**Modelling and Analytics for Supply Chain Management**
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**Lecture 25**
**Inventory Analytics - I**

Good afternoon. Today, we will be dealing with inventory analytics, which is the module 1 for week 6.

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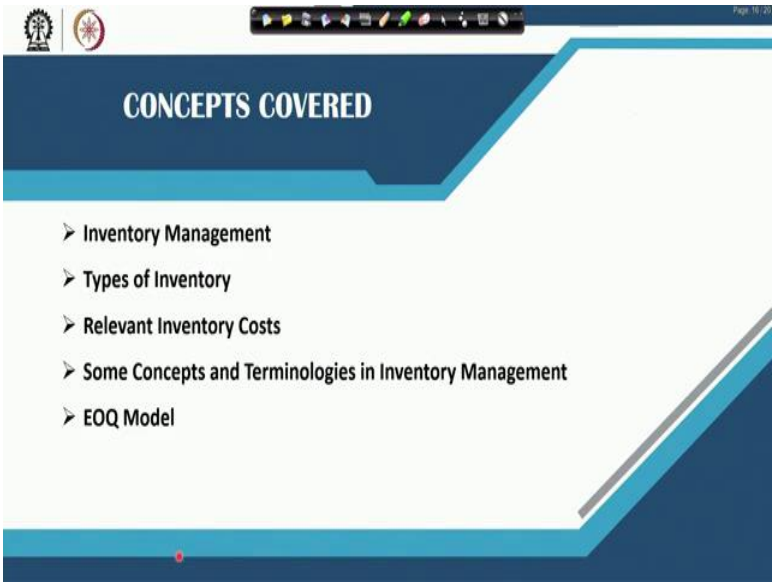


In this session, we will be covering the concept on inventory management, the different types of inventory, the relevant inventory costs associated with management of inventory, some concepts and terminologies in inventory, and then we will be dealing with the economic order quantity model.

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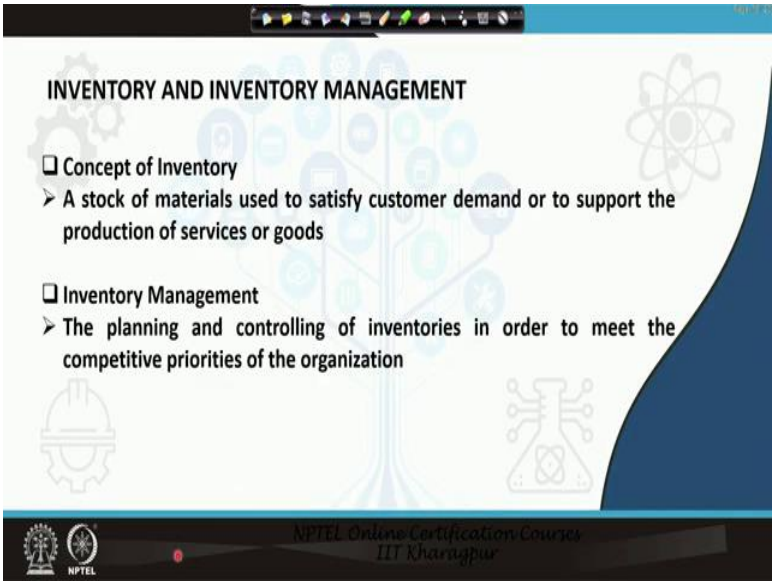


What is inventory? When we say that it is inventory, we basically mean a stock of materials used to satisfy customer demand or to support the production of services or goods. An inventory management deals with the planning and controlling of inventories in order to meet the competitive priorities of the organization.

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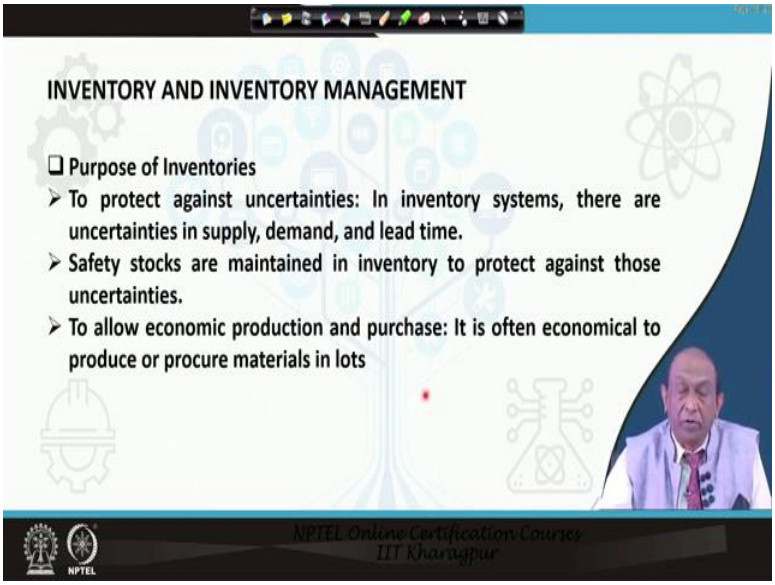


So what are the purpose of keeping inventory in a supply chain? The primary purpose is to protect against uncertainties. In inventory systems there are uncertainties related to supply, demand and lead time. And in order to protect against these fluctuations in demand, variation in lead time and such other eventualities, safety stocks are maintained in inventory to protect against those uncertainties. Sometimes, inventories are kept in the organization to allow

economic production and purchase because it is often economical to produce or procure materials in lots, whereby you can obtain discount from your suppliers when you buy in larger lots.

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Inventories are kept to cover anticipated changes in demand or supply. Examples include cases where the price or availability of raw materials is expected to change. If we know beforehand that there is going to be rise in price, we can procure more stock and keep it as inventory. Many a times this practice is being followed in many organizations. Companies often stockpile steel based on the rolling plans of those steel mills. That also gives rise to holding of inventory, which is basically known as anticipation inventory.

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Another source of anticipation inventory is a planned market promotion, where a large amount of finished goods may be bought and stocked prior to a sale. Companies who are in the businesses of seasonal type of products, for example, air conditioners, refrigerators, they often hold inventories to smooth the level of production.

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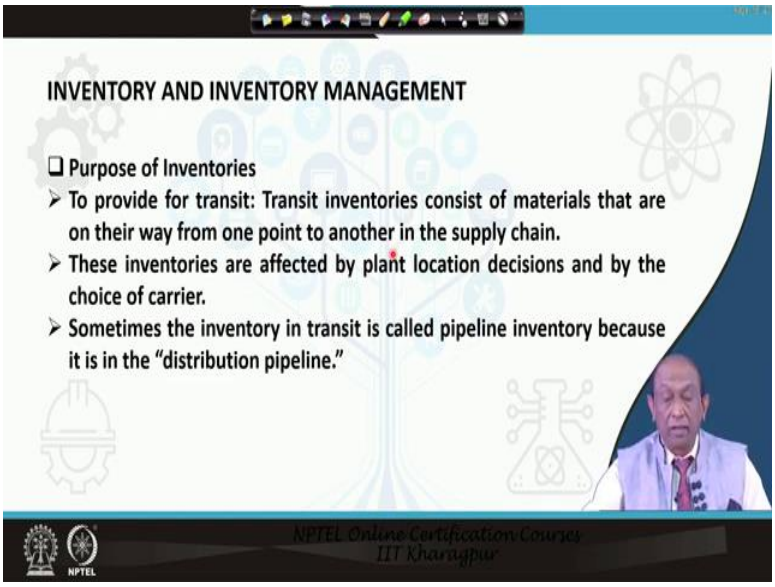


Purpose of inventory. To provide for transit. Transit inventories basically consist of materials that are on their way from one point to another in the supply chain. These inventories are affected by the location of the plant, the decisions to locate a plant in a particular place and its distance, if it is far away from the supplier, then the pipeline inventory might be more and also pipeline inventory depends on the choice of carrier. Sometimes, the inventory in transit is called pipeline inventory because it is in the distribution pipeline, the stock is yet to arrive. Order has been placed, the stock is yet to arrive and it is called pipeline inventory.

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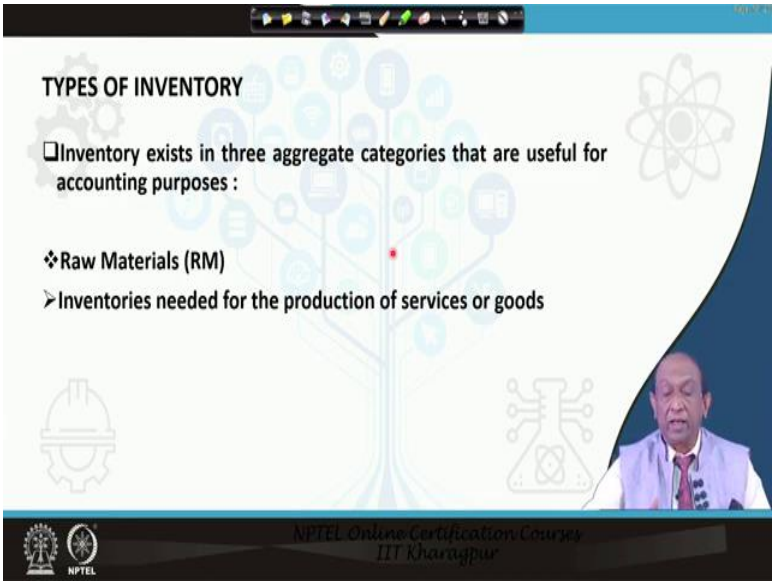


Inventory exists basically in three aggregate categories, which are normally useful for accounting purposes and also for management of inventory. So when we talk about types of inventory, first category belongs to the raw materials inventory, raw materials and components also. These raw materials and components are needed for the production of services or goods.

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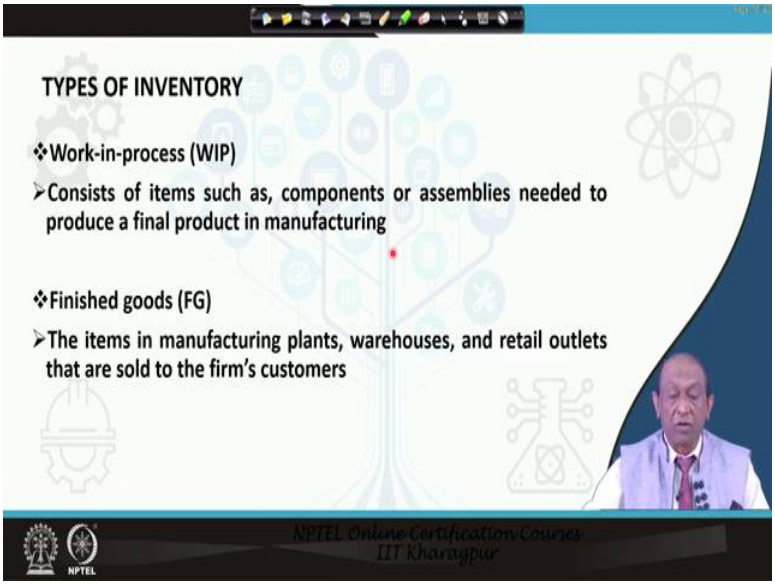


The second category basically depends on the work in process. WIP inventory consists of items such as components or assemblies, which are in semi finished stage, needed to produce a final product in manufacturing situations. Finished goods inventory is the third type of

inventory wherein the items in manufacturing plants, warehouses and retail outlets they are stocked as finished goods and they are needed to sell to the firm's customers.

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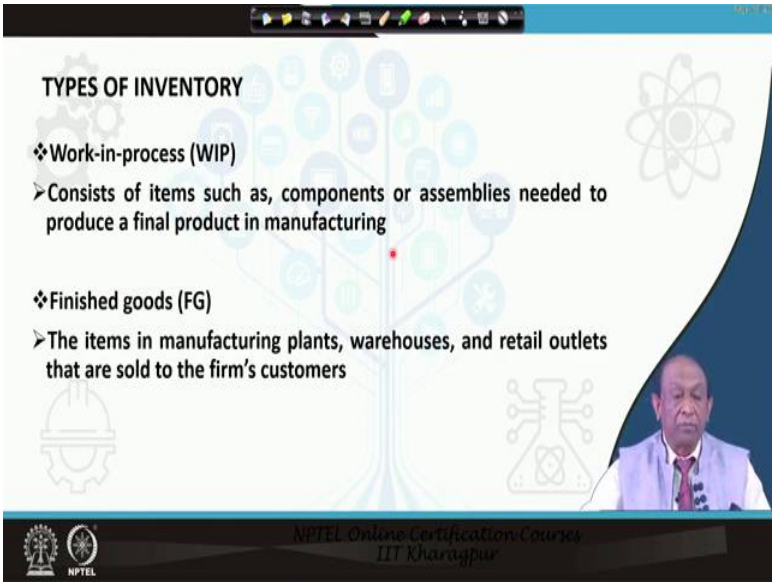


So these are the three types of inventory normally we encounter in any organization. There is another perspective from which inventory can be classified based on how those inventories are created inside the organization. In this context, the inventories are categorised into 4 forms, namely cycle inventory, safety stock inventory, anticipation inventory, and pipeline inventory. Pipeline inventory we have already discussed. Cycle inventory is the portion of total inventory that varies directly with the lot size. The application of cycle inventory in modelling, we will discuss when we will be dealing with the determination of economic order quantity.

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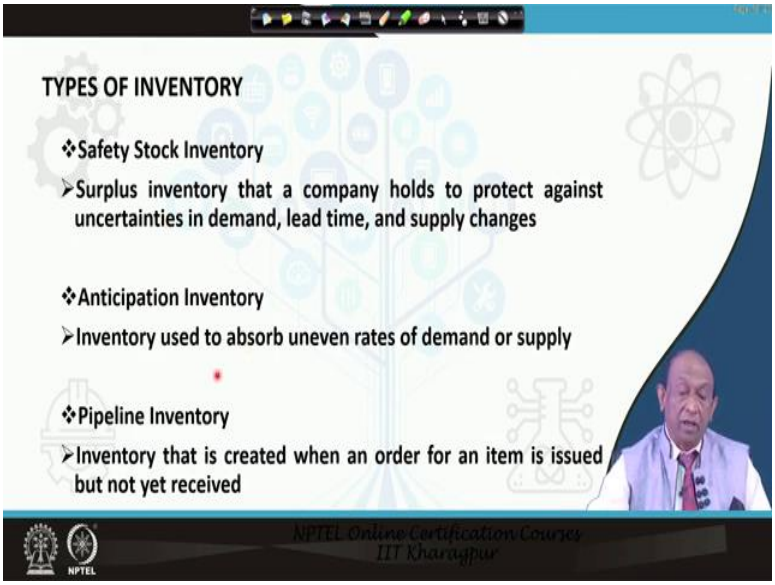


Safety stock inventory, we have already said, the safety stock is the additional stock which is kept in hand to guard against the fluctuations or the uncertainties in demand, lead time and supply changes. Anticipation inventory, we have given some examples. Inventory used to absorb uneven rates of demand or supply. Pipeline inventory, inventory that is created when an order for an item is issued, but not yet received, as if the item is in the pipeline.

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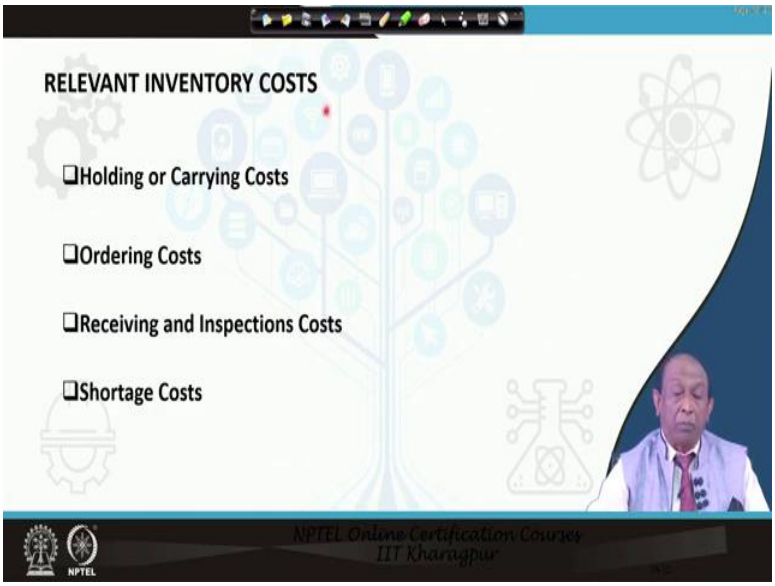


The relevant inventory costs for the purpose of modelling are inventory holding costs, sometimes also known as inventory carrying costs, ordering costs, receiving and inspection costs, and shortage costs. Now we will be dealing in detail with this type of costs.

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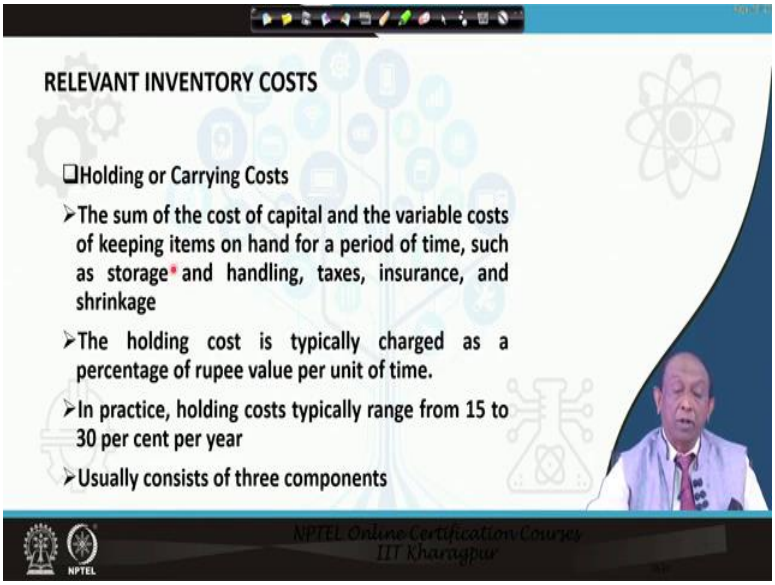


Holding or carrying costs. Holding or carrying costs means the sum of the cost of capital and the variable costs of keeping items on hand over a period of time such as storage and handling, taxes, insurance and shrinkage. These are all examples of holding or carrying costs. The holding cost or the inventory carrying cost is typically charged as a percentage of the rupee value per unit of time. And in practice, these holding costs typically range from 15 to 30 percent per year. And, this inventory carrying costs basically consists of three categories or three components.

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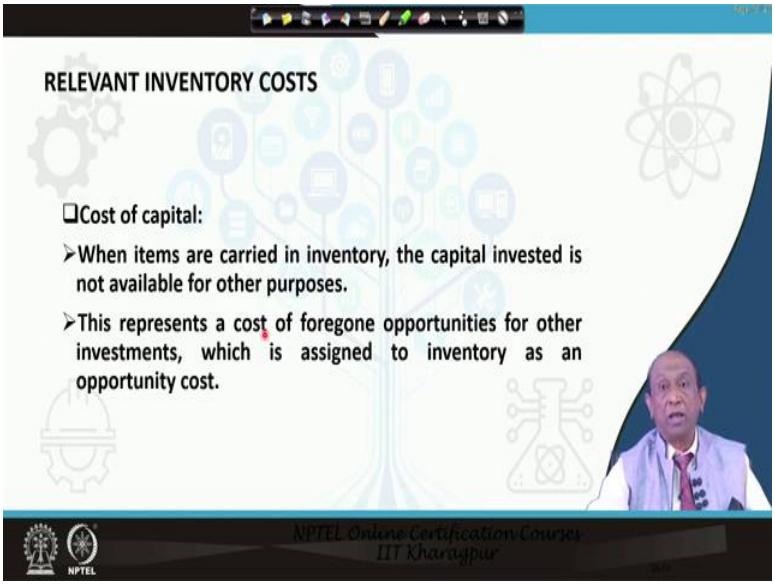


Cost of capital is the first important thing is when items are carried in inventory, the capital invested is not available for other purposes. This represent a cost of forgone opportunities for

other investments, which is assigned to inventory as an opportunity cost. The inventory or the stock of materials is basically bought through the working capital and the working capital needs are made from taking loans from banks, institutions, financial institutions on which you have to pay interest and this cost is tied up in inventory and we cannot utilize it for any other purposes. The more the inventory, the more the interest charge that you have to bear.

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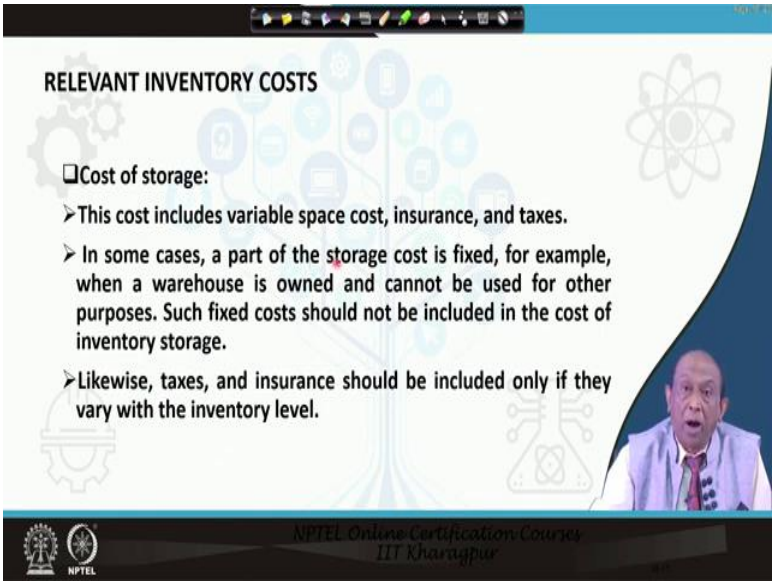


Cost of storage includes variable space cost, insurance and taxes. In some cases, a part of the storage cost is already fixed. For example, when a warehouse is owned and cannot be used for other purposes, the (()) (11:27) cost. Such fixed costs should not be included in the cost of inventory storage. Likewise, taxes and insurance should be included only if they vary with the inventory level.

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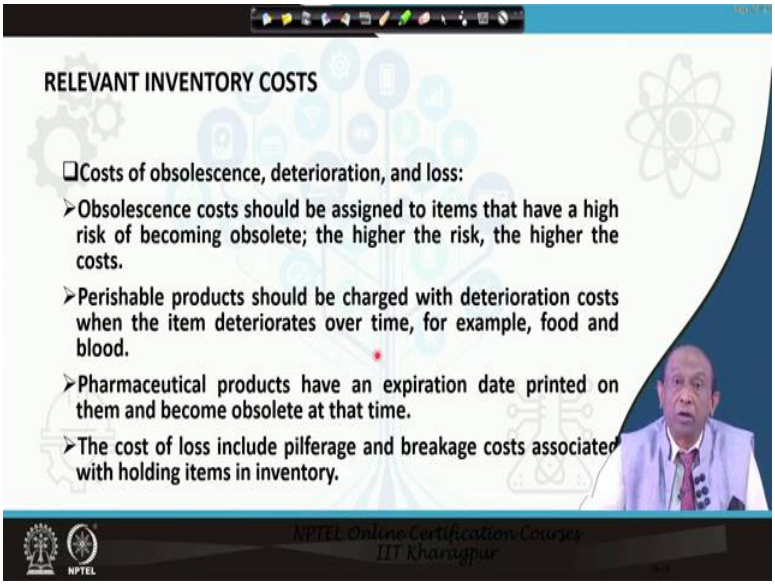


Cost of obsolescence, deterioration and loss. Obsolescence cost should be assigned to items that have a high risk of becoming obsolete. The higher the risk, the higher the cost. Perishable products should be charged with deterioration costs when the item deteriorates over time, for example, food, blood and related perishable items. Pharmaceutical products have an expiry date printed on them and they become obsolete at that time. The cost of the loss include pilferage, and breakage costs associated with holding items in inventory.

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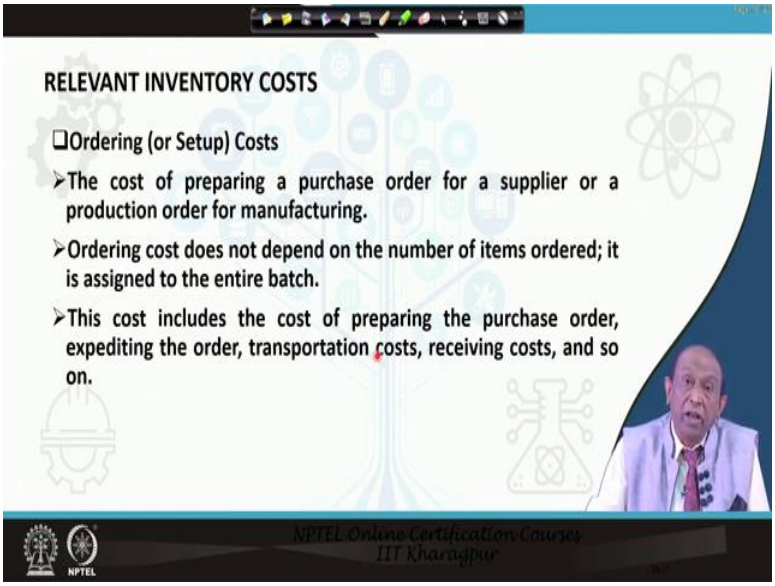


Ordering or setup costs. The cost of preparing a purchase order for a supplier or a production order for manufacturing. Ordering cost does not depend on the number of items ordered. It is assigned to the entire batch or the lot of item that you are procuring. This cost includes the

cost of preparing the purchase order, expediting the order, transportation costs, receiving costs and so on, all these related costs.

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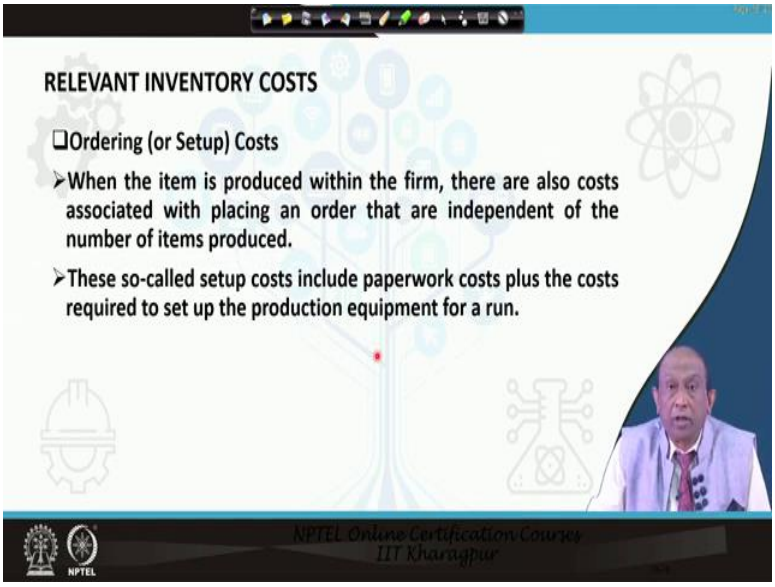


Sometimes, this ordering cost is also known as setup cost in a manufacturing situation. When the items are produced within the firm, at that time, there are also costs with placing an order that are in dependent of the number of items produced. These so called setup costs include paperwork costs plus the costs required to set up production equipment for a run.

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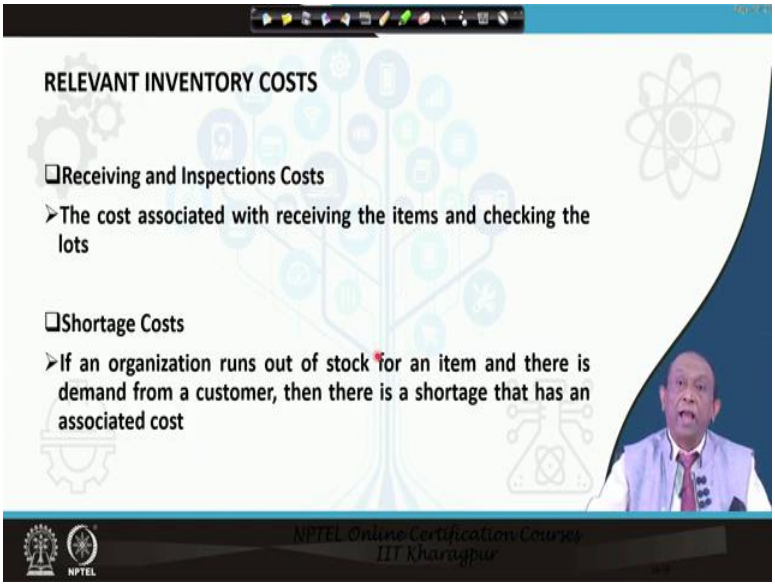


Receiving and inspection costs. These are the costs associated with receiving the items and checking the loss, maybe through sampling inspection. Then we come to shortage costs. If an

organization runs out of stock for an item and there is demand from a customer, then there is a shortage that has an associated cost. This sometimes also come into picture at the time of inventory modelling.

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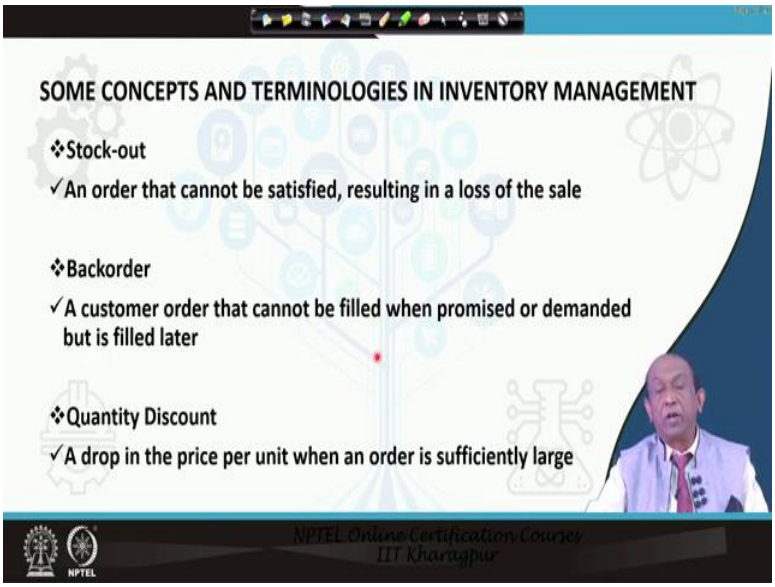


Certain terminologies used in inventory management. For example, say stock-out. We just talked about shortage cost in that context. Stock-out refers to an order that cannot be satisfied resulting in a loss of sale. Backorder refers to a customer order that cannot be filled when promised or demanded but is filled at a later point in time. Quantity discount are dropped in the price per unit when an order is sufficiently large.

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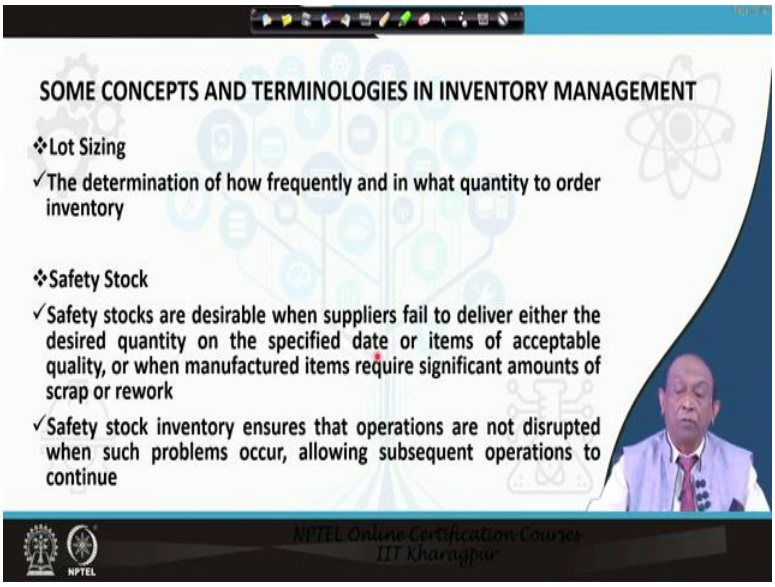

Lot siding is another term. Why it frequently used? It basically refers to the determination of how frequently and in what quantity to order stock of materials. Safety stock, we have already discussed. Safety stock basically ensures that operations are not disrupted due to shortage of materials allowing subsequent operations to continue.

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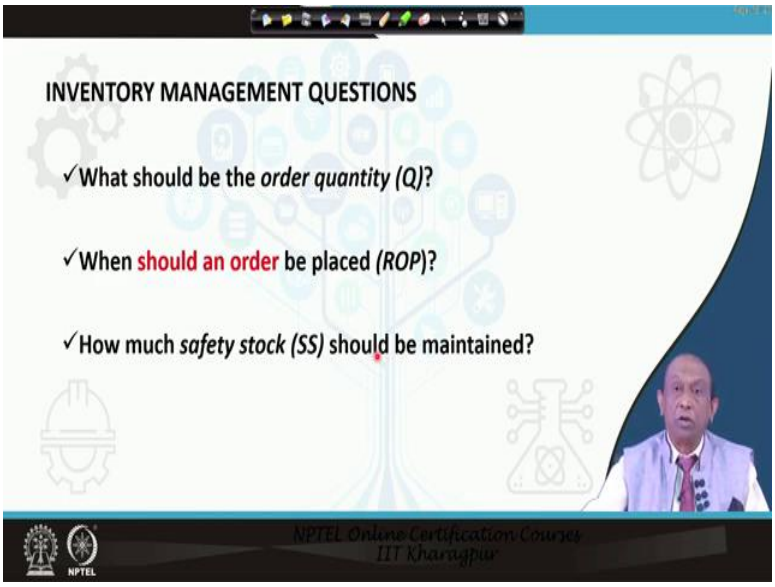


So in inventory management the questions are what should be the order quantity? When should an order be placed? And how much safety stock should be maintained? These are the three primary questions related to management of inventory and hence, we resort to certain mathematical modelling for determining these three things.

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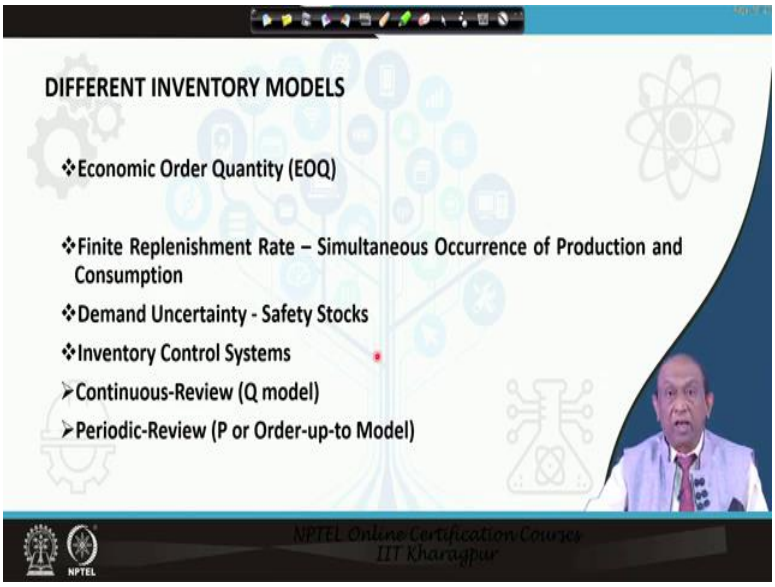

So the first kind of models that is used as a fundamental basis for developing analytics related to various kinds of inventory situation is the economic order quantity model, which we will discuss in detail. Then we will discuss about economic batch quantity models, where there is simultaneous occurrence of production and consumption. Then we will be discussing about determination of safety stock and subsequently, we will deal with two important inventory systems in practice, one is the continuous review system popularly known as the queue system and the other one is the periodic review system known as the P system.

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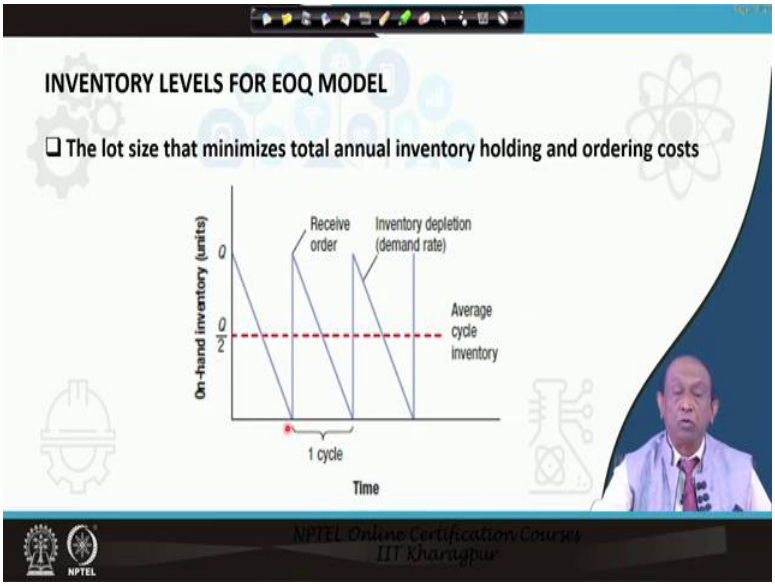


This is a picture wherein we will be designing the basis of determining the economic order quantity. Say the y axis represents the on hand inventory level in units and the x axis represents time. So basically, the stock level in a simple EOQ model fluctuates like a saw-tooth pattern. We start with a stock level of Q, the demand rate is assumed to be constant. When the stock level is 0, replenishment order comes in, we receive the order, the stock again goes up to a level of Q, again that the stock level comes to 0 and like this. So there is a inventory depletion, the demand rate is constant and in here the other important assumption is that the lead time is constant or 0.

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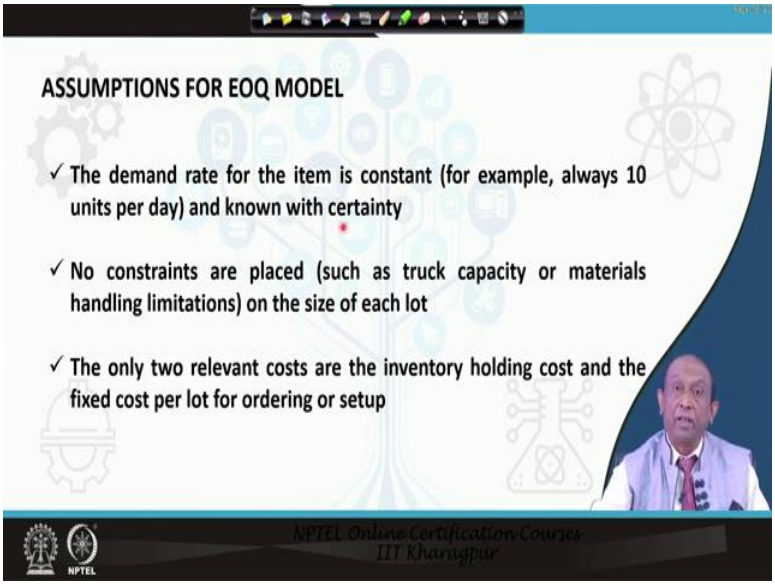


So let us first look into the various assumptions for this economic order quantity model. We have already mentioned that the demand rate for the item is constant. For example, always say 10 units per day and this demand rate is known with certainty. This model is basically for a situation where everything is known, no constraints are placed on the lot size, such as truck capacity or material handling limitations on the size of each load. The only two relevant costs are the inventory holding cost and the fixed cost per lot for ordering or setup.

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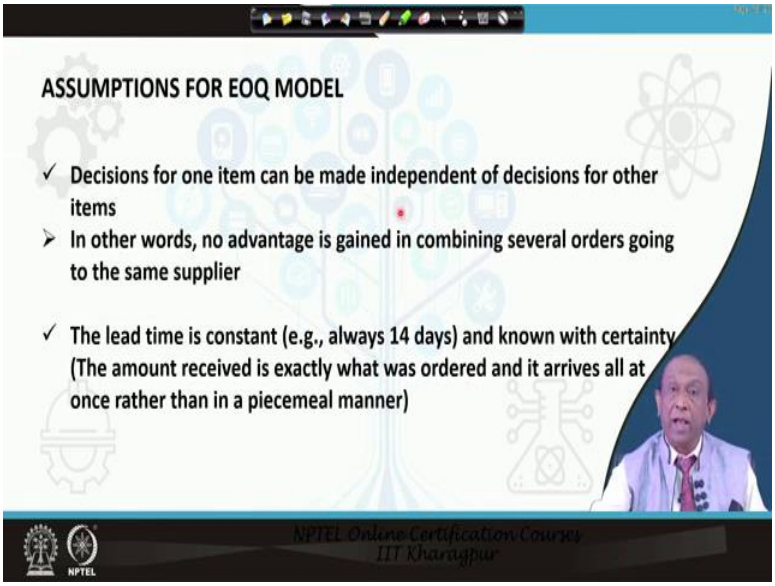


Decisions for one item can be made independent of decisions taken for other items. In other words, no advantage is gained in combining several orders going to the same supplier. In this model, they will have basic fundamental assumption that the lead time is constant. It may be

0 also and known with certainty. The amount received is exactly what was ordered and it arrives all at once rather than in a piecemeal manner.

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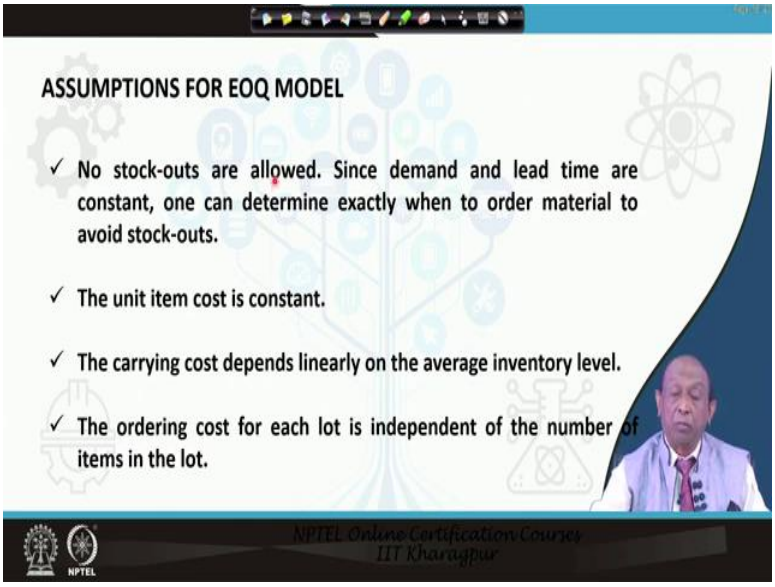


No stock outs are allowed. This is also another important assumption behind this model. Since demand and lead time are constant, anybody can determine exactly when to order material to avoid stock outs. The unit item cost is constant and the inventory carrying cost depends linearly on the average inventory level. The ordering cost for each lot is independent of the number of items in the lot.

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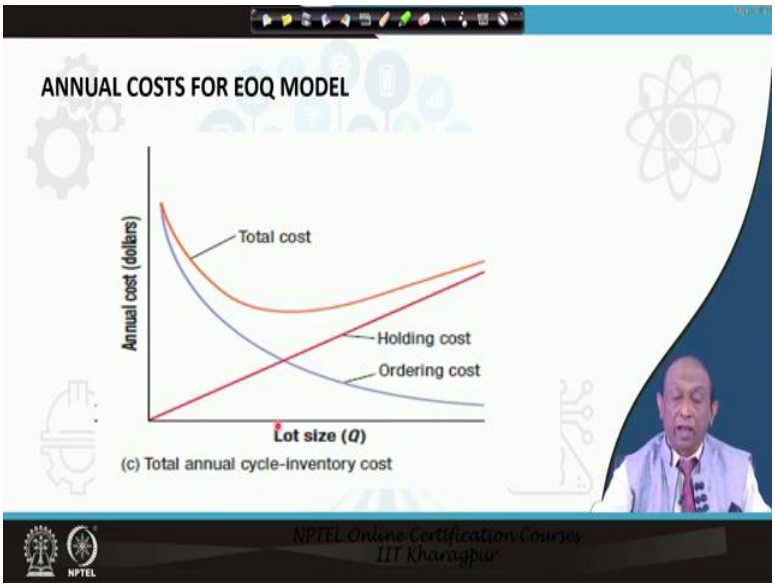

In here you see the total cost curve is a almost an U shaped curve, the holding cost we have already said varies linearly with the lot size and the ordering cost takes a shape of an exponential nature. We will be trying to find out or derive the optimal lot size such that the total cost of carrying inventory and ordering costs, the sum of these two costs is minimized.

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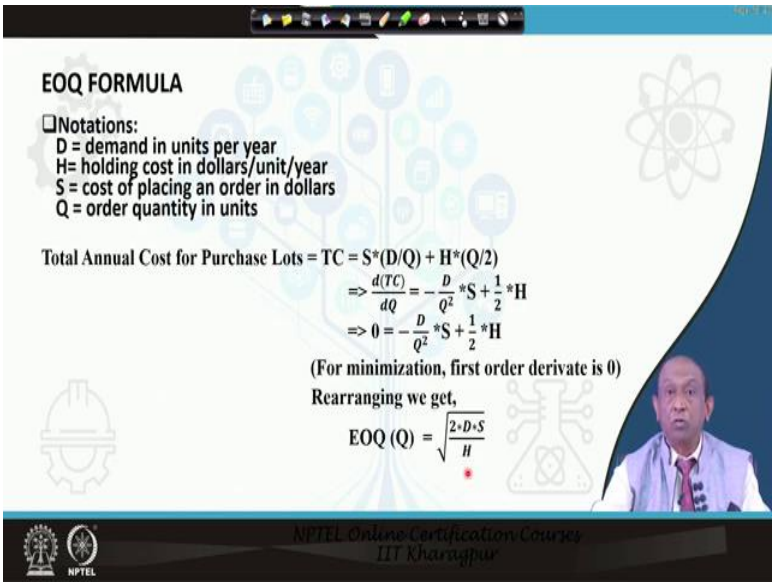


Start with certain assumptions. For example, say D equal to the demand in units per year, H is the holding cost or the inventory carrying cost say in dollars or rupees per unit per year, S is the cost of placing an order in dollars or rupees and Q is the order quantity in units. So total annual cost for purchase lots which is dependent on Q. This is very important, we are taking only those components of the total cost which is a function of the order size Q.

If we denote the total cost by TC, then TC becomes S multiplied by D by Q plus H into Q by 2. D is the total annual demand and Q is the order size. So the number of orders per year is D by Q. This when multiplied by the ordering cost S, gives the total ordering cost per year which is H into D by Q. The average inventory level is Q by 2. If you refer to that saw-tooth curve, you will find that the maximum inventory level at a point in time is Q and the minimum inventory is 0.

So the average inventory is nothing but Q plus 0 by 2 which is Q by 2. This multiplied by the holding costs H is the annual holding cost. Now, if we differentiate it with respect to Q, the total cost if we differentiate it with respect to Q, because for minimizing the total cost, we need to equate the first order derivative to 0. So we get DDQ of TC is minus D by Q squared star S plus half into H.

This when equated to 0, we can derive by manipulating this equation and EOQ equal to root over of 2 into annual demand into cost of placing an order, that is ordering cost divided by the holding cost. Holding cost may be sometimes expressed as product of the unit cost of the item C into the interest rate I.

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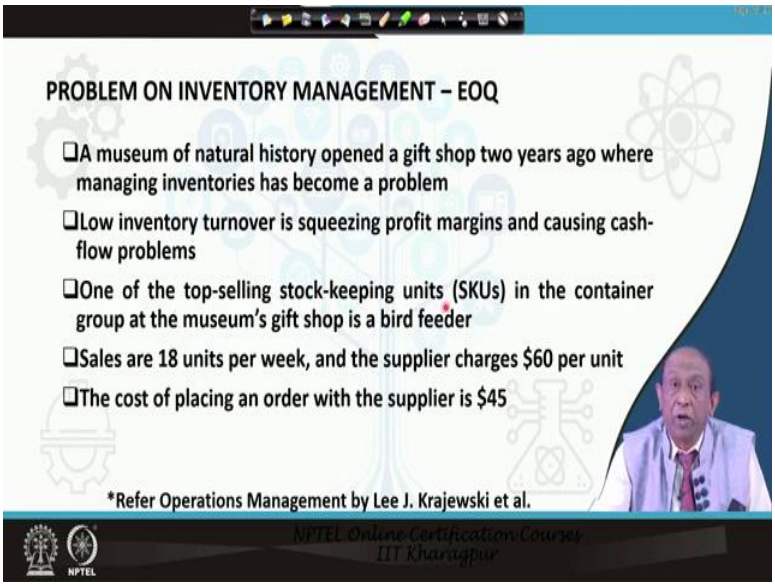


Let us look at a problem on inventory management. A museum of natural history opened a gift shop two years ago, where managing inventories has become a problem. Low inventory turnover is squeezing profit margins and causing cash flow problems. One of the top selling stock keeping units in the container group at the museum's gift shop is a bird feeder. Sales are 18 units per week and the supplier charges dollar 60 per unit. The cost of placing an order with the supplier is dollar 45. So that means you say ordering cost is 45 dollars and the supplier charges dollar 60 per unit for each of the items.

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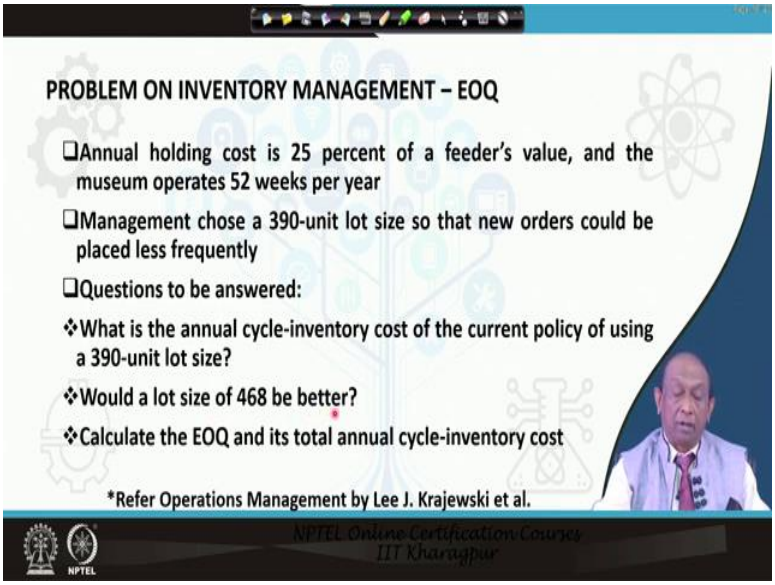


Annual holding cost is 25 percent of a feeder's value and the museum operates 52 weeks per year. Management chose a 390-unit lot size so that new orders could be placed less frequently. This is the case. Questions to be answered. What is the annual cycle inventory cost of the current policy of using a 390-unit lot size? The second question, would a lot size of 468 be better? And third, calculate the economic order quantity and the total annual cycle inventory cost.

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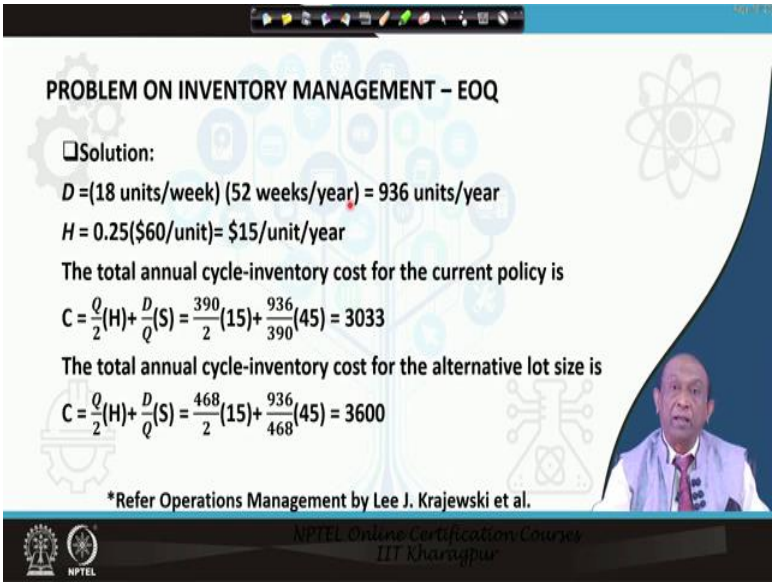


So here the demand is 18 units per week multiplied by 52 weeks per year which comes around 936 units per year. The holding cost is 25 percent of the unit cost of this item which is dollar 60 per unit, that is equal to dollar 15 per unit per year. So the total annual cycle

inventory cost for the current policy of ordering 300 unit 90 units as a lot size becomes 390 by 2 into 15 plus 936 which is the annual demand divided by Q that is 390 into 45 which becomes 3033 units. The total annual cycle inventory cost for the alternative lot size which is 468 comes about to 3600. So what is better?

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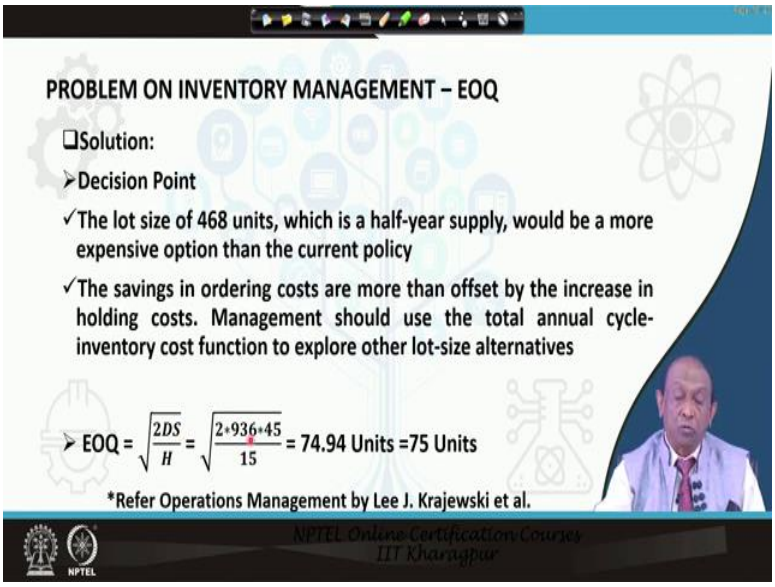


The lot size of 460 units, which is a half year supply would be a more expensive option than the current policy. The savings in ordering costs are more than offset by the increase in holding costs. Management should use the total annual cycle inventory cost function to explore other lot size alternatives. So the EOQ after exploring all other lot size alternatives, we tried to find out the optimal lot size, which is root over of 2 into annual demand into ordering cost divided by holding cost which is 2 into 936 into 45 divided by 15 which is 74.94 units, which is rounded off to 75 units.

This is a simple example on inventory control or inventory management and other models are built upon this fundamental approach. We try to modify this particular basic model to arrive at different kinds of situations, how to tackle them. So we will be dealing with all those in our subsequent modules. Thank you.

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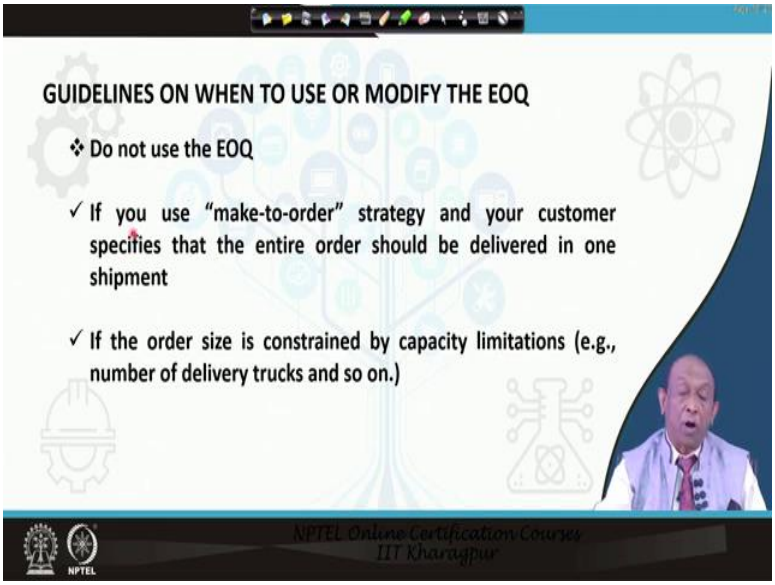


And there are guidelines, when to use or modify the economic order quantity model. Do not use the EOQ. If you are using "make to order" strategy and your customer specifies the entire order should be delivered in one shipment. Another situation where EOQ is not recommended, that if the order size is constrained by the capacity limitations for example, number of delivery trucks and so on.

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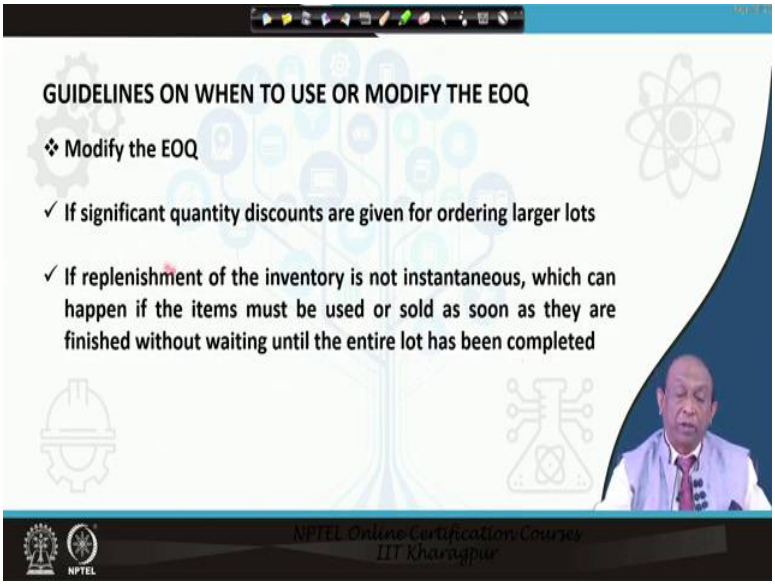


You can modify EOQ if significant quantity discounts are given for ordering larger lots. Texts on operations management deal with several models in which quantity discounts have been taken into consideration. If replenishment of the inventory is not instantaneous, which

can happen if the items must be used or sold as soon as they are finished, without waiting until the entire lot has been completed. We will deal with one such model in our next module.

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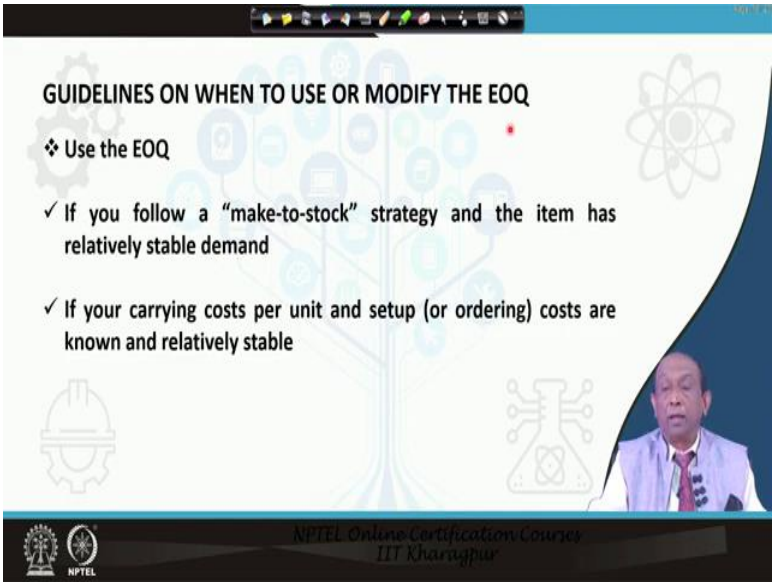


In continuing with our guidelines on when to use or modify the EOQ, we recommend that the economic order quantity model should be used extensively when we follow our make to stock strategy and the item has relatively stable demand. Or in situations when carrying costs per unit and setup costs are known and they are relatively stable then the EOQ model can extensively be used. Thank you.

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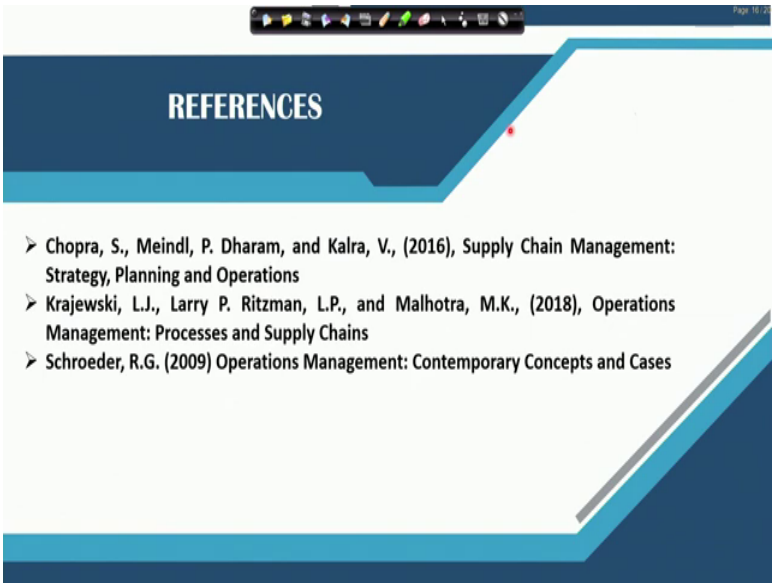

And these are the references that I have used for this particular session. All these three texts gives extensive elaborations about this model. Thanks a lot.