UNIT 5 INVENTORY MANAGEMENT AND CONTROL

Structure

5.1 INTRODUCTION

Inventory is simply a stock of physical assets having some economic value which can be either in the form of material, money or labour. Inventory is also known as an idle resource as long as it is not utilised. Inventory may be regarded as those goods which are procured, stored and used for day-to-day functioning of the organisation.

Inventory control is the technique of maintaining stock items at desired levels. In other words, inventory control is the means by which material of the correct quality and quantity is made available as and when it is required with due regard to economy in the storage costs, ordering costs, set up costs, manufacturing costs, purchase prices and working capital.

There are following three main issues involved in inventory management and control :

- How and what to prioritize for procurement ?
- How much to order ?
- When to order ?

In this unit, these issues have been discussed and their associated techniques are also described in detail.

Objectives

After studying this unit, you should be able to

- describe various concepts pertaining to inventory,
- explain the needs, objectives and functions of inventory,
- discuss various factors affecting inventory,
- apply classification methods as per the situation,
- develop simple Economic Order Quantities (EOQ) model, and
- describe 'P' and 'Q' systems of inventory.

5.2 CONCEPTS OF INVENTORY

Inventory is a part and parcel of every facet of business life. Without it, no business activity can be performed, whether it being a service organisation like hospital and banks etc. or manufacturing or any trading organisations. Inventories play an essential and pervasive role in any organisation because thay make it possible :

- to get right amount of stock at exact time of need to ensure continuous and smooth production,
- to avoid the physical impossibility and economical impracticability of getting right amount of stock at exact time of need,
- to order large quantities of goods, materials or components from the supplier at advantageous prices,
- to maintain more stable operating or work force levels,
- to take advantage of shipping economics,
- to plan overall operation strategy through decoupling of successive stages in the chain of aquiring goods, shipping to site warehouses and finally making it available to user department as and when required,
- to provide means against hedging against future price and delivery uncertainties,
- to make effective use of available capital and/or storage space, and
- to achieve favourable return on investment.

5.2.1 Need for Inventory and its Control

Inventories of materials are definitely needed by all construction agencies – big or small. But inventories tend to become big without proper control. For any organisation, there is always a need to maintain some safety or buffer stock in order to maintain the smooth flow of materials without impairing production. But, as more and more stocks of materials are held, this not only entails greater investment, but carrying and other associated costs also increase considerably. On the other hand, if minimum inventory is held, with the increase in frequency of buying, the cost of ordering and processing increases. Also the cost of stock-out poses economic problem. Thus, the inventory control is a major materials management function which requires the reduction in materials costs without impairing operational efficiency and, therefore, needs a careful attention.

The analytical approach to inventory control is fundamentally based on cost-study. It is, in fact, balancing of some opposite costs which is well enunciated in EOQ formulation, but further refinements are also necessary as the situation dictates. Sometimes, there are several costs associated with inventory, but there is always one in one direction. As mentioned earlier, the resolution of the problem generally requires two basic questions to be answered : (a) how often to order, and (b) how much and when. Determining these two basic question-answers precisely requires cost-information and the solution lies in balancing opposite costs in order to find an optimal solution. These aspects have been covered in latter sections of this unit.

Need of Inventory Control in Construction

As shown in Table 4.1, out of the total cost of a construction project, above 75% cost is associated with the cost of materials used. Therefore, an effective control over the materials cost is required for reducing the overall cost of construction. And in fact, the cost of materials can be controlled by controlling the inventory of the tools, equipment and materials.

Periodical inventory of the tools, equipment and materials should be taken up in every site to know the exact position and condition of the materials, tools and plant. Its main advantages are as follows :

- any excess material not presently required can be shifted to other site for use,
- before writing any requisition previous balance quantity may be accounted for and order may be placed for what is needed,
- any shortfall or damages to the material can be brought to notice of the higher authorities,

- repairs or modifications to storing system can be done if required,
- cross-checking of the records maintained by the store-keeper can be done,
- consideration of percentage of wastage for various materials can be studied and standardised to avoid excess inventory; and
- purchasing of material in stages as per work programme can be followed to avoid additional financial burden due to excess inventory.

5.2.2 Objectives of Inventory Control

As inventory is an essential part of any organisation, it consists of many items running into thousands. Systematic management and control of inventory for all the items is a challenging job. Main objectives of inventory control are as follows :

- to maintain the overall investment in inventory at the lowest level, consistent with operating requirements,
- to supply the product, raw material, sub-assemblies, semi-finished goods, etc. to its users as per their requirements at right time and at right price,
- to keep inactive, waste, surplus, scrap and obsolete items at the minimum level,
- to minimise holding, replacement and shortage costs of inventories and maximise the efficiency in production and distribution, and
- to reduce the risk inherent in treating inventory as an investment which is risky. For some items, investment may lead to higher returns and for others less returns.

Generally, the inventory and stock are regarded as synonymous. However, its original meaning is the list of stocked items. Such stock normally consists of following :

(a) direct items which is included in the finished product,

(b) indirect items which is not included in the finished product like cleaning materials, stationery, etc.

(c) supporting items directly supporting production like spares for the emergency generator, and

(d) reserved items which are committed to some specific purpose but need not be kept separate from other.

SAQ 1

(a) What is inventory control ? Why industry keeps inventory ?

(b) Why inventory control is essential for an organisation ?

(c) Why holding of inventory always tie up capital ?

(d) Discuss the various objectives of inventory control needed for an organisation.

SAQ 2

(a) How inventory control helps construction by reducing the overall cost of construction project ?

(b) Describe the important advantages of maintaining of inventory in a construction site.

5.3 FACTORS AFFECTING INVENTORY

As mentioned earlier, the major problems of inventory control are two, i.e. (a) How much to order ? and (b) When to order ? These can be answered by developing a model. An inventory model is based on the consideration of two main aspects of inventory, viz. the demand and the costs associated with that. Many factors related with these main issues are discussed in subsequent paragraphs.

Economic Parameters

These parameters usually include the following :

Purchase Price or Production Cost

The cost of the item is the money paid to the supplier for the item received or the direct manufacturing cost, if produced. It is normally equal to purchase price. When the market prices go on fluctuating, planning for inventory is based on the average price mostly taken as a fixed price. The price factor is of special interest when price discounts can be secured or when large production runs may result in a decrease in the production cost.

Selling Price

In some inventory situations, the demand may be affected by the quantity stocked. In such cases, the inventory model is based on a profit maximisation criterion which includes the revenue from selling the commodity. The unit selling price may be constant or variable, depending upon whether quantity discount is allowed or not.

Procurement Costs

These costs are those incurred on a purchase (known as ordering costs) or incurred as set up costs related with the initial preparation of a production system if manufactured. These costs vary directly with each purchase order placed or with the set up made and are usually assumed independent of the quantity ordered or produced. Procurement costs include costs of administration (such as salaries of the persons concerned, telephone calls, computer costs, postage etc.), transportation of items ordered, expediting and follow up, receiving and inspection of goods, processing payments etc. This cost is expressed as the cost per order or per set up.

Carrying (or Holding) Costs

The cost associated with carrying of stocks of items is called holding cost or storage cost or possession cost. Holding costs include handling cost, maintenance cost, wages, insurance, safety measures, warehouse rent, depreciation, theft, obsolescence, interest on the money locked-up, etc.

Considering all the above elements, the storage cost is expressed either as per unit of item held per unit of time or as a percentage of average rupee value of inventory held. The size of all these carrying costs usually, increases or decreases in proportion to the amount of inventory that is carried.

Cost of Operating the Information Processing System

As stock levels change, someone must update records either by hand or by computer. Where the inventory levels are not recorded daily, this operating cost is incurred in obtaining accurate physical counts of inventories. Such operating costs are more fixed than variable over a wide quantity (volume) range.

Shortage (or Stock out) Costs

These are penalty costs incurred as a result of running out of stock when the commodity is needed. One form of these costs is known as back-order on the selling side (or backlogging costs on the manufacturing side) when the unfilled demand can be satisfied at a later date, i.e. customer waits till he gets the supply. Another form of these costs is known as lost sales costs on the selling side (or no backlogging cost on the manufacturing side) when the unfilled demand is lost. It happens when the customer does not wait for the supply and goes elsewhere as shown in Figure 5.1

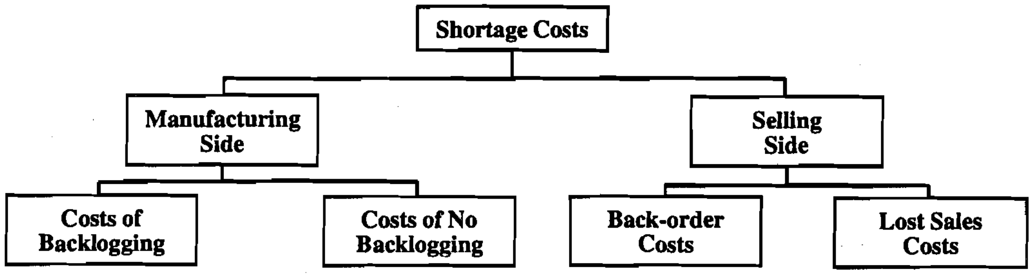


Figure 5.1 : Nature of Shortage Costs

These include the costs of production stoppage, overtime/idle time payments, expediting special orders at higher price, idle machine, loss of goodwill, loss of opportunity to sell, loss of profitability etc.

Demand

The demand pattern of a commodity may be either deterministic or probabilistic. In the deterministic case, it is assumed that the quantities needed over subsequent periods of time are known with certainty. This may be expressed over equal periods of time in terms of known constant demands or in terms of known variable demands. The two cases are referred to as static and dynamic demands respectively.

Probabilistic demand occurs when requirements over a certain period of time are not known with certainty but their pattern can be described by a known probability distribution. In this case, the probability distribution is said to be either stationary or non-stationary over time. These terms are equivalent to static and dynamic demands in the deterministic case.

The demand for a given period of time may be satisfied instantaneously at the beginning of the period or uniformly during that period. Instantaneous and uniform demand affects directly the total cost of holding inventory.

Ordering Cycle

This is concerned with the time taken to built up inventory. An ordering cycle may be identified as the time period between two successive placement of orders. This reckoning of time may be carried out in following two ways :

Continuous Review

Where a record of the inventory level is updated continuously until a certain lower limit is reached at which point a new order is placed. This is referred to sometimes as the two-bin system.

Periodic Review

Where orders are placed usually at equally spaced intervals of time.

Delivery Lag or Lead Time

When the need of the material is felt and an order is placed, it may be delivered instantaneously or it may require sometime before delivery is effected. The time between the placement of the requisition for an item and its receipt for actual use is called delivery lag or lead time. In general, lead time has four components, viz. administrative lead time, supplier's lead time, transportation lead time and inspection lead time. While administrative lead time and inspection lead time can be fixed, the supplier's lead time and transportation lead time can never be fixed. In general, the lead time may be deterministic or probabilistic.

Time Horizon

This is also known as the planning period over which inventory is to be controlled. The planning period may be finite or infinite. Mostly inventory planning in an enterprise is done on an annual basis.

Number of Supply Echelons

There may be several stocking points in the inventory system. These points are organised such that one point acts as a supply source for some other points. For example, the factory supplies the products to warehouse, and the warehouse supplies to the retailer who, in turn, supplies to the customer. Each level is called an echelon in multi-echelon inventories. As illustrated in Figure 5.2, it shows products stocked at the various levels in the distribution system.

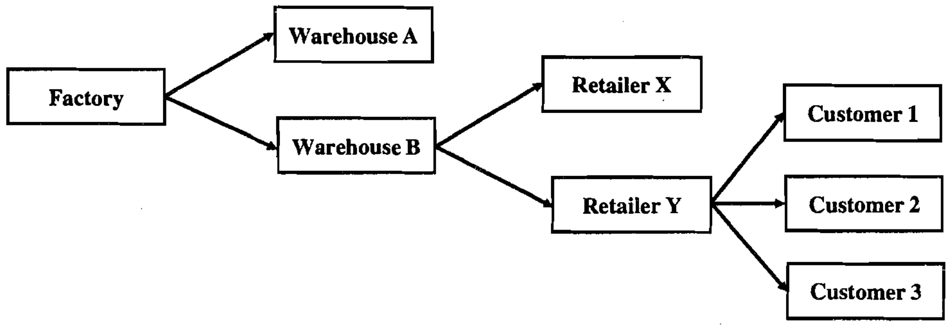


Figure 5.2 : Multi-echelon Supply System

Number of Stages of Inventory

When parts are stocked at more than one stage in the sequential production process, they are called multi-stage inventories.

Number of Items

An inventory system involves, generally, more than one commodity. The number of items held in inventory affect the system when these items compete for limited floor space or limited total capital.

Availability of Items

Sometimes supply position is badly affected due to various market situations which in turn affects the inventory system in an enterprise.

Government's/Company's Policy

For items to be imported as well as for other items like explosives, highly inflammable liquids and other hazardous items, the Government has laid down some rules. Similarly, a company may also lay down certain policies based on available capital etc. All these affect the level of inventories in any organisation.

All the above factors responsible for the development of inventory system are known as inventory characteristics. Major factors affecting the inventory system are demand, cost factors and lead time. Excepting these two, all other factors can be treated as completely known in an inventory system.

SAQ 3

(a) What are the costs associated with inventory ? What are the elements of different costs ?

(b) Which factor do you think most influences the inventory of industry and state the one which influences the least ?

5.4 WHAT TO PRIORITISE FOR PROCUREMENT ? (CLASSIFICATION METHODS)

Materials procurement and management requires grading of materials according to the importance or significance of the same. This can be based on many factors such as

- consumption value of the item (ABC Method)
- consumption rate of the item (XYZ-FSN Classification)
- ease of availability of the item (SDE and GOLF Methods)
- criticality of the item (VED/RAM/VEIN Method)
- combination of above factors (Multivariable Methods)
- mathematical modelling (Econometric Models)

Details of some of the methods based on above are given in subsequent paragraphs.

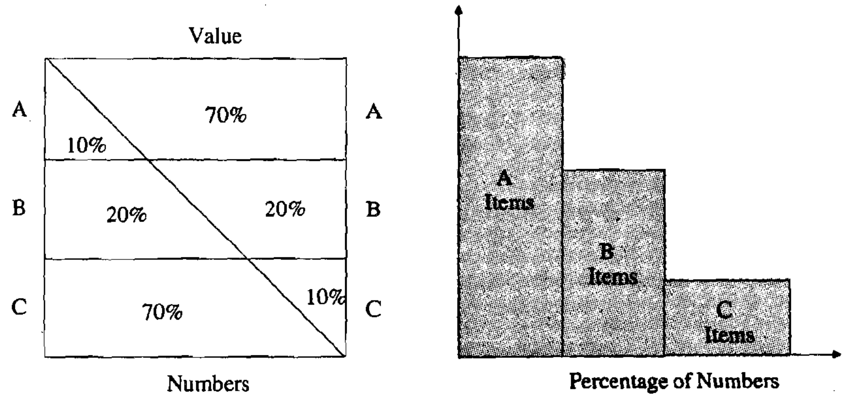
5.4.1 ABC Classification

In this method, "the value" of the items determines the amount of involvement that the department/organisation needs to pay towards its management. In a typical scenario, it has been observed that items can be grouped into three categories, i.e. A, B and C in accordance with the consumption value. This has been shown in Table 5.1 and Figure 5.3. This is an example only and the percentages can vary from case to case.

Table 5.1

Classification Category	Percentage of the Number of Items	Percentage of Annual Consumption Value
A	10	70
B	20	20
C	70	10

Therefore, we can say now that the efforts in managing items classified as 'A' should be comparably large when compared to others. Managing this category well should in all probability yield more significant savings in costs.



(a) ABC- Classification (Tabular Form)

(b) ABC–Classification (Frequency Form)

Figure 5.3 : ABC Classification of Inventories

This classification provides clear cut indications for fixing up the priorities of control of the items. 'A' class items must receive the attention first in every control operation, i.e. tight control, sound operating doctrine, attention of security etc.

How to Actually Do the Classification Process ?

The use of computers can be a significant help in classifying these items by multiplying the annual consumption with unit price. The exact cut of points of A, B and C depends from firm to firm. For example, if the number of items under category under A is very small then a higher percentage of items may be considered under A. It is also possible to plot them in a decreasing order of annual value of comsumption of the items and considering at each stage the cumulative value of consumption.

Another method can be to use a "High, Medium & Low" price method of grading.

It is advisable, however, to remove an item/items that take up a very high percentage of value into classification. For example, in a coal fired power plant, coal takes up nearly 80% of the value. Such situations require specific handling. "Once-in-a-while" categories also should be removed while categorising as they may skew the priorities if they are high value or require extensive development efforts like "custom made machinery" or require special storage uses, e.g. uranium storage requires special containers requiring extensive costs and efforts.

Drawbacks of the Method

By stressing only consumption value and not criticality or availability, the ABC method has significant drawbacks. For example, the piston rings of a generator may not fail in 10 years. But if it fails, it may stop or significantly hinder the work till spares and repair are arranged.

5.4.2 XYZ-FSN Classification

Consumption value of an item may not necessarily imply that the consumption rate is high. For example, a genset bought for a project may have high value but a low rate of consumption. A *jhadoo* (broom) on the other hand has low value but a high rate of consumption.

This procedure requires the following three steps :

Step 1 : The Materials are Graded into F, S and N Categories

Classify materials into F, S and N categories, i.e. fast moving (F), slow moving (S) and non-moving (N) categories. Say, items moved once in a year (for spares) or regularly consumed in case of raw materials, can be classified as fast moving (F). Spares moved once in two years or five years or raw materials moved once a year, may be called slow moving (S). Spares (other than critical items) which have not been drawn in a year may be considered non-moving items (N).

Step 2 : The Materials are Graded into X, Y and Z Categories

Items can be grouped into three categories, i.e. X, Y and Z in accordance with the "year-end stores inventory value". This has been elaborated in Table 5.2. This is an example only and the percentages can vary from case to case.

Table 5.2

Classification Category	Percentage of the Number of Items	Percentage of Year End Stores Inventory Value
X	10	70
Y	20	20
Z	70	10

Step 3 : A Matrix is Made between the FSN and XYZ Categorisations

In fact, a match is made between the speed of movement of the items and its value required in the inventory. The materials are classified accordingly (with × marks). As can be seen from Table 5.3 that this can help group the materials as per the priorities that can be made from this information.

Table 5.3

Category	Inventory Value		Movement Analysis		
	Item Code	Item Value	F	S	N
X Top 10% Number 70% Value	Item 1		×		
	Item 2				×
	⋮			×	
Y 20% Number 20% Value	Item m		×		
	Item n			×	
	⋮			×	
Z Low 70% Number 10% Value	Item p				×
	Item q			×	
	⋮				×

5.4.3 SDE and GOLF Methods

These methods classify the items according to the difficulty/problems faced in their procurement with respect to their required procurement times.

SDE Method

Here, 'S' stands for "scarce to obtain", 'D' stands for "difficult to obtain" and 'E' stands for "easy to obtain". Scarce can mean that production is made to order or very few vendors are available for differentiating the product. Easy means that plenty of products with a wide range of products is available. Lead times for different items in these categories can be ascertained in tabular form as shown in Table 5.4.

Table 5.4 : Lead Times Required in Different Categories

Classification	Lead Times		
	Long	Medium	Short
'S' Scarce items Item 1 Item 2 :			
'D' Difficult items Item 5 Item 6 :			
'E' Easy items Item 15 Item 16 :			

GOLF Method

Here, 'G' stands for "government controlled", 'O' stands for "open market", 'L' stands for "locally available", and 'F' stands for "foreign supplier or imported". Lead times for different items in these categories can be ascertained in tabular form as shown in Table 5.5.

Table 5.5 : Lead Times Required in Different Categories

Classification	Lead Times		
	Long	Medium	Short
'G' Government Controlled Items Item 1 Item 2 :			
'O' Open Market Items Item 5 Item 6 :			
'L' Locally Available Items Item 15 Item 16 :			
'F' Foreign or Imported Items Item 15 Item 16 :			

This method though less used but can be useful in framing general policies for procurement and also assigning responsibilities.

5.4.4 VEIN/VED/RAM Methods

This method of classification is very suitable for equipment and machinery. Here, the degree of importance is tackled at three levels, namely equipment level, spare parts level, and importance of degree of breakdown of machine/non-availability.

At the equipment level, the VEIN classification is done as follows :

V : Vital equipment

E : Essential equipment

I : Important equipment

N : Normal equipment

A "Vital" equipment is normally, a piece of equipment which is feeding a battery of downstream equipment, e.g. a generator at an offshore construction site. A "Normal" equipment may be something like say a "lawn-mover". "Essential" and "Important" equipment are in between above two extremities.

Similarly, spare parts contained in the equipment are classified as V, E and D where 'V' stands for "Vital", 'E' for "Essential", and 'D' for "Desirable". A vital spare may be piston ring of a truck while a desirable one can be the "indicating lamps".

The RAM aspect emphasises the importance of severity of repercussions in case of breakdown :

- R – stands for reliability factor – the equipment should NOT breakdown when in operation, e.g. the brakes of a truck. The stockout (non-avilability) costs are enormous.
- A – stands for the fact that the equipment may breakdown but it should be available for the specified period of time, e.g. a crane may breakdown while in operation but should be available for 95% of time it is used.
- M – maintainability factor states that the equipment or spare should be required for normal maintenance purpose only.

The above is very useful while ordering spare parts. The degree of importance reduces from a "vital equipment – vital part to normal equipment – desirable part". The procurement plan is thus planned accordingly. Due to its technical nature, it is technical people like engineers, designers etc. who plan this system. However, the end users, generally, tend to classify everything as vital and critical to play safe. Therefore, to ensure that this system takes time, frequent meetings and other convincing efforts are needed for the classification.

Finally, in this classification, a matrix is made between the VEIN, VED and RAM categorisations and is shown in Table 5.6.

Table 5.6

Equipment Requirement Classification		Spares Requirement Classification (VED)								
		Vital			Essential			Desirable		
		spare-1	spare-2	....	spare-15	spare-16	....	spare-n	spare-n+1	....
V Vital	eqpt - 1									X (M)
	eqpt -2		X (R)							
	:	X (R)							X (M)	
E Essential	eqpt - 9				X (A)					X (M)
	eqpt -10					X (M)				
	:									
I Important	eqpt - 22		X (A)							
	eqpt -23							X (M)		
	:					X (M)				
N Normal	eqpt -m	X (M)								
	eqpt -m+1								X (M)	
	:	X (M)					X (M)			

Legend
- (dark shading) = Reliability Factor (R)
- (dotted shading) = Availability Factor (A)
- (no shading) = Maintenance Factor (M)

5.4.5 Multi-variable (MV) Methods

Multi-variable (MV) methods are based on more complex models considering all factors, namely consumption value, availability, criticality etc. simultaneously. A matrix showing three-dimensional multivariable model is given in Table 5.7.

Table 5.7 : Three-dimensional Multivariable Model

	High Consumption Value Items		Low Consumption Value Items	
	Long Lead Time	Short Lead Time	Long Lead Time	Short Lead Time
Critical	1	2	3	4
Non-critical	5	6	7	8

In Table 5.7, now the cells may be considered individually to describe the characteristics treatment desired. By knowing the facts, the individual cell's characteristic can be defined. Some examples have been shown below :

Cell 3 contains "low consumption value – long lead time – critical" Items. They are critical from operations viewpoint. Therefore, the following treatment may be applied :

Purchase quantity may be large with annual ordering. The coverage can be large if working capital requirement is large, adequate shelf space is available and goods are not perishable. The stocking point should be numerous with minimum control as cost of control can get very high keeping in view the low value of the items. The service level issue expected should be 100% without stockouts (material getting finished). The clerical work involved in this should be minimum.

Cell 6 is the opposite to that constituted in Cell 3. This may be treated as follows :

The purchase quantity should be nil as the item is non-critical and has a high consumption value. They should be bought as and when required with the associated delays in procurement. Stockouts are possible and the concept of virtual zero inventory should be followed. All cost reduction experiences and experiments should be allowed and one of the ideal methods may be allowed to go in for even rate contract, and procurement should be allowed with minimum controls at the procurement level. Delegation of power to order may be sent to the lowest permissible level in the organisation.

Cell 1 and 2 contain "high consumption value – short lead time – critical" items. Following treatment may be applied :

Here, strict control is desired by developing methods of accurate forecasts. The ordering can be on a staggered basis with frequent weekly or monthly orders. Procedures and methods for follow up has to be developed for these items and more than one vendor should be cultivated. The MIS developed for these should be fast, simple to operate and accurate. Kardex or Bincard systems should be developed so that the stock position is known to all concerned personnels.

Thus, we see that a case specific scenario is developed by this multivariable method. The following aspects and systems need to be in place for the system to be effective :

(a) Purchase quantity,

(b) Follow up procedures,

(c) Safety stock,

(d) Average inventory calculations,

(e) Powers of delegation,

(f) Effective computer systems,

(g) Application of Value Engineering and other cost reduction methods,

(h) Development of new vendors,

(i) Reporting systems,

(j) Obsolescence detection and automatic updation systems,

(k) Quick and safe movement of items,

(l) Central purchase,

(m) Price, quality and demand forecasting methods,

(n) Consumption norms, and

(o) Working capital planning and budgetary control methods.

5.4.6 Econometric Methods

These methods are pure mathematical models of procurement and take virtually all variables into account. These methods require experienced material planners as guides who are very strong on statistical methods and procedures. In addition, application of these methods depend a lot on the computer systems available in the place and a very strong MIS department to keep them updated and running. These methods have a long development time and is a work unto itself. It may not be possible to use regular line managers and staff to develop it though their advice and guidance is very necessary. The disadvantage of these methods is that it is complex to understand and personnel may feel that they are working according to the responses made by a "computer monster".

SAQ 4

(a) Discuss different classification methods used for prioritising items for procurement.

(b) Describe merits and demerits of ABC classification.

(c) In what respect, SDE classification is different from GOLF classification ?

(d) Explain the classification procedure normally adopted for equipment and machinery and is primarily based on criticality of items.

5.5 HOW MUCH TO ORDER ? (EOQ – ECONOMIC ORDER QUANTITIES)

An efficient materials management system ensures that the stocks are maintained at optimum levels and in quantities that prevent interruption in flow of needed resources. The aim is to avoid the negative effects of both insufficient and excess stocks which can cause both operational and financial problems. Optimum inventories act as a cushion between the supply and demand variances. It is, therefore, necessary to study all categories of inventory – raw materials, work in process and finished goods inventory.

The determination of the right quantity assumes tremendous importance while satisfying conflicting views of

(a) not too much,

(b) not too little,

(c) minimising total cost, and

(d) maximising profitability.

Before deriving the EOQ model, some common terms which have been used in derivation are as follows :

Stockout : The situation in which a given item is required for the construction, repair or maintenance and is not in stock.

Stockout Costs : The costs incurred, directly or indirectly, when a given item is "stocked out". This may be directly when say, while laying a slab, the cement or sand is out of stock. In this situation, the labour loss (wages to be paid), costs of salaries of staff etc. are direct costs. Indirect costs may arise due to penalties (liquidatory damages) or damage to reputation.

Inventory Carrying Costs : It is the cost of maintaining a unit item in the inventory. This cost is composed of the cost of warehouse space, interest loss, cost of cleaning of stores and item cost, manpower required to maintain the inventory but excludes the cost going towards procurement.

Ordering Costs : It is the cost incurred in ordering a lot/unit item. This includes the costs towards inviting quotations, travel, inspection, quality checks, placing orders, follow up etc. but excludes the cost of the item procured.

Economic Order Quantity (EOQ) : This is that quantity of items which when ordered in one procurement order results in the total ordering costs equaling the total inventory carrying costs.

Economic Lot Size : It is same as EOQ. Normally, this term is used more in the manufacturing Industry.

Derivation of Economic Order Quantity (EOQ) Model

It is an inventory model with all the parameters known with certainty. That's why, it is called "deterministic single item inventory model". The concept of EOQ applies to items which are replenished periodically into inventory in lots covering periods needs. The EOQ concept is applicable under the following conditions :

(a) The item is replenished in lots or batches either by purchasing or by manufacturing,

(b) Consumption of items (or sales or usage rate) is uniform and continuous,

(c) Planning period is one year, and

(d) Demand is deterministic and indicated by parameter M units per year.

Let ordering cost per order under consideration = C_O

Carrying costs expressed as percentage of average inventory = C_C

Therefore, the total costs may be shown as given in Figure 5.4.

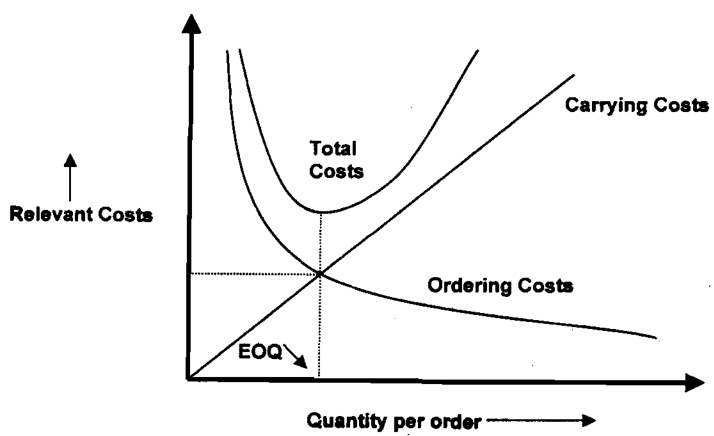


Figure 5.4

The annual demand/forecast for consumption = M

Let us assume that the price per unit = R

Therefore, the total cost = $M \times R$

Let the unknown quantity to be ordered in a lot = q

Therefore, the number of orders to be placed in the year = $\frac{M}{q}$

Therefore, the cost of ordering or total ordering costs = $\left(\frac{M}{q}\right) \times C_O$

Let us say that the average inventory being carried is $q/2$. It is with the assumption that there is zero inventory at the beginning, thereafter, there is an even rate of consumption and at the end, all the items get consumed. In practice, it is usual to take the average of the opening and closing inventories for a given period.

Thus, the value of the average inventory = $\left(\frac{q}{2}\right) \times R$

Therefore, the inventory carrying charges = $\left(\frac{q}{2}\right) \times R \times C_C$

We know,

The total costs of inventory control (T_C)

= Total costs of ordering + Total costs of carrying the inventory

$$T_C = \left(\frac{M}{q}\right) \times C_O + \left(\frac{q}{2}\right) \times R \times C_C$$

To see how T_C varies with respect to q, we differentiate T_C with respect to q.

$$\frac{dTc}{dq} = -\left(\frac{M}{q^2}\right) \times C_O + \left(\frac{1}{2}\right) \times R \times C_C$$

At the minimum position (where the total inventory control costs does not increase with quantity change or is minimum), we have, $\frac{dTc}{dq} = 0$

Thus, we get,

$$-\left(\frac{M}{q^2}\right) \times C_O = \left(\frac{1}{2}\right) \times R \times C_C$$

or

$$q\ (\text{EOQ}) = \sqrt{\left(\frac{2MC_O}{RC_C}\right)}$$

Following example will illustrate the concept with more clearity.

Example 5.1

The 500 millilitre bottles are used for certain tablets and powders. Annual requirements are 250000, the price is Rs. 8 per thousand and cost of carrying stock is 15% per annum, and the cost of ordering is Rs. 1.2. Find out the most economic order quantity (EOQ).

Solution

Let the unit of materials is 1000 bottles, then

$M = 250$ $\qquad$ R = Rs. 8 per thousand

C_O = Rs. 1.2 $\qquad$ C_C = 15% of average inventory carried

Substituting these values in the equation, we get,

$$q\ (\text{EOQ}) = \sqrt{\left(\frac{2 \times 250 \times 1.2}{0.15 \times 8}\right)} = 22.4 \text{ or } 22400 \text{ bottles}$$

The EOQ could well be rounded off to 20000 or 25000 bottles. The difference in total cost would be negligible.

In actual situations, there is a lot of variation in calculating EOQ. Some of them are :

(a) The price is assumed to be fixed and equal to R. However, this is not usually the case as larger orders may mean discounts. Moreover, a vendor may offer more discounts in lean seasons and less during rush.

(b) Carrying costs may jump if a new warehouse is created to cater to EOQ.

(c) Individual calculation of EOQ is a tedious process and in itself may add to costs of ordering.

(d) The average inventory may not be real. For example, if in a year, the maximum production is required say only two months before *Diwali*, the average inventory for the year may give skewed figures. Or in other words, the consumption pattern may not be uniform.

(e) Actually, delivery variations by the vendor may not be in line with committed or planned figures.

(f) EOQ for one company may not be the right ordering quantity for the desired company.

SAQ 5

(a) What constitute inventory ordering cost, carrying cost and stock out costs ? Explain the behaviour and relationship of these costs.

(b) Define "Economic Order Quantity (EOQ)". State its significance on effective inventory control.

(c) An item is required at a rate of 18000 units per year. Per unit cost of the item is Rs. 2. Storage cost is Rs. 0.10 per unit per month. If the cost of placing an order is Rs. 400, find economic order quantity (EOQ).

5.6 WHEN TO ORDER ?

While EOQ specifies how much to order, it does not say when is to be ordered. In order to go up further, some more concepts need to be defined. Consider the diagram given in Figure 5.5 and the definitions given subsequently.

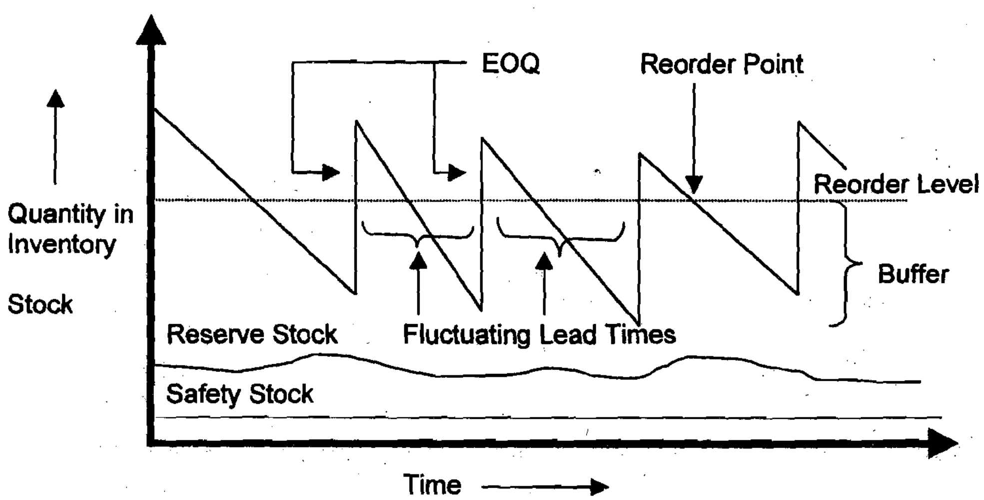


Figure 5.5

Reorder Level : That point of level in the inventory at which an order is placed. In the above figure, it is a fixed inventory level that an order is placed irrespective of the consumption figure expected.

Buffer Stock : The average demand during the average lead time in procurement.

Safety Stocks : Demand and lead time are never constant in real life. Statistical methods can be used to derive the lead times and average demand during the lead times. To prevent stockouts and cater to the changing demand being affected by lead time delays, the safety stock is given by the average demand during maximum delay multiplied by the probability of occurrence. The past record is used to compute these figures. Thus, we get,

Safety Stock

= Average Demand During Maximum Delay Period × Probability of Occurrence

Reserve Stocks : Unlike safety stock where average demand during maximum delay is considered, reserve stock projects the variation in consumption pattern. Consumption patterns are usually measured by the daily, weekly, monthly and yearly patterns and lead time will be a multiple of the time span. In order to measure the fluctuations in consumption in the lead periods, the most appropriate measure is the standard deviation during this period.

Method of Calculation

The standard deviation of a given time span is multiplied by the square root of the multiplying factor. This operation is based on the Convulsion Theory of statistics. For example, if 20 is the standard deviation in consumption for a month and if the lead time is 4 months, then the standard deviation for the lead time is to be given by (20 × square root of 4 = 40 units) or 40 is the reserve stock to be used for the period.

Reserve Stock

$$= \text{Standard Deviation in consumption pattern for a period} \times \sqrt{\left(\frac{\text{Lead time}}{\text{Time period considered for calculating SD}}\right)}$$

Service Level : The efficiency of the "right quantity" is measured on a negative scale, i.e. in terms of stockouts. The achievement of the utopian goal of a zero stock out will require a heavy inventory which is possible only with having heavy inventories blocking a lot of capital. So the service level approaches the problem as a percentage of times that a demand was satisfied by stock availability to that of the number of times the demand was made.

Generally, two terms are used in this regard :

(a) **Understocking Costs** – The opportunity cost loss due to non-availability of the material.

(b) **Overstocking Costs** – The opportunity cost loss due to overstocking of the material.

Thus, we get,

$$\text{Required Service Level} = \frac{\text{Understocking Cost}}{(\text{Understocking Cost} + \text{Overstocking Cost})}$$

As can be seen here, that for critical and vital items where stockout costs are high, the desired service level is very high. Similarly, high value but not critical items have lower required service levels.

5.6.1 Fixed Quantity System of Placing Order or 'Q' Method

In the 'Q' system, as the name implies, the quantity of the order is fixed while the order period is varied. The quantity to be ordered is normally based on the economic order quantity. But the time of reordering is based on the following three components :

(a) **Buffer Stock** – The average demand during average lead time.

(b) **Safety Stock** – The average demand during the expected delivery delay period.

(c) **Reserve Stock** – The variations in demand during the average lead time.

Thus, we get,

Reordering point or ROP = Buffer Stock + Safety Stock + Reserve Stock.

Thus, in the fixed quantity system or 'Q' system, since time period is not fixed, a constant vigil is required to check when inventory levels have reached the reordering point. Thus, this constant monitoring increases the cost of the system. Since it is very expensive to monitor all items in the inventory this way, only high value items are normally, subjected to this method. Needless to mention here that if a change in consumption pattern is detected, the system has to be reviewed.

5.6.2 Fixed Period System of Placing Orders or 'P' Method

In the 'P' system, the period between placement of orders is fixed, while the quantity ordered is varied. Therefore, it is necessary to plan for any increase in quantity required between the periods under consideration. Hence, in this method, the average inventory level is higher though the effort in time spent in monitoring is reduced.

The method has following steps :

(a) Decide review period by dividing EOQ by the annual consumption level. Thus, we get,

$$\text{Review Period} = \frac{\text{EOQ}}{\text{Annual Consumption}} = \frac{\text{Value of EOQ}}{\text{Total Consumption Value}}$$

Using the past formulae, we get,

$$\text{Review Period} = \left(\sqrt{\frac{2MC_O}{RC_C}}\right) \times R \times \frac{1}{MR}$$

$$= \left(\sqrt{\frac{2C_O}{C_C}}\right) \times \frac{1}{\sqrt{MR}}$$

Since in the above equation, the numerator is constant, the review period is inversely proportional to the annual consumption value. This enables the bunching of items having equal consumption figures. For the fast moving spares, this method is particularly useful.

(b) Calculate the desired inventory level (DIL) as per following :

Desired Inventory Level (DIL)

= Buffer Stock + Safety Stock + Reserve Stock.

Here, the buffer stock is the sum of average demand during lead time and review time,

The reserve stock is the sum of fluctuations in demand during average lead time and review time, and

The safety stock is the average demand during delays in supply.

5.6.3 Complex Econometric Methods

The items which are fast moving, high value and show a complex consumption pattern by being used in different equipment having different sales figures or other such situations, complex econometric methods may be developed. Since such systems are difficult to develop, costly to implement and require experts to handle difficult situations, these are used only if the cost advantage gained is high. An example of the situation is the stocking food grains and relief supply across the country for preparing for cyclone relief. Since vagaries of nature are difficult to predict and short preparation times are available, this is very challenging work.

SAQ 6

(a) List the products for which fixed quantity order system is applicable. What are the benefits of this system ?

(b) Differentiate between "reordering point" and "reordering level".

(c) Define review period (RP) and Desired Inventory Level (DIL).

(d) State the situation in which complex econometric methods are applicable.

5.7 SUMMARY

This unit has illustrated the introductory concepts of inventory and inventory control. Objectives, various concepts of inventory, functions of inventory, and various factors that affect the maintaining of inventories are described.

The unit covers different classification methods, namely ABC classification, XYZ-FSN classifications, SDE and GOLF methods, VEIN/VED/RAM methods, Multi-variable (MV) methods, and econometric methods used for prioritising the items for procurement.

It is necessary to understand all methods since in a company more than one method may be used for various items. Every company/institution is unique in its own way and the learning cycle determines which method is eventually adopted.

These methods of prioritisation is organisation specific and varies from case to case. However, the more the variables that an organisation starts to consider in its materials management, the more savings potential is created. Moreover, these systems are learned through experiences, i.e. one develops systems based on one's experience. In fact, training is very essential at all rungs including all affected parties, i.e. finance, production, warehouse, marketing and sales etc.

The basic question relating to inventory control, i.e. how much material should be ordered and when, has been explained with the help of illustration along with Economic Order Quantity (EOQ), re-order point and lead time.

In EOQ modelling, the calculations are given in the most simplest form. Sometimes, more complex calculations are done to take care of the limitations of the model. However, EOQ is still the best tool with which one may scientifically arrive at a figure of ordering lot.

As regards to "when to order ?", towards end, the unit outlines three different methods, namely Q method, P method and complex econometric methods.

5.8 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topics listed in the section "Further Reading" given at the end of the block to get the answers of the self-assessment questions.