Inventory Models

Inventory planning and managing represents a critical task for every organization and business on today's highly competitive world, which should be used as a competitive advantage to achieve optimum production levels at the lowest costs possible.

Inventory is defined as any idle resource of an enterprise: it's a stock of goods, commodities or economic resources that are kept for the purpose of future business. Inventory may be kept in any form-raw material in process, finished product, packaging, spares and others stocked in order to meet the expected demand. It's important to maintain some inventory for the smooth functioning of an enterprise. Suppose a firm is not maintaining inventories-if a sales order comes it has to purchase the raw materials required, wait till these arrive and then start production. This increases the waiting time of customers to get the delivery of goods.

The disadvantage of not maintaining inventories are; raw materials are purchased at a high price because of the piecemeal buying, production costs would be high because of not being able to take advantage of batching e.t.c.

Inventory control is defined as "the function of directing the movement of goods through the entire manufacturing cycle from the requisition of raw materials to the inventory of finished goods in an orderly manner to meet the objectives of maximum customer service with minimum investment and low-cost. There are two basic functions of inventory control: (1) maintaining an accounting record to handle inventory transactions concerning each inventory item (2) Deciding inventory replenishment decisions which are: ***when is it necessary to place an order(or produce) to replenish inventory, How much is to be ordered?***

It's essential for any firm to have inventory because of the following reasons: it provides adequate service to the customers; it helps in the smooth and efficient running of business; it reduces the possibility of duplicating orders; enables timely shipment of customer orders to improve cashflow; takes care of economic fluctuations; helps in minimizing loss due to deterioration, obsolescence, damage; acts as a buffer stock when raw materials are received late and shop rejections are too many; takes advantage of price discounts by bulk purchasing; improves the manpower, equipment and facility utilization because of better planning and scheduling.

Maintenance of inventories costs money by means of expenses on stores, equipment, personnel e.t.c. So excess inventories are undesirable. This calls for controlling the inventories in the most profitable manner.

There are five types of inventories

- Fluctuation Inventories (Buffer inventories). These are inventories that meet uncertainities of demand and supply. They are buffer inventories in excess of those necessary to meet the average demand during lead time (the time lapsing beween placing an order and having the goods in stock ready for use) and held for protecting against the fluctuations in demand and lead time, are termed as safety stocks or reserve stocks.
- Anticipation Inventories: these are built up in advance for the season of large sales, a promotion programme, or a plant shut-down period.
- Cycle (lot size) Inventories: these are built up in advance because the purchases are usually made in lots rather than the exact amounts needed at a point of time.
- Transportation inventories (or pipeline inventories): such inventories exist because of the transportation of inventory items to various distribution centres and customers from the production centres. This type of inventory is also called process inventory where the significant amount of time is consumed in the trans-shipment of items from one location to another. To meet the demand its essential to hold extra stock at various workstations. The amount of transportation inventory depends on the time taken in transportation and the nature of demand.
- Decoupling inventories: if various production stages operarte successfully, then the breakdown of one or many may affect the entire system. This kind of interdependence is not only expensive but also disruptive for the entire system. The inventories used to reduce the interdependence of various stages of the production system are known as decoupling inventories. These inventories may be classified as: (i) raw materials and component parts-it decouples the producer from suppliers. It acts as buffer to take care of delays on the part of the suppliers. (ii) work-in-process inventory-as it takes time to convert raw materials into finished products, work-in-process inventory is developed. This inventory takes the form of orders waiting to be transported between machines or of orders waiting to be processed on a particular machine. The level of such inventory can be increased by

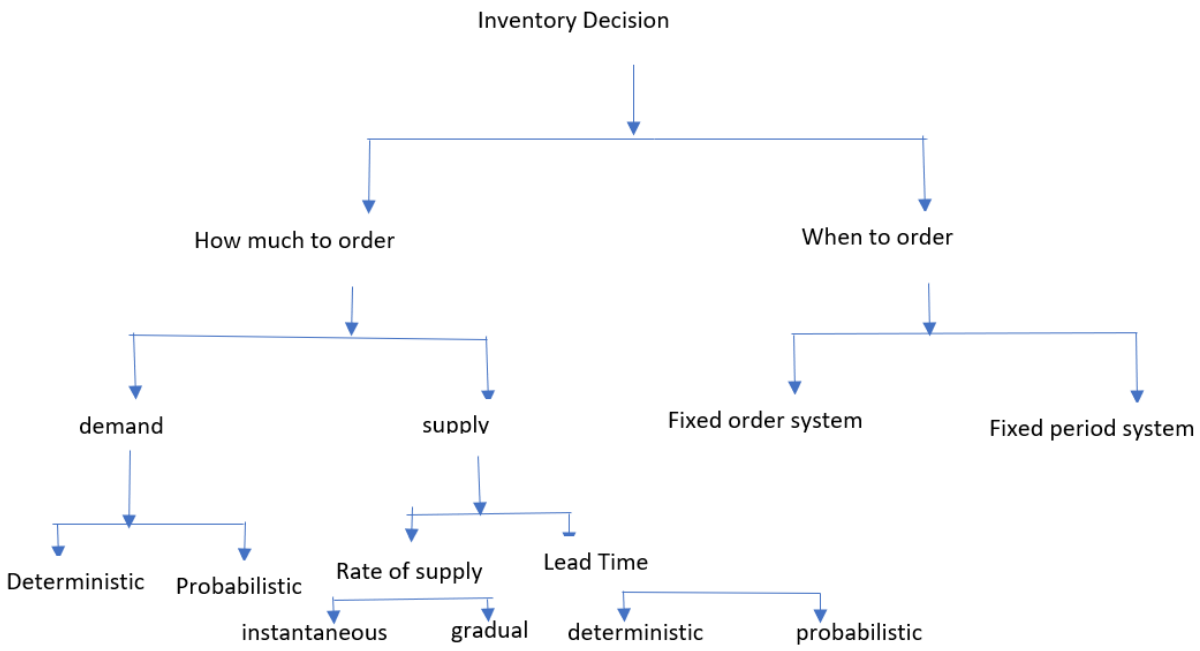
changing the production process, lot sizes e.t.c (iii) finished goods inventory-it's the inventory of final product which could be released for sale to the customers. The size of this inventory depends upon the demand and the ability of the firm to sell its products. (iv) spare-parts inventory: these are the parts which are used in the production process but do not become part of the product.

Operating constraints

The stock level of various items in the inventory is governed by various constraints such as limited warehouse space, limited budget available for inventory, customer service level to be achieved and management attitude about the individual items in the inventory.

Operating Decision Rules: Two types of decisions need to be made in managing inventories; How much (Size) is to be ordered when the inventory of that item is to be replenished? When to place an order (or set up production) to replenish inventory.

These two questions can be classified as in the diagram below:



The size and timing of replenishment of orders for an item can be decided using any one of the four inventory control decision rules given below:

Inventory decision rules

	Order Quantity	
Order Frequency	Fixed Q	Variable S
Variable (R)	(Q R)	(S R)
Fixed (t)	(Q t)	(S,t)

The table above involves placing orders for either a fixed or variable quantity (size) with either a fixed or variable time between successive orders. E.g under (Q R) rule, an order for a fixed quantity Q for replenishment is placed when the inventory balance drops to a certain point (reorder level R). This policy is called a **Fixed Order quantity or a re-order point policy.**

Similarly, under (S t) rule, order of replenishment are placed after a fixed interval (t) for an amount equal to the difference between the current stocklevel in hand and a predetermined maximum level. This policy is known as the **fixed-interval policy or order-period policy or periodic review policy.**

The success of any inventory decision rule depends on the accurate determination of its parameters Q, R.

Steps of inventory model Building

The steps to build up a suitable inventory model and then to derive decision rules are as follows:

Step 1: 1st take physical stock of all the inventory items in the organization

Step 2; classify the stock of items into various categories

Step 3: After classification of inventories, each item should be assigned a suitable code

Step 4: build up a mathematical model to achieve the objective function of minimizing the total inventory costs subject to changes in inventory reorder policy and constraints of limited resources. The model would either be an unconstrained optimization model or a mathematical programming model depending upon whether the constraints are imposed or not.

Step 5: derive an optimal inventory policy (i.e Economic order of quantity) by using an appropriate solution procedure to ensure balance among inventory costs.

Cost Involved in Inventory Problems

Various costs involved in inventory problems may be classified as:

(a) Set-up cost (C_s or C_3): these include the fixed cost associated with obtaining goods through placing orders or purchasing or manufacturing or setting up machinery before starting production. The costs include ordering of raw materials for production purposes, advertisement, postage, telephone charges, travel expenditure e.t.c. these are also called order costs or replenishment costs per production run. Ordering cost may be calculated as

Ordering Cost = (cost per order) *(Number of orders)

Purchase or production cost: the cost of purchasing (or producing) a unit of item is known as purchase (or production) cost. Purchase cost per 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 discount 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 case the purchase cost is given by

Purchase Cost = (Price per unit when order size is Q) * (Demand per unit time)

(b) Carrying or Holding Cost (C_1 or C_h): The cost associated with carrying or holding goods in stick is called **holding or carrying cost** per unit of item for a unit of time. Its assumed to vary directly with the size of inventory as well as the time the item is held in stock. This cost generally includes ***invested capital cost:*** this is the interest charged on the capital investment, ***Record keeping and administrative cost***, ***handling Costs***; these include all costs associated with movement of stock, cost of labor. ***Storage Costs***: these involve the rent for storage space or depreciation and interest even if own space is used. ***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 expiry e.t.c ***Taxes***

and insurance Costs; these costs require careful study and generally amounts of 1 percent to 2 percent of the invested capital.

(c) Shortage (or stock out) Cost (C_2): 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 customers therefore there is no loss in sales (ii) customers are not ready to wait and therefore there's 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.

Shortage cost may be calculated as:

Shortage Cost = (cost of being one unit short in the inventory planning period) * (Average number of units short in the inventory planning period)

Average number of units short = ((minimum shortage in the inventory planning period + maximum shortage in the inventory planning period)/2) * (time for which shortage occurs)

Salvage Cost (or Selling Cost):When the demand for commodity is affected by the quantity stocked then 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.

Revenue cost: when its 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 except when the organization cannot meet the demand and the sale is lost. The revenue lost may or may not be included in the study of inventory.

Total inventory cost: if the unit price of an item depends on the quantity purchase, i.e. price discount is available, then we formulate an inventory policy that considers the purchase cost of the items held in stock .

Total Inventory cost= Ordering cost + Carrying Cost + Shortage cost

When price discounts are not offered, the purchase cost remains constant, and is independent of the quantity purchase.

Other factors that play a role in the study of inventory problems are:

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.

Lead Time: the time gap between placing of an order and its actual arrival in the inventory is known as the lead time. The level of inventory of an item depends upon the length of its lead time. The longer the lead time, the higher is the average inventory. Lead time has two components; administrative lead time-time from the initiation of procurement action to the placing of an order, delivery lead time-time from placing of an order to the delivery of an ordered material.

Order Cycle: the time period between placement of two successive orders is refered to as an order cycle. The order may be placed on the basis of the following two types of inventory review systems; (i) continuous review-the record of inventory level is checked continuously until a specified point is reached where a new order is placed (ii) periodic review-the inventory levels are reviewed 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.

Stock replenishment: 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.

Time Horizon: the time period over which the inventory level will be controlled is called time horizon.

Reorder level: the level between maximum and minimum stock, at which purchasing (production) activities start for replenishment is what is called reorder level.

Variables in inventory problem are of two types: Controlled variables and uncontrolled variables. Controlled variable-how much quantity to buy(purchase, production e.tc), the frequency or timing of acquisition, the completion stage of stocked items; uncontrolled-holding costs, shortage or penalty costs, set-up costs, demand, lead time and supply of goods.

The most common deterministic models used in inventory control today are:

- Economic Ordering Quantity (EOQ) Model
- ABC Analysis
- Inventory Turnover Ratio

Economic Ordering Quantity (EOQ)

The concept of economic ordering quantity was 1st developed by F.Harries in 1916. The inventory problems in which the demand is assumed to be fixed and completely predetermined are usually refered to as Economic Ordering Quantity. When the size of order increases the ordering costs will decrease, whereas the carrying charges will increase. Hence there are two opposite costs in the production process, one encouraging increase in order size and other discourages. Hence EOQ is that size of order which minimizes total

annual (or any other time period as determined by individual firms) costs of carrying inventory and cost of ordering.

Assignment: Explore EOQ with the aim of creating an engine in Python that calculates EOQ

Use the following as a start point:
https://medium.com/swlh/economic-order-quantity-with-python-7129b471c68e