

Examples of modules in an ERP which formerly would have been stand-alone applications include: Product lifecycle management, Supply chain management (e.g. Purchasing, Manufacturing and Distribution), Warehouse Management, Customer Relationship Management, Sales Order Processing, Online Sales, and Decision Support Systems.

More specifically the term ERP can be placed at third place in the development cycle of these planning systems as shown below

- MRP: Material Requirements Planning
- MRP II: Manufacturing Resource Planning
- ERP: Enterprise Resource Planning

How the computer changed everything! The computer began the journey into modern-day planning systems. The confusion started after the introduction of the computer. By 1975 enough MRP systems had been installed to begin the formation of MRP II systems. Confusion began with the introduction of MRP II. For the most part, there was a basic understanding that MRP II evolved out of MRP. The problem began with education and the generic definitions of MRP and MRP II. When students, consultants, practitioners, and educators started using the term MRP, it was unclear whether the discussion was about MRP or MRP II.

The initials ERP originated as an extension of MRP (material requirements planning; later manufacturing resource planning) It was introduced by research and analysis firm Gartner in 1990. ERP systems now attempt to cover all core functions of an enterprise, regardless of the organization's business or charter. These systems can now be found in non-manufacturing businesses, non-profit organizations and governments.

A complete definition of an ERP system is defined as: ERP, standing for Enterprise Resource Planning, is a complete enterprise-wide software solution. The ERP system consists of software support modules such as: marketing and sales, field service, product design and development, production and inventory control, procurement, distribution, industrial facilities management, process design and development, manufacturing, quality, human resources, finance and accounting, and information services. Integration between the modules is stressed without the duplication of information. ERP systems are an outgrowth of MRP II systems.

11.2 OVERVIEW OF ERP SOLUTIONS

Some organizations- typically those with sufficient in-house IT skills to integratemultiple software products - choose to implement only portions of an ERP system and develop an external interface to other ERP or stand-alone systems for their other application needs. For example, one may choose to use supply chain management system from one vendor, and the financial systems from another, and perform the integration between the systems themselves.

This is common to retailers, where even a mid-sized retailer will have a discrete Point-of-Sale (POS) product and financials application, then a series of specialized applications to handle business requirements such as warehouse management, staff rostering, merchandising and logistics.

Ideally, ERP delivers a single database that contains all data for the software modules, which would include:

Manufacturing

Engineering, bills of material, scheduling, capacity, workflow management, quality control, cost management, manufacturing process, manufacturing projects, manufacturing flow.

Supply Chain Management

Order to cash, inventory, order entry, purchasing, product configurator, supply chain planning, supplier scheduling, inspection of goods, claim processing, commission calculation.

Financials

General ledger, cash management, accounts payable, accounts receivable, fixed assets.

Project Management

Costing, billing, time and expense, performance units, activity management.

Human Resources

Human resources, payroll, training, time and attendance, rostering, benefits.

Customer Relationship Management

Sales and marketing, commissions, service, customer contact and call center support.

Data Warehouse

Various self-service interfaces for customers, suppliers, and employees.

Access Control

User privilege as per authority levels for process execution.

Customization

To meet the extension, addition, change in process flow.

ERP systems saw a large boost in sales in the 1990s as companies faced the Y2K problem in their legacy systems. Many companies took this opportunity to replace their legacy information systems with ERP systems. This rapid growth in sales was followed by a slump in 1999, at which time most companies had. already implemented their Y2K solution.

ERPs are often incorrectly called back-office systems indicating that customers and the general public are not directly involved. This is contrasted with front office systems like customer relationship management (CRM) systems that deal directly with the customers, orthe eBusiness systems such as e-Commerce, e-Government, e-Telecom, and e-Finance, or supplier relationship management (SRM) systems.

ERPs are cross-functional and enterprise wide. All functional departments that are involved in operations or production are integrated in one system. In addition to manufacturing, warehousing, logistics, and information technology, this would include accounting, human resources, marketing and strategic management.

11.2.1 Before

Prior to the concept of ERP systems, it was usual for each department within an organization - such as human resources, payroll and financial - to have its own customized computer system.

Typical difficulties involved integration of data from potentially different computer manufacturers and systems. For example, the HR computer system would typically manage employee information while the payroll department would typically calculate and store paycheck information for each employee, and the financial department would typically store financial transactions for the organization. Each system would have to integrate using a predefined set of common data which would be transferred between each computer system. Any deviation from the data format or the integration schedule often resulted in problems.

11.2.2 After

ERP software combined the data of formerly separate applications. This simplified keeping data in synchronization across the enterprise as well as reducing the complexity of the required computer infrastructure. It also contributed to standardizing and reducing the number of software specialties required within IT departments.

11.3 BEST PRACTICES

Best practices are incorporated into most ERP vendor's software packages. When implementing an ERP system, organizations can choose between customizing the software or modifying their business processes to the "best practice" function delivered in the "out- of-the-box" version of the software.

Prior to ERP, software was developed to fit the processes of an individual business. Due to the complexities of most ERP systems and the negative consequences of a failed ERP implementation, most vendors have included "Best Practices" into their software. These "Best Practices" are what the Vendor deems as the most efficient way to carry out a particular business process in an Integrated Enterprise-Wide system.

SELF-CHECK EXERCISE – I

1. ________ is a company-wide computer software system used to manage and coordinate all the resources, information, and functions of a business from shared data stores.

2. What do we call a software-based production planning and inventory control system used to ensure that materials and products are available for production and delivery to customers?

11.4 IMPLEMENTATION

Because of their wide scope of application within a business, ERP software systems are typically complex and usually impose significant changes on staff work practices Implementing ERP software is typically not an "in-house" skill, so even smaller projects are more cost effective if specialist ERP implementation consultants are employed The length of time to implement an ERP system depends on the size of the business, the scope of the change and willingness of the customer to take ownership for the project A small project (e.g., a company of less than 100 staff) may be planned and delivered within 3-9 months; however, a large, multi-site or multi-country implementation may take years.

To implement ERP systems, companies often seek the help of an ERP vendor or of third-party consulting companies. These firms typically provide three areas of professional services: consulting, customization and support. The client organization may also employ independent program management, business analysis and change management to ensure their business requirements remain a priority during implementation.

Data migration is one of the most important activities in determining the success of an ERP implementation. Since many decisions must be made before migration, a significant amount of planning must occur. Unfortunately, data migration is the last activity before the production phase of an ERP implementation, and therefore receives minimal attention due to time constraints. The following are steps of a data migration strategy that can help with the success of an ERP implementation:

Identifying the data to be migrated

1. Determining the timing of data migration
2. Generating the data templates
3. Freezing the tools for data migration
4. Deciding on migration related setups
5. Deciding on data archiving

11.4.1 PROCESS PREPARATION

ERP vendors have designed their systems around standard business processes, based upon best business practices. Different vendor(s) have different types of processes but they are all of a standard, modular nature. Firms that want to implement ERP systems are consequently forced to adapt their organizations to standardized processes as opposed to adapting the ERP package to the existing processes. Neglecting to map current business processes prior to starting ERP implementation is a main reason for failure of ERP projects. It is therefore crucial that organizations perform a thorough business process analysis before selecting an ERP vendor and setting off on the implementation track. This analysis should map out all present operational processes, enabling selection of an ERP vendor whose standard modules are most closely aligned with the established organization. Redesign can then be implemented to achieve further process congruence. Research indicates that the risk of business process mismatch is decreased by:

- linking each current organizational process to the organization's strategy;
- analyzing the effectiveness of each process in light of its current related business capability;
- understanding the automated solutions currently implemented.

ERP implementation is considerably more difficult (and politically charged) in organizations structured into nearly independent business units, each responsible for their own profit and loss, because they will each have different processes, business rules, data semantics, authorization hierarchies and decision centers. Solutions include requirements coordination negotiated by local change management professionals or, if this is not possible, federated implementation using loosely integrated instances (e.g. linked via Master Data Management) specifically configured and/or customized to meet local needs.

A disadvantage usually attributed to ERP is that business process redesign to fit the standardized ERP modules can lead to a loss of competitive advantage. While documented cases exist where this has indeed materialized, other cases show that following thorough process preparation ERP systems can actually increase sustainable competitive advantage.

11.4.2 CONFIGURATION

Configuring an ERP system is largely a matter of balancing the way you want the system to work with the way the system lets you work. Begin by deciding which modules to install, then adjust the system using configuration tables to achieve the best possible fit in working with your company's processes.

Modules - Most systems are modular simply for the flexibility of implementing some functions but not others. Some *common* modules, such as finance and accounting are adopted by nearly all companies implementing enterprise systems; others however such as human resource management are not needed by some companies and therefore not adopted. A service company for example will not likely need a module for manufacturing. Other times companies will not adopt a module because they already have their own proprietary system, they believe to be superior. Generally speaking, the greater number of modules selected, the greater the integration benefits, but also the increase in costs, risks and changes involved.

Configuration Tables - A configuration table enables a company to tailor a particular aspect of the system to the way it chooses to do business. For example, an organization can select the type of inventory accounting - FIFO or LIFO - it will employ or whether it wants to recognize revenue by geographical unit, product line, or distribution channel.

So, what happens when the options the system allows just aren't good enough? At this point a company has two choices, both of which are not ideal. It can re-write some of the enterprise system's code, or it can continue to use an existing system and build interfaces between it and the new enterprise system. Both options will add time and cost to the implementation process. Additionally, they can dilute the system's integration benefits. The more customized the system becomes the less possible seamless communication becomes between suppliers and customers.

11.4.3 CONSULTING SERVICES

Many organizations did not have sufficient internal skills to implement an ERP project. This resulted in many organizations offering consulting services for ERP implementation. Typically, a consulting team was responsible for the entire ERP implementation including planning, training, testing, implementation, and delivery of any customized modules. Examples of customization includes additional product training; creation of process triggers and workflow; specialist advice to improve how the ERP is used in the business; system optimization; and assistance writing reports, complex data extracts or implementing Business Intelligence.

For most mid-sized companies, the cost of the implementation will range from around the list price of the ERP user licenses to up to twice this amount (depending on the level of customization required). Large companies, and especially those with multiple sites or countries, will often spend considerably more on the implementation than the cost of the user licenses — three to five times more is not uncommon for a multi-site implementation

Unlike most single-purpose applications, ERP packages have historically included full source code and shipped with vendor-supported team IDEs for customizing and extending the delivered code. During the early years of ERP, the guarantee of mature tools and supportfor extensive customization was an important sales argument when a potential customer was considering developing their own unique solution in-house, or assembling a cross-functional solution by integrating multiple "best of breed" applications.

11.4.1 "CORE SYSTEM" CUSTOMIZATION VS CONFIGURATION

Increasingly, ERP vendors have tried to reduce the need for customization by providing built-in "configuration" tools to address most customers' needs for changing how the out-of-the-box core system works. Key differences between customization and configuration include:

- Customization is always optional, whereas some degree of configuration (e.g. setting up cost/profit center structures, organizational trees, purchase approval rules, etc.) may be needed before the software will work at all.
- Configuration is available to all customers, whereas customization allows individual customer to implement proprietary "market-beating" processes.
- Configuration changes tend to be recorded as entries in vendor-supplied data tables, whereas customization usually requires some element of programming and/or changes to table structures or views.
- The effect of configuration changes on the performance of the system is relatively predictable and is largely the responsibility of the ERP vendor. The effect of customization is unpredictable and may require time-consuming stress testing by the implementation team,
- Configuration changes are almost always guaranteed to survive upgrades to new software versions. Some customization s (e.g. code that uses pre-defined "hooks" that sure called before/after displaying data screens) will survive upgrades, though they will still need to be re-tested. More extensive customizations (e.g. those involving changes to fundamental data structures) will be overwritten during upgrades and must be re-implemented manually.

By this analysis, customizing an ERP package can be unexpectedly expensive and complicated, and tends to delay delivery of the obvious benefits of an integrated system. Nevertheless, customizing an ERP suite gives the scope to implement secret recipes for excellence in specific areas while ensuring that industry best practices are achieved in less sensitive areas.

11.4.5 EXTENSION

In this context "Extension" refers to ways that the delivered ERP environment can be extended with third-party programs. It is technically easy to expose most ERP transactions to outside programs, e.g.

- Scenarios to do with archiving, reporting and republishing (these easiest to achieve, because they mainly address static data);
- Transactional data capture scenarios, e.g. using scanners, tills or RFIDs, are relatively easy (because they touch existing data);

  .... however, because ERP applications typically contain sophisticated rules that control how master data can be created or changed, some scenarios are very difficult to implement.

11.4.6 MAINTENANCE AND SUPPORT SERVICES

Maintenance and support services involves monitoring and managing an operational ERP system. This function is often provided in-house using members of the IT department, or may be provided by a specialist external consulting and services company.

11.5 ADVANTAGES

In the absence of an ERP system, a large manufacturer may find itself with many software applications that neither talk to each other nor interface effectively. Tasks that need to interface with one another may involve:

- Integration among different functional areas to ensure proper communication, productivity and efficiency
- Design engineering (how to best make the product)
- Order tracking, from acceptance through fulfillment
- The revenue cycle, from invoice through cash receipt
- Managing inter-dependencies of complex processes bill of materials
- Tracking the three-way match between purchase orders (what was ordered), inventory receipts (what arrived), and costing (what thevendor invoiced)
- The accounting for all of these tasks: tracking the revenue, cost and profit at a granular level.
- ERP Systems centralize the data in one place, example customer, financial data. This eliminates the problem of synchronizing changes and can reduce the risk of loss of sensitive data by consolidating multiple permissions and security models into a single structure.

Some security features are included within an ERP system to protect against both outsider crime, such as industrial espionage, and insider crime, such as embezzlement. A data-tampering scenario, for example, might involve a disgruntled employee intentionally modifying prices to below-the-breakeven point in order to attempt to interfere with the company's profit or other sabotage, ERP systems typically provide functionality for implementing internal controls to prevent actions of this kind. ERP vendors are also moving toward better integration with other kinds of information security tools.

11.6 DISADVANTAGES

Problems with ERP systems are mainly due to inadequate investment in ongoing training for the involved IT personnel - including those implementing and testing changes - as well as a lack of corporate policy protecting the integrity of the data in the ERP systems and the ways in which it is used.

Disadvantages

- Customization of the ERP software is limited.
- Re-engineering of business processes to fit the "industry standard" prescribed by the ERP system may lead to a loss of competitive advantage.
- ERP systems can be very expensive (This has led to a new category of "ERP light" solutions)
- ERPs are often seen as too rigid and too difficult to adapt to the specific workflow and business process of some companies-this is cited as one of the main causes of their failure.

- Many of the integrated links need high accuracy in other applications to work effectively. A company can achieve minimum standards, then over time "dirty data" will reduce the reliability of some applications.
- Once a system is established, switching costs are very high for any one of the partners (reducing flexibility and strategic control at the corporate level).
- The blurring of company boundaries can cause problems in accountability, lines of responsibility, and employee morale.
- Resistance in sharing sensitive internal information between departments can reduce the effectiveness of the software.
- Some large organizations may have multiple departments with separate, independent resources, missions, chains-of-command, etc., and consolidation into a single enterprise may yield limited benefits.
- The system may be too complex measured against the actual needs of the customers.

ERP Systems centralize the data in one place, example customer, financial data. This can increase the risk of loss

SELF-CHECK EXERCISE – II

3. Maintenance and support services involves __________ and managing an operational ERP system.

4. ___________ refers to ways that the delivered ERP environment can be extended with third-party programs.

Ql. Differentiate ERP to MRP.

Q2.

11.7 GLOSSARY

- **Enterprise resource planning (ERP)** is a company-wide computer software system used to manage and coordinate all the resources, information, and functions of a business from shared data stores.
- **Material Requirements Planning (MRP)** is a software-based production planning and inventory control system used to ensure that materials and products are available for production and delivery to customers.
- **Supply chain management (8CM)** is the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers.
- **Manufacturing Resource Planning (MRP II)**: Itis a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capability to answer "what-if" questions and extension of closed loop MRP.
- **Capacity Planning**: It is the process of determining the production capacity needed by an organization to meet changing demands for its products.

11.8 KEYWORDS

Enterprise Resource Planning, Supply Chain Management, Manufacturing Resource Planning, Material Requirements Planning, Capacity Planning

11.9 EXERCISES

11.9.1 SHORT QUESTIONS

1. What is the difference between Material Requirement Planning and Enterprise Resource Planning?
2. What kind of data is stored in the ERP systems?
3. What changes can be seen after using the ERP systems in enterprises?
4. What do you mean by capacity planning?

11.9.2 LONG QUESTIONS

1. What are the merits and demerits of an ERP system?
2. Discuss the evolution of the ERP systems.
3. What are the factors which are to be borne in mind while implementing ERP in an organization?

11.10 ANSWERS TO SELF-CHECK EXERCISES

1. Enterprise Resource Planning; 2. Material Requirements Planning; 3. Monitoring; 4. Extension.

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IM 311
INVENTORY MANAGEMENT
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SUPPLY CHAIN MANAGEMENT

STRUCTURE

12.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the concept of supply chain management
- Know the activities of supply chain management.
- Know the developments in the field of supply chain management.

12.1 INTRODUCTION

Supply Chain Management (SCM)is the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers). Supply Chain Management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point-of-origin to point-of- consumption (supply chain).

The definition one American professional association put forward is that Supply Chain Management encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies. More recently, the loosely coupled, self-organizing network of businesses that cooperates to provide product and service offerings has been called the Extended Enterprise.

Supply Chain Management can also refer to Supply chain management software which are tools or modules used in executing supply chain transactions, managing supplier relationships and controlling associated business processes.

Supply chain event management (abbreviated as SCEM) is a consideration of all possible occurring events and factors that can cause a disruption in a supply chain. With SCEM possible scenarios can be created and solutions can be planned.

12.2 SUPPLY CHAIN MANAGEMENT PROBLEMS

Supply chain management must address the following problems:

- **Distribution Network Configuration:** Number, location and network missions of suppliers, production facilities, distribution centers, warehouses, cross-docks and customers.
- **Distribution Strategy:** Including questions of operating control (centralized, decentralized or shared); delivery scheme (e.g., direct shipment, pool point, shipping, Cross-docking, DSD (direct store delivery), closed loop shipping); mode of transportation (e.g., motor carrier, including truckload, LTL, parcel; railroad; intermodal, ocean freight; airfreight); replenishment strategy (e.g., pull, push or hybrid); and transportation control (e.g., owner-operated, private carrier, common carrier, contract carrier and 3PL).
- **Trade-offs in Logistical Activities:** Trade-offs exist that increase the total cost if only one of the activities is optimized. For example, full truckload (FTL) rates are more economical on a cost per pallet basis than less than truckload (LTL) shipments. If, however, a full truckload of a product is ordered to reduce transportation costs there will be an increase in inventory holding costs which may increase total logistics costs. These trade-offs are key to developing the most efficient and effective logistics and SCM strategy.
- **Information:** Integration of and other processes through the supply chain to share valuable information, including demand signals, forecasts, inventory, transportation, and potential collaboration etc.
- **Inventory Management:** Quantity and location of inventory including raw materials, work-in-progress (WIP) and finished goods.
- **Cash flow:** Arranging the payment terms and the methodologies for exchanging funds across entities within the supply chain.

Supply chain execution is managing and coordinating the movement of materials, information, and funds across the supply chain. The flow is bi-directional.

SELF-CHECK EXERCISE – I

1. ______ is the management of a network of interconnected business involved in the ultimate provision of product and service packages required by end customers.

2. A name used to describe a company that partners with a manufacturer or producer to market and sell the manufacturer’s products, services, or technologies.

12.3 ACTIVITIES/FUNCTIONS

Supply chain management is a cross-function approach to manage the movement of raw materials into an organization, certain aspects of the internal processing of materials into finished goods, and then the movement of finished goods out of the organization toward the end-customer. As organizations strive to focus on core competencies and becoming more flexible, they have reduced their ownership of raw materials sources and distribution channels. These functions are increasingly being outsourced to other entities that can perform the activities better or more cost effectively. The effect is to increase the number of organizations involved in satisfying customer demand, while reducing management control of daily logistics operations. Less control and more supply chain

Partners led to the creation of supply chain management concepts. The purpose of supply chain management is to improve trust and collaboration among supply chain partners, thus improving inventory visibility and improving inventory velocity.

Several models have been proposed for understanding the activities required to manage material movements across organizational and functional boundaries. SCOR is supply chain management model promoted by the Supply chain Management Council. Another model is the SCM Model proposed by the Global Supply Chain Forum (GSCF). Supplychain activities can be grouped into strategic, tactical, and operational levels of activities.

12.3.1 STRATEGIC

- Strategic network optimization, including the number, location, and size of warehouses, distribution centers, and facilities
- Strategic partnership with suppliers, distributors, and customers, creating communication channels for critical information and operational improvements such as cross docking, direct shipping, and third-party logistics
- Product lifecycle management, so that new and existing products can be optimally integrated into the supply chain and capacity management
    - Information Technology infrastructure, to support supply chain operations
- Where-to-make and what-to-make-or-buy decisions
- Aligning overall organizational strategy with supply strategy

12.3.2 TACTICAL

- Sourcing contracts and other purchasing decisions.
- Production decisions, including contracting, scheduling, and planning process definition.
- Inventory decisions, including quantity, location, and quality of inventory.
- Transportation strategy, including frequency, routes, and contracting.
- Benchmarking of all operations against competitors and implementation of best practices throughout the enterprise.
- Milestone payments
- Focus on customer demand.

12.3.3 OPERATIONAL

- Daily production and distribution planning, including all nodes in the supply chain.
- Production scheduling for each manufacturing facility in the supply chain (minute by minute).
- Demand planning and forecasting, coordinating the demand forecast of all customers and sharing the forecast with all suppliers.
- Sourcing planning, including current inventory and forecast demand, in collaboration with all suppliers.
- Inbound operations, including transportation from suppliers and receiving inventory.
- Production operations, including the consumption of materials and flow of finished goods.
- Outbound operations, including all fulfillment activities and transportation to customers.
- Order promising, accounting for all constraints in the supply chain, including all suppliers, manufacturing facilities, distribution centers, and other customers.

12.4 DEVELOPMENTS IN SUPPLY CHAIN MANAGEMENT

Six major movements can be observed in the evolution of supply chain management studies:Creation, Integration, and Globalization (Lavassani et al., 2008a), Specialization Phases One and Two, and SCM 2.0.

1. **Creation Era**

The term supply chain management was first coined by an American industry consultant in the early 1980s. However, the concept of supply chain in management, was of great importance long before in the early 20th century, especially by the creation of the assembly line. The characteristics of this era of supply chain management include the need for large scale changes, re-engineering, downsizing driven by cost reduction programs, and widespread attention to the Japanese practice of management.

2. **Integration Era**

This era of supply chain management studies was highlighted with the development of Electronic Data Interchange (EDI) systems in the 1960s and developed through the 1990s by the introduction of Enterprise Resource Planning (ERP) systems. This era has continued to develop into the 21st century with the expansion of internet-based collaborative systems. This era of SC evolution is characterized by both increasing value-added and cost reduction through integration.

3. **Globalization Era**

The third movement of supply chain management development, globalization era, can be characterized by the attention towards global systems of supplier relations and the expansion of supply chain over national boundaries and into other continents. Although the use of global sources in the supply chain of organizations can be traced back to several decades ago (e.g. the oil industry), it was not until the late 1980s that a considerable number of organizations started to integrate global sources into their core business. This era is characterized by the globalization of supply chain management in organizations with the goal of increasing competitive advantage, creating more value-added, and reducing costs through global sourcing.

4. **Specialization Era — Phase One — Outsourced Manufacturing and Distribution**

In the 1990s industries began to focus on "core competencies" and adopted a specialization model. Companies abandoned vertical integration, sold off non-core operations, and outsourced those functions to other companies. This changed management requirements by extending the supply chain well beyond the four walls and distributing management across specialized supply chain partnerships.

This transition also re-focused the fundamental perspectives of each respective organization. OEMs became brand owners that needed deep visibility into their supply base. They had to control the entire supply chain from above instead of from within. Contract manufacturers had to manage bills of material with different part numbering schemes from multiple OEMs and support customer requests for work -in-process visibility and vendor- managed inventory (VMI).

The specialization model creates manufacturing and distribution networks composed of multiple, individual supply chains specific to products, suppliers, and customers who work together to design, manufacture, distribute, market, sell, and service a product. The set of partners may change according to a given market, region, or channel, resulting in a proliferation of trading partner environments, each with its own unique characteristics and demands.

5. **Specialization Era — Phase Two — Supply Chain Management as a Service**

Specialization within the supply chain began in the 1980s with the inception of transportation brokerages, warehouse management, and non-asset-based carriers and has matured beyond transportation and logistics into aspects of supply planning, collaboration, execution and performance management.

At any given moment, market forces could demand changes within suppliers, logistics providers, locations, customers and any number of these specialized participants within supply chain networks. This variability has significant effect on the supply chain infrastructure, from the foundation layers of establishing and managing the electronic communication between the trading partners to the more-complex requirements, including the configuration of the processes and work flows that are essential to the management of the network itself.

Supply chain specialization enables companies to improve their overall competencies in the same way that outsourced manufacturing and distribution has done; it allows them to focus on their core competencies and assemble networks of best-in-class domain specific partners to contribute to the overall value chain itself - thus increasing overall performance and efficiency. The ability to quickly obtain and deploy this domain specific supply chain expertise without developing and maintaining an entirely unique and complex competency in house is the leading reason why supply chain specialization is gaining popularity.

Outsourced technology hosting for supply chain solutions debuted in the late 1990s and has taken root in transportation and collaboration categories most dominantly. This has progressed from the Application Service Provider (ASP) model from approximately 1998 through 2003 to the On-Demand model from approximately 2003-2006 to the Software as a Service (SaaS) model we are currently focused on today.

6. **Supply Chain Management 2.0 (SCM 2.0)**

Building off of globalization and specialization, SCM 2.0 has been coined to describe both the changes within the supply chain itself as well as the evolution of the processes, methods and tools that manage it in this new "era".

Web 2.0 is defined as a trend in the use of the World Wide Web that is meant to increase creativity, information sharing, and collaboration among users. At its core, the common attribute that Web 2.0 brings is it helps us navigate the vast amount of information available on the web to find what we are looking for. It is the notion of a usable pathway. SCM 2.0 follows this notion into supply chain operations. It is the pathway to SCM results - the combination of the processes, methodologies, tools and delivery options to guide companies to their results quickly as the complexity and speed of the supply chain increase due to the effects of global competition, rapid price fluctuations, surging oil prices, short product life cycles, expanded specialization, near/far and off shoring, and talent scarcity.

SCM 2.0 leverages proven solutions designed to rapidly deliver results with the agility to quickly manage future change for continuous flexibility, value and success. This is delivered through competency networks composed of best of breed supply chain domain expertise to understand which elements, both operationally and organizationally, are the critical few that deliver the results as well as the intimate understanding of how to manage these elements to achieve desired results, finally the solutions are delivered in a variety of options as no-touch via business process outsourcing, mid-touch via managed services and software as a service (SaaS), or high touch in the traditional software deployment model.

12.5 SUPPLY CHAIN BUSINESS PROCESS INTEGRATION

Successful SCM requires a change from managing individual functions to integrating activities into key supply chain processes. An example scenario: the purchasing department places orders as requirements become appropriate. Marketing, responding to customer demand, communicates with several distributors and retailers as it attempts to satisfy this demand. Shared information between supply chain partners can only be fully leveraged through process integration.

Supply chain business process integration involves collaborative work between buyers and suppliers, joint product development, common systems and shared information. According to Lambert and Cooper (2000) operating an integrated supply chain requires continuous information flow. However, in many companies, management has reached the conclusion that optimizing the product flows cannot be accomplished without implementing a process approach to the business. The key supply chain processes stated by Lambert (2004) are:

- Customer relationship management
- Customer service management
- Demand management
- Order fulfillment
- Manufacturing flow management
- Supplier relationship management
- Product development and commercialization
- Returns management

Much has been written about demand management. Best in Class companies have similar characteristics. They include the following:

a) Internal and external collaboration
b) Lead time reduction initiatives
c) Tighter feedback from customer and market demand
d) Customer level forecasting

One could suggest other key critical supply business processes combining these processes stated by Lambert such as:

a) **Customer service management process**

Customer Relationship Management concerns the relationship between the organization and its customers. Customer service provides the source of customer information. It also provides the customer with real-time information on promising dates and product availability through interfaces with the company's production and distribution operations. Successful organizations use following steps to build customer relationships:

- determine mutually satisfying goals between organization and customers
- establish and maintain customer rapport
- produce positive feelings in the organization and the customers

b) **Procurement process**

Strategic plans are developed with suppliers to support the manufacturing flow management process and development of new products. In firms where operations extend globally, sourcing should be managed on a global basis. The desired outcome is a win-win relationship, where both parties benefit, and reduction times in the design cycle and product development are achieved. Also, the purchasing function develops rapid communication systems, such as electronic data interchange (EDI) and Internet linkages to transfer possible requirements more rapidly. Activities related to obtaining products and materials from outside suppliers requires performing resource planning, supply sourcing, negotiation, order placement, inbound transportation, storage, handling and quality assurance, many of which include the responsibility to coordinate with suppliers in scheduling, supply continuity, hedging, and research into new sources or programs.

c) **Product Development and Commercialization**

Here, customers and suppliers must be united into the product development process, thus to reduce time to market. As product life cycles shorten, the appropriate products must be developed and successfully launched in ever shorter time-schedules to remain competitive. According to Lambert and Cooper (2000), managers of the product development and commercialization process must:

1. coordinate with customer relationship management to identify customer- articulated needs;
2. select materials and suppliers in conjunction with procurement, and
3. develop production technology in manufacturing flow to manufacture and integrate into the best supply chain flow for the product/market combination.

d) **Manufacturing Plow Management Process**

The manufacturing process is produced and supplies products to the distribution channels based on past forecasts. Manufacturing processes must be flexible to respond to market changes, and must accommodate mass customization. Orders are processes operating on a just-in-time (JIT) basis in minimum lot sizes. Also, changes in the manufacturing flow process led to shorter cycle times, meaning improved responsiveness and efficiency of demand to customers. Activities related to planning, scheduling and supporting manufacturing operations, such as work-in-process storage, handling, transportation, and time phasing of components, inventory at manufacturing sites and maximum flexibility in the coordination of geographic and final assemblies' postponement of physical distribution operations.

e) **Physical Distribution**

This concerns movement of a finished product/service to' customers. In physical distribution, the customer is the final destination of a marketing channel, and the availability of the product/service is a vital part of each channel participant's marketing effort. It is also through the physical distribution process that the time and space of customer service become an integral part of marketing, thus it links a marketing channel with its customers (e.g. links manufacturers, wholesalers, retailers).

f) **Outsourcing/partnerships**

This is not just outsourcing the procurement of materials and components, but also outsourcing of services that traditionally have been provided in-house. The logic of this trend is that the company will increasingly focus on those activities in the value chain where it has a distinctive advantage and everything else it will outsource. This movement has been particularly evident in logistics where the provision of transport, warehousing and inventory control is increasingly subcontracted to specialists or logistics partners. Also, to manage and control this network of partners and suppliers requires a blend of both central and local involvement. Hence, strategic decisions need to be taken centrally with the monitoring and control of supplier performance and day-to-day liaison with logistics partners being best managed at a local level,

g) **Performance Measurement**

Experts found a strong relationship from the largest arcs of supplier and customer integration to market share and profitability. By taking advantage of supplier capabilities and emphasizing a long-term supply chain perspective in customer relationships can be both correlated with firm performance. As logistics competency becomes a more critical factor in creating and maintaining competitive advantage, logistics measurement becomes increasingly important because the difference between profitable and unprofitable operations becomes narrower. A.T. Kearney Consultants (1985) noted that firms engaging in comprehensive performance measurement realized improvements in overall productivity. According to experts, internal measures are generally collected and analyzed by the firm including

1. Cost
2. Customer Service
3. Productivity measures
4. Asset measurement, and
5. Quality.

External performance measurement is examined through customer perception measures and "best practice" benchmarking, and includes 1) customer perception measurement, and 2) best practice benchmarking. Components of Supply Chain Management are 1. Standardization 2. Postponement 3. Customization.

SELF-CHECK EXERCISE – II

3. What do you call a practice in logistics of unloading materials from an incoming semi-trailer truck or rail car and loading the materials in outbound trailers with little or no storage in between?

4. ______ is the branch of military science having to do with procuring, maintaining and transporting material, personnel and facilities.

Ql. What is 'Supply Chain Management'?
Q2. Discuss the concept of global SCM. Give examples.

12.6 GLOSSARY

- **Private Carrier:** It provides transportation or delivery of goods or services for a single entity, often a corporation.
- **Common Carrier:** It is a business that transports people, goods, or services and offers its services to the general public under license or authority provided by a regulatory body.
- **Third-party Logistics Provider (abbreviated 3PL):** It is a firm that provides outsourced or "third party" logistics services to companies for part, or sometimes all of their supply chain management function.

  Product Lifecycle Management (PLM): It is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal.
- **Benchmarking:** It is the process of comparing the cost, cycle time, productivity, or quality of a specific process or method to another that is widely considered to be an industry standard or best practice.
- **Process Integration:** A holistic approach to process design which considers the interactions between different unit operations from the outset, rather than optimizing them separately. This can also be called integrated process design or process synthesis.

- **Best Practice:** It asserts that there is a technique, method, process, activity, incentive or reward that is more effective at delivering a particular outcome than any other technique, method, process, etc.
- **Reverse Logistics:** It stands for all operations related to the reuse of products and materials. It is "the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.

12.7 KEYWORDS

Logistics, Benchmarking, Supply chain management, Process integration, Reverse logistics.

12.8 EXERCISES

12.8.1 SHORT QUESTIONS

1. Explain the concept of supply chain management (SCM).
2. What are the problems associated with supply chain?
3. Elaborate the operational activities of supply chain management.
4. How creation era shows the development in supply chain?

12.8.2 LONG QUESTIONS

1. What are the functions and problems of supply chain management?
2. What are the recent developments in the field of Supply Chain Management?
3. Explain the supply chain business process integration.

12.9 ANSWERS TO SELF-CHECK EXERCISES

1. Supply Chain Management; 2. Channel Partner; 3. Cross-docking; 4. Logistics.

12.10 SUGGESTED READINGS

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MBA-DE(Second Year) **IM 311**
Semester-III **INVENTORY MANAGEMENT**
Lesson No. 13 **AUTHOR: Dr. DYAL BHATNAGAR**

ROLE OF OPERATIONS RESEARCH IN INVENTORY MANAGEMENT

STRUCTURE

13.0 OBJECTIVES

After reading this chapter, the reader should be able to:

- Understand the concept of operations research and its role in inventory management
- Understand the concept of linear programming and its role in inventory management
- Understand the concept of queuing theory and its role in inventory management.

13.1 OVERVIEW

Operational Research, is an interdisciplinary branch of applied mathematics and formal science that uses methods such as mathematical modeling, statistics, and algorithms to arrive at optimal or near optimal solutions to complex problems. It is typically concerned with optimizing the maxima (profit, assembly line performance, crop yield, bandwidth, etc.) or minima (loss, risk, etc.) of some objective function. Operations research helps management achieve its goals using scientific methods.

Some of the primary tools used by operations researchers are statistics, optimization, probability theory, queuing theory, game theory, graph theory, decision analysis, and simulation. Because of the computational nature of these fields, OR also has ties to computer science, and operations researchers use custom-written and off-the-shelf software.

13.2 SCOPE OF OPERATIONS RESEARCH

Examples of applications in which operations research is currently used include:

- Critical path analysis or project planning: identifying those processes in a complex project which affect the overall duration of the project.
- designing the layout of a factory for efficient flow of materials.
- managing the flow of raw materials and products in a supply chain based on uncertain demand for the finished products.
- efficient messaging and customerresponse tactics.
- robotizing or automating human-driven operations processes.
- globalizing operations processes in order to take advantage of cheaper materials, labor, land or other productivity inputs.
- managing freight transportation and delivery systems scheduling:
  - personnel staffing
  - manufacturing steps
  - project tasks
  - network data traffic: these are known as queueing models or queueing systems.
  - sports events and their television coverage
- blending of raw materials in oil refineries.
- determining optimal prices, in many retail and B2B settings, within the disciplinesof pricing science.

13.3 LINEAR PROGRAMMING PROBLEMS

In mathematics, **linear programming** (LP) is a technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints. Informally, linear programming determines the way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model and given some list of requirements represented as linear equations.

Linear programs are problems that can be expressed in canonical form:

Maximize

Subject to

represents the vector of variables (to be determined), while and are vectors of (known) coefficients and is a (known) matrix of coefficients. The expression to be maximized or minimized is called the objective function (in this case). The equations are the constraints over which the objective function is to be optimized.

Linear programming can be applied to various fields of study. Most extensively it is used in business and economic situations, but can also be utilized for some engineering problems. Some industries that use linear programming models include transportation, energy, telecommunications, and manufacturing. It has proved useful in modeling diverse types of problems in planning, routing, scheduling, assignment, and design.

13.3.1 USES

Linear programming is a considerable field of optimization for several reasons. Many practical problems in operations research can be expressed as linear programming problems. Certain special cases of linear programming, such as *network flow* problems and*multicommodity flow* problems are consider important enough to have generated much research on specialized algorithms for their solution.

A number of algorithms for other types of optimization problems work by solving LP problems as sub-problems. Historically, ideas from linear programming have inspired many of the central concepts of optimization theory, such as *duality, decomposition,* and the importance of *convexity* and its generalizations. Likewise, linear programming is heavily used in microeconomics and company management, such as planning, production, transportation, technology and other issues. Although the modern management issues are ever-changing, most companies would like to maximize profits or minimize costs with limited resources. Therefore, many issues can boil down to linear programming problems.

13.3.2 STANDARD FORM

Standard form is the usual and most intuitive form of describing a linear programming problem. It consists of the following three parts:

- **A linear function to be maximized**
  e.g., maximize $c_1x_1 + c_2x_2$
- Problem constraints of the following form
  e.g., $a_{11}x_1 + a_{12}x_2 \le b_1$
  $a_{21}x_1 + a_{22}x_2 \le b_2$
  $a_{31}x_1 + a_{32}x_2 \le b_3$
- Non-negative variables
  e.g., $x_1 \ge 0$
  $x_2 \ge 0$

The problem is usually expressed in matrix form, and then becomes: maximize

$C^T X$ subject to $Ax \le B$, $x \ge 0$

Other forms, such as minimization problems, problems with constraints on alternative forms, as well as problems involving negative variables can always be rewritten into an equivalent problem in standard form.

In inventory management, linear programming can be made use of in many situations, but its main contribution has been in transportation-distribution of raw materials and/or finished goods to their destinations. We shall consider quite a trivial transportation problem to show what the essence of the problem is. This programming technique, no doubt a powerful tool of optimality analysis has many applications, such as, in production, scheduling and inventory control, personnel assignment, etc. However, typical problems are characterized by:

1. One plan of action must be selected out of many alternatives,
2. the objective is to maximize or minimize a critical function, such as, maximizing profit or minimizing cost, subject to certain restrictions, and
3. the relationship of variables in the problems are linear or they are capable of being converted into a linear relationship.

13.3.3 AN EXAMPLE

A multinational company has two factories that ship three regional warehouses. The costs of transportation per unit are:

Transportation costs (Rs)

Warehouse	Factory	
	FI	F2
W1	2	4
W2	2	2
W3	5	3

Factory F2 is old and has a variable manufacturing cost of Rs. 20 per unit. Factory FI is modern and produces for Rs. 10 per unit. Factory F2 has a monthly capacity of 250 units, and factory FI has a monthly capacity of 400 units. The requirements at the warehouses are: _________

Warehouse	Requirement
W1	200
W2	100
W3	250

The logistics manager wants to know that how should each factory ship to each warehouse in order to minimize the total cost. For the purpose the total cost matrix (manufacturing plus transportation is given below.

	Warehouse			Availability
Factory	W1	W2	W3	
FI	12	12	15	400
F2	24	22	23	250
Requirement	200	100	250	550/650

This problem can be converted into a linear programming problem as follows:

Let x_{ij} be the quantity shipped from ith factory to jth warehouse. The linear programming problem is:

Minimize $Z = 12x_{11} + 12x_{12} + 15x_{13} + 24x_{21} + 22x_{22} + 23x_{23}$

Subject to

$x_{11}+x_{12}+x_{13} \leq 400$

$x_{21} + x_{22} + x_{23} \leq 250$

$x_{11} + x_{21} = 200$

$x_{12} + x_{22} = 100$

$x_{13} + x_{23} = 250$

$x_{ij} \geq 0$ for I = 1, 2 and j = 1, 2, 3

Such a linear programming problem can be solved using simplex method or the transportation models can also be used for solving such problems.

SELF-CHECK EXERCISE – I

1. _______ is a technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints.

2. The study of problems in which one seeks to minimize or maximize a real function by systematically choosing the values of real or integer variables from within an allowed set is called _______.

13.4 QUEING THEORY

Queueing theoryis the mathematical study of waiting lines (or queues). The theory enables mathematical analysis of several related processes, including arriving at the (back of the) queue, waiting in the queue (essentially a storage process), and being served by the server(s) at the front of the queue. The theory permits the derivation and calculation of several performance measures including the average waiting time in the queue or the system, the expected number waiting or receiving service and the probability of encountering the system in certain states, such as empty, full, having an available server or having to wait a certain time to be served.

13.4.1 ELEMENTS OF QUEUING SYSTEM

13.4.1.1 Arrival Process

1. **According to Source:**The source for a queuing system can be finite or infinite. The number of potential customers arriving at a supermarket can be taken as infinite, whereas, ten machines in a factory requiring repairs in a factory would exemplify finite population.
2. **According to Numbers:**The material may arrive for service individually or in groups. For example, in a repair shop the material would reach individually as compared to an assembly shop, where the material to be assembled would reach in groups.
3. **According to Time:**Material may arrive in the systemat known times, or they might arrive in a random manner. The queuing models where arrival time is known are categorized as 'deterministic models’ and are easier to handle. In contrast where arrival time is unknown the ’probabilistic models’ are used. Although, the arrivals might follow any pattern, the frequently employed assumption, which adequately supports many real-world situations, is that the arrivals axe Poisson distributed. The Poisson process has been discussed in detail in an ensuing section.

13.4.1.2 Service System

There are two aspects of a service system: (a) structure of the service system, and (b) the speed of service.

a) **Structure of the Service System:**By the structure of the service system, we mean how the service facilities exist. There are several possibilities, such as

- A single service facility,
- Multiple, parallel facilities with single queue,
- Multiple, parallel facilities with multiple queues, and
- Service facilities in a series.

b) **Speed of Service:**In a queuing system, the speed with which service is provided can be expressed in either of two ways - as service rate and as service time. The service rate describes the number of materials/items serviced during a particular time period. The service time indicates the amount of time needed to service materials/items. Service rates and times are reciprocals of each other and either of them is sufficient to indicate the capacity of the facility. Generally, however, we consider the service time only.

If these service times are known exactly, the problem can be handled easily. But, as generally happens, if these are different and not known with certainty, we have to consider the distribution of the service times in order to analyze the queuing system. Generally, the queuing models are based on the assumption that service times are exponentially distributed about some average service time. The exponential distribution has been discussed in detail in an ensuing section.

13.4.1.3 Queue Structure

Here are details of four queueing structures which can be used in various fields of inventory management:

First in First Out

This principle states that items/customers are served one at a time and that the item/ customer that has been waiting the longest is served first.

Last in First Out

This principle also serves customers one at a time, however the item/customer with the shortest waiting time will be served first.

Processor Sharing

Customers are served equally. Serving capacity is shared between items/customers and they all effectively experience the same delay.

Priority

Items/customers with high priority are served first.

These queuing criteria can be extensively used in various aspects of inventory control and management, such as, scheduling of units of materials to be served at a machine or at a manual service counter or issuing of material at the stores department for avoiding delays at crucial production points. The principles of queuing theory can also be used in for arrival of trucks to carry material from warehouses and factories to a market, where the service facility will be the loading crew and the loading equipment.

Based on above discussion some formulae can be mentioned here:

If, Arrival rate is denoted by 'λ'

And, service rate be denoted as 'μ'

Then, service time required for a single unit (traffic intensity) is λ/μ

Thus, Idle time will be $1 - \lambda/\mu$

Expected number of material/items in a queue will be $\lambda^2/\mu(\mu - \lambda)$

and, mean waiting time in a queue can be found as $l/(\mu - \lambda)$

13.4.2 ROLE OF POISSON PROCESS, EXPONENTIAL DISTRIBUTIONS

A useful queueing model both (a) represents a real-life system with sufficient accuracy and (b) is analytically tractable. A queueing model based on the Poisson process and its companion exponential probability distribution often meets these two requirements. A Poisson process models random events (such as a customer arrival, a request for action from a web server, or the completion of the actions requested of a web server) as emanating from a memoryless process. That is, the length of the time interval from the current time to the occurrence of the next event does not depend upon the time of occurrence of the last event. In the Poisson probability distribution, the observer records the number of events that occur in a time interval of fixed length. In the (negative) exponential probability distribution, the observer records the length of the time interval between consecutive events. In both, the underlying physical process is memoryless.

Models based on the Poisson process often respond to inputs from the environment in a manner that mimics the response of the system being modeled to those same inputs. The analytically tractable models that result yield both information about the system being modeled and the form of their solution. Even a queueing model based on the Poisson process that does a relatively poor job of mimicking detailed system performance can be useful.

The fact that such models often give "worst-case" scenario evaluations appeals to system designers who prefer to include a safety factor in their designs. Also, the form of the solution of models based on the Poisson process often provides insight into the form of the solution to a queueing problem whose detailed behavior is poorly mimicked. As a result, queueing models are frequently modeled as Poisson processes through the use of the exponential distribution.

13.4.3 LIMITATIONS OP MATHEMATICAL APPROACH

Classic queueing theory is often too mathematically restrictive to be able to model all real-world situations exactly. This restriction arises because the underlying assumptions of the theory do not always hold in the real world.

For example; the mathematical models often assume infinite numbers of customers, infinite queue capacity, or no bounds on inter-arrival or service times, when it is quite apparent that these bounds must exist in reality. Often, although the bounds do exist, they can be safely ignored because the differences between the real-world and theory is not statistically significant, as the probability that such boundary situations might occur is remote compared to the expected normal situation. In other cases, the theoretical solution may either prove intractable or insufficiently informative to be useful.

Alternative means of analysis have thus been devised in order to provide some insight into problems which do not fall under the mathematical scope of queueing theory, though they are often scenario-specific since they generally consist of computer simulations and/or of analysis of experimental data.

SELF-CHECK EXERCISE – II

3. Name one of the elements of the queuing system.

4. Customers with high priority are served first in which queue structure?

13.5 GLOSSARY

- **Operational Research:** It is an interdisciplinary branch of applied mathematics and formal science that uses methods such as mathematical modeling, statistics, and algorithms to arrive at optimal or near optimal solutions to complex problems.
- **Linear Programming (LP):** It is a technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints. Informally, linear programming determines the way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model and given some list of requirements represented as linear equations.
- **Optimization:** It refers to the study of problems in which one seeks to minimize or maximize a real function by systematically choosing the values of real or integer variables from within an allowed set.
- **Constraint:** It is a condition that a solution to an optimization problem must satisfy. There are two types of constraints: equality constraints and inequality constraints. The set of solutions that satisfy all constraints is called the feasible set.
- **Queueing theory:** It is the mathematical study of waiting lines (or queues). The theory enables mathematical analysis of several related processes, includingarriving at the (back of the) queue, waiting in the queue (essentially a storage process), and being served by the server(s) at the front of the queue.

13.6 KEYWORDS

Linear programming, Constraint, Queuing Theory,Poisson Distribution, Exponential Distribution

13.7 EXERCISES

13.7.1 SHORT QUESTIONS

1. Explain the scope of operations research.
2. How do you formulate a linear programming problem.
3. What are the aspects of a service system?
4. Explain the elements of queuing structure.

13.7.2 LONG QUESTIONS

1. How did the concept of operation research evolved? What is the role of operations research in inventory management?
2. What is linear programming? How it can be applied in inventory management?
3. What is Queuing theory? How it can be applied in inventory management?

13.8 ANSWERS TO SELF-CHECK EXERCISES

1. Linear programming; 2. Optimization; 3. Arrival procedure; 4. Priority

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INVENTORY INFORMATION SYSTEM AND ROLE OF COMPUTERS IN INVENTORY MANAGEMENT

STRUCTURE

14.0 INVENTORY INFORMATION SYSTEM

A Computerized Inventory Management System is a type of management software that performs functions in support of management and tracking of inventory related activities. Computerized Inventory Management System systems automate most of the logistical functions performed by maintenance staff and management. Computerized Inventory Management System systems come with many options and have many advantages over manual maintenance tracking systems. Depending on the complexity of the system chosen, typical MMS functions may include the following:

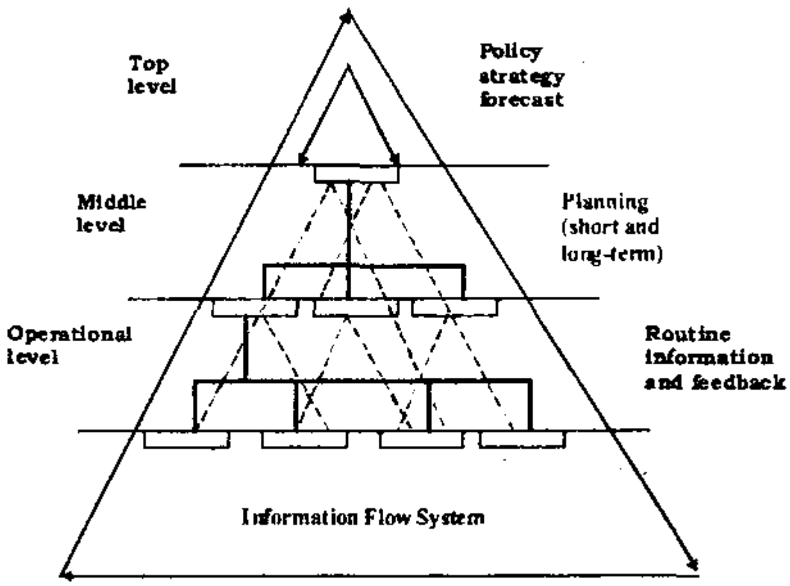
- Work order generation, prioritization, and tracking by equipment/component.
- Historical tracking of all work orders generated which become sortable by equipment, date, person responding, etc.
- Tracking of scheduled and unscheduled maintenance activities.
- Storing of maintenance procedures as well as all warranty information by component.
- Storing of all technical documentation or procedures by component.
- Real-time reports of ongoing work activity.
- Calendar- or run-time-based preventive maintenance work order generation.
- Capital and labor cost tracking by component as well as shortest, median, and longest times to close a work order by component.
- Complete parts and materials inventory control with automated reorder capability.
- PDA interface to streamline input and work order generation.
- Outside service call/dispatch capabilities.

Many Computerized Inventory Management System programs can now interface withexisting energy management and control systems (EMCS) as well as property management systems. Coupling these capabilities allows for condition-based monitoring and component energy use profiles.

An organization is primarily a system of people, methods and means to attain some pre-determined objectives. The final objective sought to be achieved by planned organizational change is a new state of equilibrium for the proper functioning of organizational system. In the simple language all the significant components in the organizational system (socio- technical) are in a state of adjustment built in to the changed state (if it did not exist previously), is a tendency towards movement (change), development and growth. A change may be brought by many means, including natural organizational or evolutionary change, that is to say a change, that is not the result of deliberate organizational effort. But, in the context of planned organizational change the concept of integrated MIS is sure to act as a change agent, being both structural and optional.

However, the efficient functioning of any organizational system largely depends upon a continuous process of information flow in which information are received, stored, processed and exchanged. Such ^n information system is again the combined effort of the people, equipment used (hardware as it is called in the computer language), processing facility (software) and the procedure, which are aimed at meeting the information requirements of the organization.

Many managements live in a make-believe word that an integrated MIS can be developed without developing an advocate management system. A management system is the organizational arrangement, structure and procedure for advocate planning and control with clear-cut and established objective. Only within the management structure and framework, can a good MIS be designed and developed. Only the MIS can provide the needed information in the right form, at right time and right place.



Information Flow...............................
Flow of Authority...............................

Fig 1: Information flow and feedback in a three-tier management structure.

levels in which information are needed for decision making. The first level may be said to be at the top-level management, where a summarized report is sufficient. At the second level, that is to say at the middle management level, the information requirements are of control level in nature, which may be described as exception report. At the third level, which needs day- to-day conformation, where formal reporting at fixed intervals is in the nature of routine procedure of system. The information requirements are numerous. At this level, information requirements are optional in character and, therefore, they are needed largely for the purpose of operational control. Therefore, this level needs a continuous information-flow. Here, in reality, continuous information flow with quick feedback is the objectivity test for inventory management. The frequency and the number of information handled are the test criteria for efficient flow of materials for operational purposes at the third level, whereas 'management by exception' and 'information by summary' are the governing principal at the second and the first levels respectively, of the information pyramid.

14.1 INFORMATION FLOW VS INVENTORY FLOW

General information flow chart is designed indicating the general structure of the integrated information system. This information flow system can then reflect the design efforts for

1. Setting objectives
2. Establishing constraints, and
3. Determining the information needs and sources.

However, it may be noted that specific steps which have gone into processing the data and the nature of equipment and people involved, are also extremely important because they provide the foundation upon which detailed specifications will follow.

The way in which an integrated MIS works and the framework within which it operates is illustrated in the figure 2.

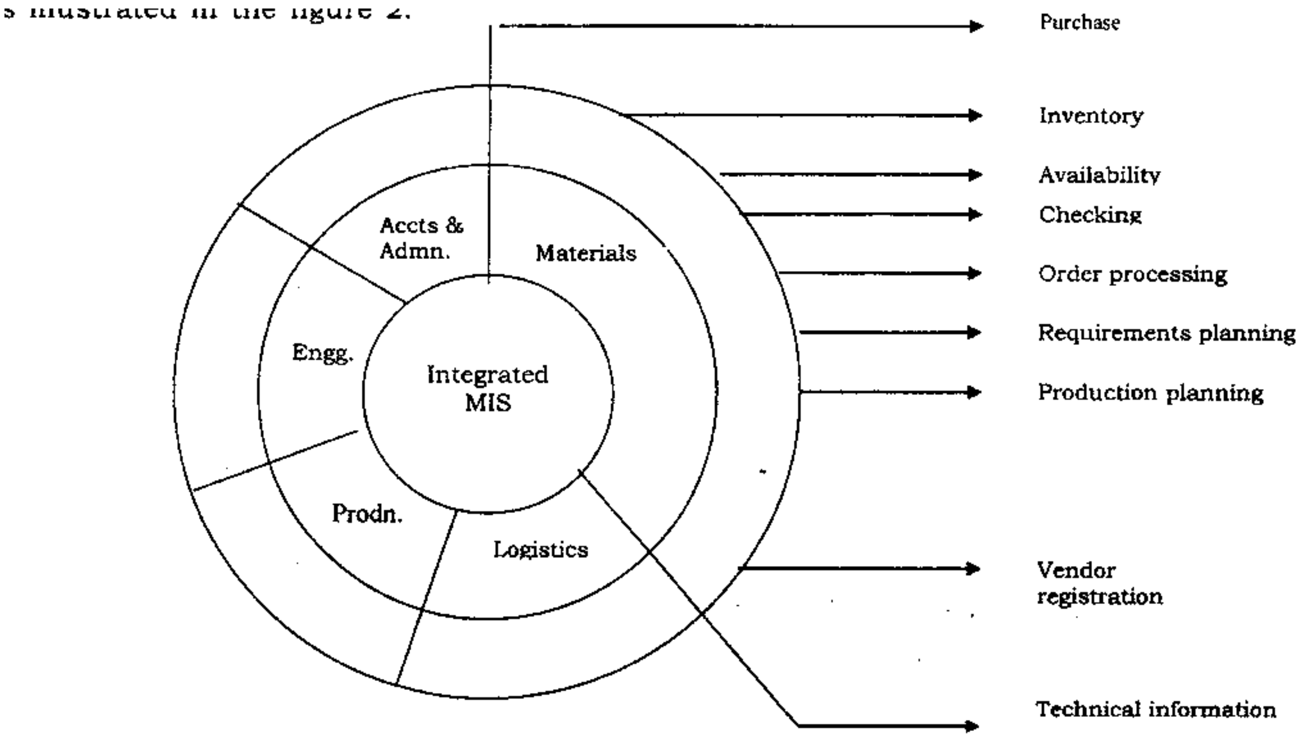


Fig. 2 : Framework for operation of integrated MIS

It must be mentioned however, that before an MIS is designed and developed, it should be validated by cost benefit analysis covering all the aspects in their entirety. Integrated inventory information system cannot be, however, developed in isolation and implemented all at once. Important as it is its successful development and implementation necessitates elaboration of the total process of information flow and the total integral concept of MIS, along with the total organizational need. This can be developed step by step in order to step up the process. The total information system of stock registration, control, movement and flow of materials must first be analyses by splitting up the information in such areas as:

1. materials, suppliers, components and/or parts list information,
2. capacity planning and manufacturing instructions,
3. material requirement planning and materials bill explosion,
4. production scheduling and planning,
5. procurement and purchase planning.

The traditional way of handling such information is through interflow of information between related departments but with the use of computerized information system this has become increasingly data based, which permits the physical separation and retrieval of information from programs that are used to process the information data. To sum up, an integrated approach to MIS is intended to ensure that data processing gives due recognition and consideration to the whole information requirements of the company, operating as it does as an integral part of organization.

SELF-CHECK EXERCISE – I

1. What do we call a type of management software that performs functions in support of management and tracking of inventory?

2. What is the first step of designing the inventory information system?

14.2 COMPUTER INTEGRATED MIS AND INVENTORY MANAGEMENT

Computerized integrated MIS has opened up vast possibilities for inventory management. As the objective of inventory management is efficient flow of materials at economic cost, MIS can be directed for use by the different sectors of inventory management organization for controlling the materials flow and planning for efficient use of materials for manufacture. No doubt, inventory management is a part of the total MIS organization. Structure and information needs are inextricably interlaced and interwoven. An analogy between the human body and the central nervous system is appropriate. This system takes into view the integrative concept of information flow, where each organizational entity is seen as a system for information requirements with the components of input, processing, storage and output. Each again is connected with each other through the information and communication channels and each organizational entity becomes a decision-making point.

The computer system for MIS has as its basic cycle: hardware, software, personal and operations. This basic cycle can be broken down into many parts. However, it is not thought necessary here to delay it more elaborately on the schematic representation of the computer system. Nor is it necessary in order to comprehend the rudiments of the computer system for inventory management. Suffice it is to say that in broad terms the concurrent activities in hardware, software and personal acquisition are all pointed towards the operational phase of the system. As the operation commences, certain cybernetic feedback occurs, and various phases are repeated, though mostly at a higher level of accomplishment.

Management information service is for management. The whole information system is a management tool, but too often this is forgotten.

Thus, the neglected facet of MIS is that without management it is useless. Management must be bent on utilizing the information which it obtains. MIS is therefore, a means to an end and not an end itself. Management is often plugged with lack of useful information at the propitious time. Faced with such shortcomings many managers substitute a more easily attainable goal for the intuitively correct ones. However, as MIS is oriented towards the needs of management, MIS enhances the ability of management. MIS enhances the ability of management by delivering the decision supporting information to a cognizant management.

14.3 PITFALLS OF COMPUTERIZED INVENTORY MANAGEMENT SYSTEM

While Computerized Inventory Management System can go a long way toward automating and improving the efficiency of most operations management programs, there are some common pitfalls. These include the following:

- **Improper selection of a Computerized Inventory Management System vendor.**This is a site-specific decision. Time should be taken to evaluate initial needs and look for the proper match of system and service provider.
- **Inadequate training of the operations management administrative staff on proper use of the Computerized Inventory Management System.**This staff needs dedicated training on input, function, and maintenance of the Computerized Inventory Management System. Typically, this training takes place at the customer's site after the system has been installed.
- **Lack of commitment to properly implement the Computerized Inventory Management System.**A commitment needs to be in place for the start-up/ implementation of the Computerized Inventory Management System. Most vendors provide this as a service and it is usually worth the expense.
- **Lack of commitment to persist in Computerized Inventory Management System use and integration**. While Computerized Inventory Management System provides significant advantages, they need to be maintained. Most successful Computerized Inventory Management System installations have a "champion" of its use who 'ushers and encourages its continued use.

14.4 COMPUTERIZED INVENTORY MANAGEMENT SYSTEM BENEFITS

One of the greatest benefits of the Computerized Inventory Management System is the elimination of paperwork and manual tracking activities, thus enabling the building staff to become more productive. It should be noted that the functionality of a Computerized Inventory Management System lies in its ability to collect and store information in an easily retrievable format.

A Computerized Inventory Management System does not make decisions; rather it provides the O&M manager with the best information to affect the operational efficiency of a facility.

Benefits to implement a Computerized Inventory Management System include the following:

- Detection of impending problems before a failure occurs resulting in fewer failures and customer complaints.
- Achieving a higher level of planned maintenance activities that enables a more efficient use of staff resources.
- Affecting inventory control enabling better spare parts forecasting to eliminate shortages and minimize existing inventory.
- Maintaining optimal equipment performance that reduces downtime and results in longer equipment life.

As reported in A.T. Kearney's and Industry Week's survey of 558 companies that are currently using a computerized maintenance management system (DPSI 1994), companies reported an average of: 28.3% increase in maintenance productivity 20.1% reduction in equipment downtime 19.4% savings in lower material costs 17.8% reduction in MRO inventory 14.5 months average payback time.

SELF-CHECK EXERCISE – II

3. The total information system of _______, control, movement and flow of materials must first be analyzed by splitting up the information in different areas.

4. Improper selection of a _______ can be a drawback as he/she needs to understand the requirements first.

14.5 GLOSSARY

- **Management Information System (MIS):** It is a subset of the overall internal controls of a business covering the application of people, documents, technologies, and procedures by management accountants to solving business problems such as costing a product, service or a business-wide strategy.
- **Inventory Information System:** A Computerized Inventory Management System is a type of management software that performs functions in support of management and tracking of inventory related activities,
- **Computerized Inventory Management System:** A computerized Inventory management system is a type of management software that performs functions in support of management and tracking of inventory management activities.

14.6 KEYWORDS

Inventory Information System, Management Information System, Inventory Flow, Information Flow, Integrated MIS.

14.7 EXERCISES

14.7.1 SHORT QUESTIONS

1. What is Inventory Information System?
2. What is a computerized inventory management system?

14.7.2 LONG QUESTIONS

1. How the flow of information and inventory in an organization are related?
2. What are the merits and demerits of computerized inventory management system?

14.8 ANSWERS TO SELF-CHECK EXERCISES

1. Inventory Information System; 2. Setting Objectives; 3. Stock registration; 4. System Vendor.

14.9 SUGGESTED READINGS

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