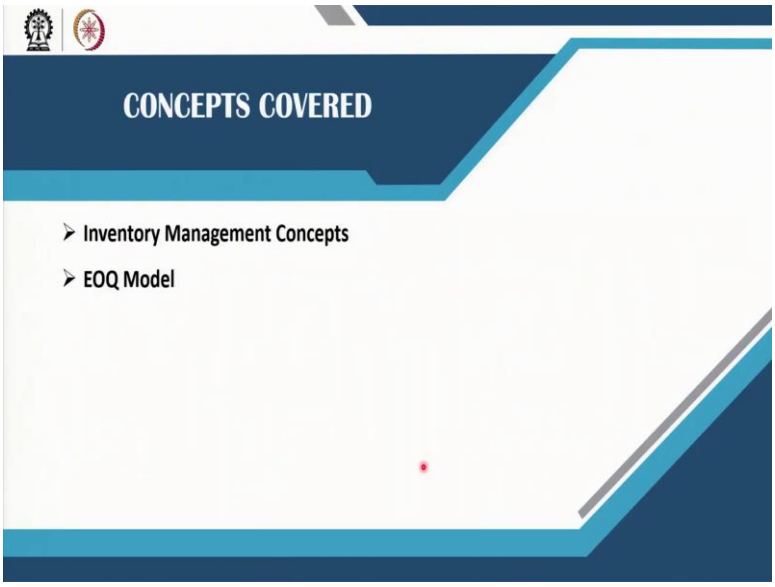
Decision Support System for Managers
Prof. Kunal Kanti Ghosh
Vinod Gupta School of Management
Indian Institute of Technology, Kharagpur

Week - 11
Module - 01
Lecture - 50
Decision Support Systems for Inventory Management

Hi, welcome to our 1st module for the week 11 on 'Decision Support Systems for Inventory Management'; ok. In this 1st module, we will cover the concepts on basically: what is inventory? Because that is very important; concept of inventory; and then, we will be deliberating on the 'economic order quantity' model, known as the EOQ model.

(Refer Slide Time: 00:39)



This is a very fundamental model and is the basis for all advanced modeling concepts in the area of inventory management. And these models will be embedded in the decision support systems which are mainly used by operations managers and materials managers. So, in the area of procurement and supply chain management, this concept of inventory modeling is very popular.

(Refer Slide Time: 01:28)

So, what is inventory? The another name of inventory is stock; ok. So, when we basically explain inventory, we first need to know that inventory refers to a stock of materials used to satisfy the demand from the customers end or to support the operations management function in their production of services or goods. So, in a manufacturing environment, the operations management function can be thought of as internal customer of the materials management function.

So, inventory management basically deals with the planning and controlling of the stock of material that is inventories; in order to meet the competitive priorities of the organization. And these competitive priorities are spelt out by the business strategy of the organization, linked with that in a very consistent manner the operation strategy and the materials management strategy.

(Refer Slide Time: 03:18)

Now, you might ask that what is the purpose of inventory; because inventory means stock of materials and how organizations are meeting these needs? They are buying these stocks in terms of raw materials or even semi-finished components or even components which will be needed for final assembly.

All these things cost money and organizations, they cater to this requirement of funds from their working capital and how do they get this working capital? They have to take loans from the banks or financial institutions and on these loans, they have to pay interest. So, more the amount of stock, more the amount of inventory tied up; means they have to organizations have to pay more interest charges which will affect their profit.

So, people might say that then, why do we need inventories, we should do away with these inventories. But definitely, inventory must have some purpose. So, what are those purpose of inventories? See one of the major components of the total inventory that is being held by a firm is the safety stock or buffer stock.

The safety stocks are maintained in inventory to protect against uncertainties related to demand and supply situation. Suddenly, your consumption rate might go up because the customers have placed more order. So, there is a fluctuation in the average consumption or demand rate. The suppliers might delay in sending their orders or materials based on the purchase orders that they receive.

And all of us know that there is a concept of lead time, which is the difference in time between placement of purchase order on to the suppliers and receipt of the materials at the factory gate. This is basically the lead time and this lead time is not fixed. In reality, it is a random variable, it fluctuates. If the average lead time is 7 days, sometimes the material might come in 5 days, sometimes the material might come in 10 days, 11 days.

So, if the material comes late from the supplier's end, organizations must have some additional stock in their hand to cater to the requirements of production or consumption for this additional 4 or 5 days. As long as materials or stocks arrive from the suppliers end within the average lead time, not much of a problem is there.

But if the expected arrival of lots the time is more than the average lead time, we must have some additional stock to cater to that particular situation and sometimes what we do that, the suppliers they give us some discount that if you place an order whose size is this much, we will give you some discount.

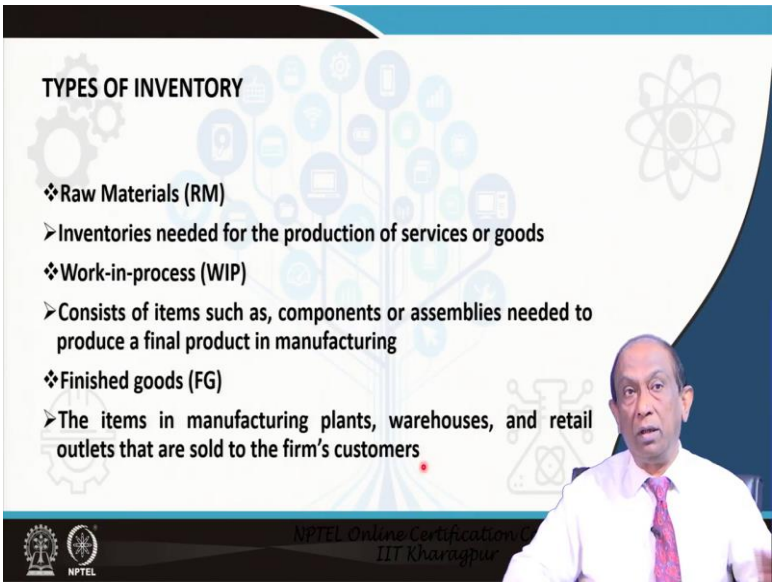
So, to take advantage of that discount, sometimes organizations, they are placing purchase order size much more than what they require. But the justification from their end is that it will allow them to have economic production and purchase ok. So, it is often economical to produce or procure material in lot sizes and there are decision models to determine the best or the optimum lot size or batch size under certain constraints dictated by the operating environment.

(Refer Slide Time: 08:26)

Sometimes organizations, they hold inventories which is basically known as anticipation inventory to absorb uneven rates of demand and supply. For example, companies who are in the seasonal business manufacturing say air conditioners, refrigerators, fans, they often hold extra stock to smooth production because say in the winter months, the demand for air conditioners, refrigerators, they may not be as high as the demand that is evidenced in the summer season.

But organizations, they basically want to maintain a smooth production rate. So, the excess amount that is being produced during the winter season is utilized during the summer months, when the demand for such products exceeds the production capacity. Then, at that point in time, from the stock that has been built up during the winter months, the demand from the customers end, they get satisfied.

(Refer Slide Time: 10:07)



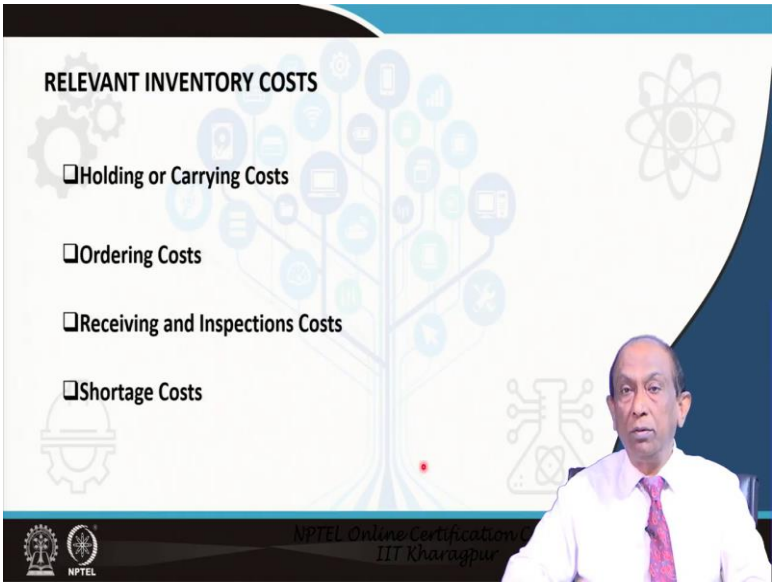
Now, let us get into the topic of different types of inventory. Raw materials inventory is the primary type or classification. Raw materials inventory refers to the inventories needed for the production of goods or services. Next classification is working progress inventory is also known as Work-In-Process inventory. In the factory shop floor, they call it WIP in short.

Now, Work-in-process inventory consists of items, where some value has been added to the raw materials that gets processed during different stage of manufacturing and it

consists of items such as components or assemblies needed to produce a final product in manufacturing.

So, raw materials plus value addition during different stages of production will lead to Work-in-process inventory. And then, the third and final classification is the finished goods inventory, which refers to the items in manufacturing plants, warehouses and retail outlets that are kept ready to be sold to the organization's customers; ok. So, all of you know about.

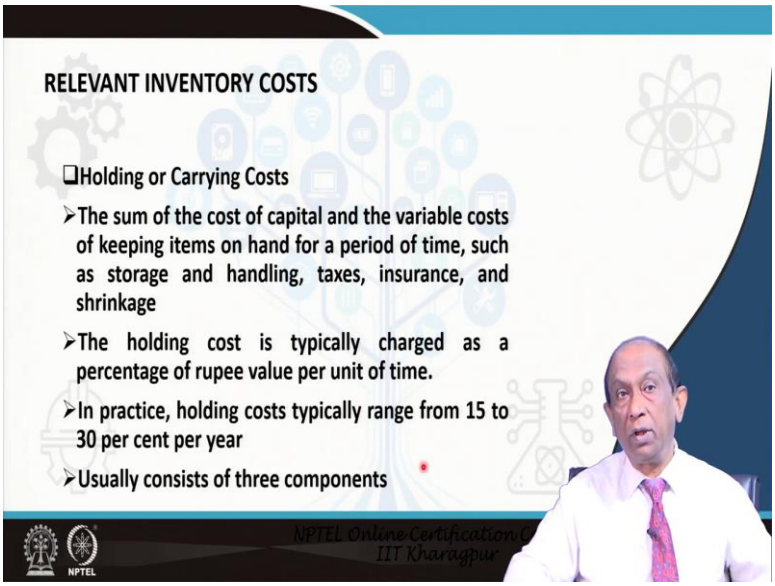
(Refer Slide Time: 12:06)



Now, when we talk about inventory modeling, ok, there are certain cost elements, and certain terminologies that we need to consider. One of the major cost element is the inventory holding cost or sometimes referred to as inventory carrying costs. Then there is a cost associated with placement of orders onto the suppliers which is basically called the ordering cost which might also include the cost of transportation from the suppliers' end to the manufacturing end.

Then, there are costs associated with receiving an inspection and sometimes, there is a cost which is not very directly evidenced; but we call it a shortage cost; that means, the opportunity cost of not being able to satisfy the demand from the customers end.

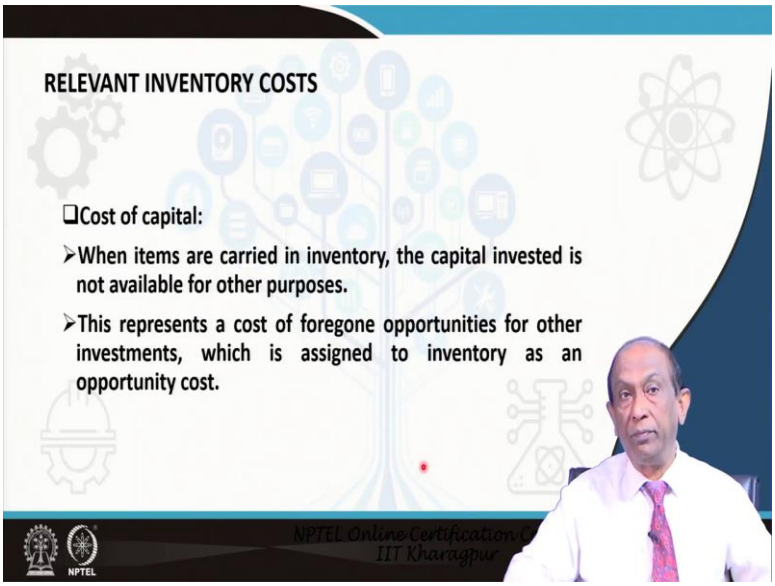
(Refer Slide Time: 13:25)



So, holding or carrying cost is basically the sum of the cost of capital and the variable cost of keeping items on hand for a period of time including cost of storage and handling, tax component, insurance and shrinkage. The holding cost for the purpose of inventory modeling is typically charged as a percentage of rupee value per unit of time.

And in practice, the holding cost or the holding rate typically ranges from 15 to 30 percent per year and usually, consists of three components. In fact, for the purpose of modeling, what we do that we multiply the unit of unit cost of the item with this holding rate that is 15 percent or 30 percent to arrive at the inventory carrying cost per unit item.

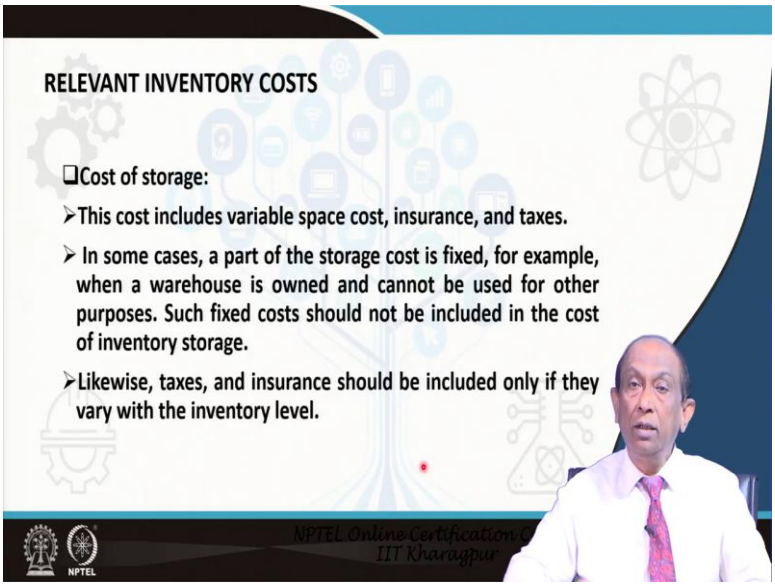
(Refer Slide Time: 15:00)



Now, in order to determine this holding rate or the holding cost, you have to consider very carefully the elements like cost of capital. When items are carried in inventory, the capital that is invested in is not available for other purposes and this represents a cost of foregone opportunities for other investments which is assigned to inventory as an opportunity cost.

And if the cost of capital is very high for an organization; that means, the organization might get high amount of return from other investments, then the materials manager or the supply chain manager and the operations managers must jointly think that how to reduce the level of inventory; ok.

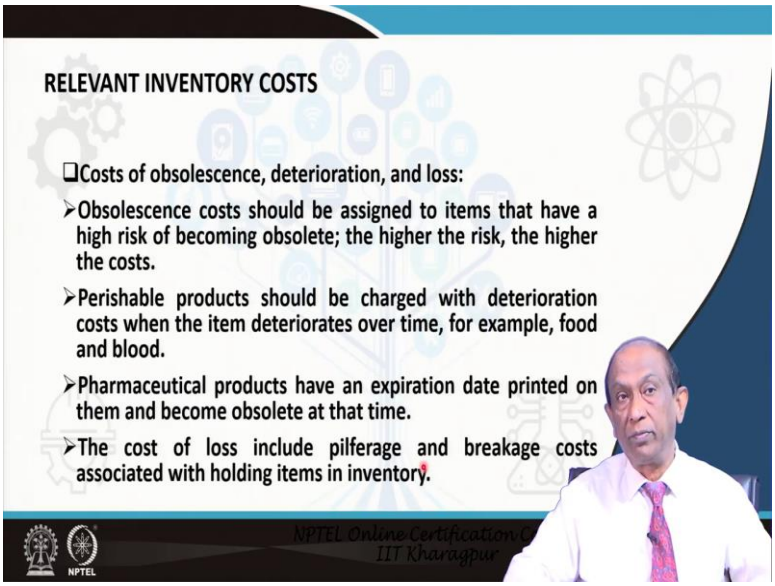
(Refer Slide Time: 16:12)



Then, the another component related to inventory carrying cost is the cost of storage. This cost includes variable space cost, insurance and taxes. In some cases, a part of the storage cost is fixed. For example, when a warehouse is owned and cannot be used for other purposes, basically we call it a sunk cost.

Such fixed cost should not be included in the cost of inventory storage. Similarly, taxes and insurance should be included only if they vary with the inventory level; otherwise, there is no reason why we should include that component because anyway we have to pay for that.

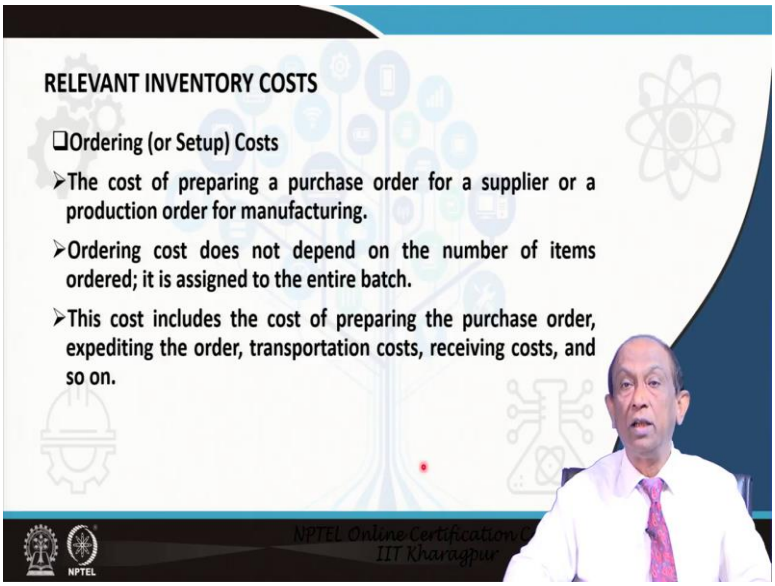
(Refer Slide Time: 17:18)



Then, the third component that we need to consider while determining inventory carrying cost is the costs related to obsolescence, deterioration and loss. Obsolescence cost should be assigned to items that have a high risk of becoming obsolete and the higher the risk, the higher the costs. Perishable products should be charged with deterioration costs, when the item deteriorates over time.

For example: food and blood. Pharmaceutical products have an expiration date printed on them and they become obsolete at that point in time. The cost of loss include pilferage and breakage cost associated with holding items in inventory. So, if these components, they cost very high; then, appropriately that should get incorporated in the inventory carrying cost.

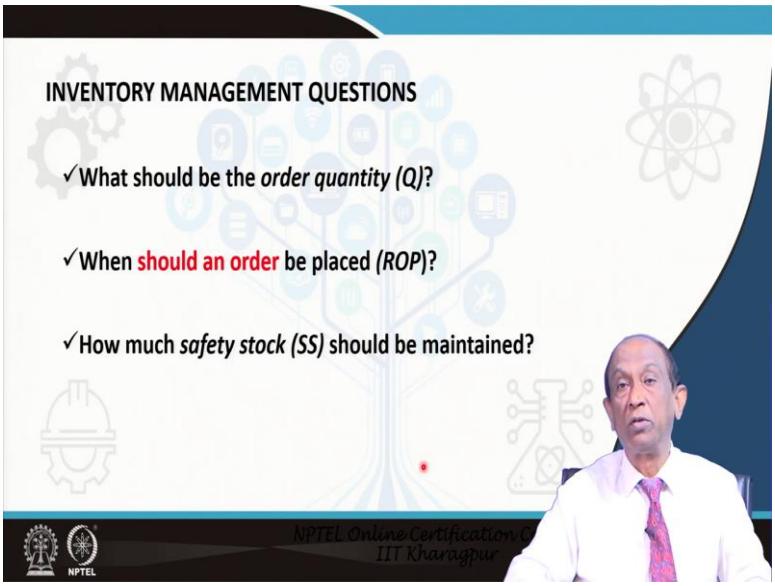
(Refer Slide Time: 18:41)



Then, let us come back to the concept of ordering costs which is also known as setup costs in a manufacturing environment. Ordering cost refers to the cost of preparing a purchase order for a supplier or a production order for manufacturing. In today's environment, this portion of the cost is not very high. The ordering cost does not depend on the number of items ordered; it is assigned to the entire batch.

This cost includes the cost of preparing the purchase order, expediting the order, transportation cost as I had mentioned from the suppliers end that is that might be reasonable amount, then receiving costs and so on. So, all these together if we look at it, then in some cases the ordering costs may be high.

(Refer Slide Time: 19:58)



Now, three important questions arise when we basically try to determine the simplest model related to inventory control that is the economic order quantity model. In here, the important management questions are what should be the order quantity?

That means, when we are placing order on to our suppliers under the given conditions that will spell out what should be the size of the order, best size of the order which is basically called optimum order quantity and related by Q, and when an order should be placed.

Stocks get depleted, when items are issued from the stores as and when the stock level goes down below a certain specified level, we place an order on to the suppliers. This specified predetermined level is called a Reorder level or that point is basically called the reorder point, ROP.

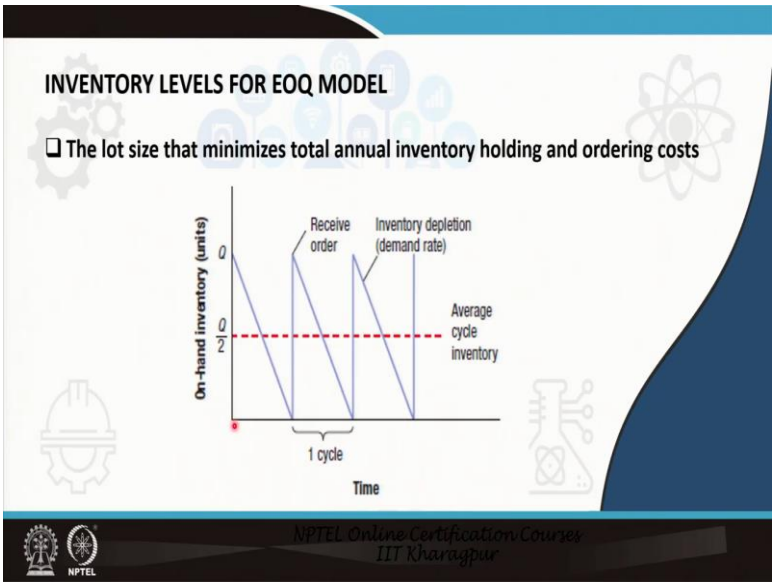
Then, we have also mentioned that some amount of stock should be maintained all throughout the operating cycle to guard against this fluctuation in the lead time, fluctuations in the consumption rate or to guard against fluctuations in both. So, how much safety stock should be maintained? And we will deliberate more on this determination of safety stock in a separate module.

(Refer Slide Time: 22:22)

Now, let us discuss about this fundamental inventory model, which is the economic order quantity model. Here there are certain assumptions which we will discuss in the next slide. Then, the other different inventory models of interest are that, what is the economic batch size, when there is simultaneous occurrence of production. And consumption in the economic order quantity model that we are going to discuss, there is no simultaneous occurrence of production and consumption; ok.

Then, there are lot of modeling aspects that will be dealing with related to determination of the safety stocks. And then, we will do discuss about two very popular inventory control systems; one of them is the continuous review model popularly known as the Q model and the other one is the periodic review model, which is called the P model or Order-up-to Model.

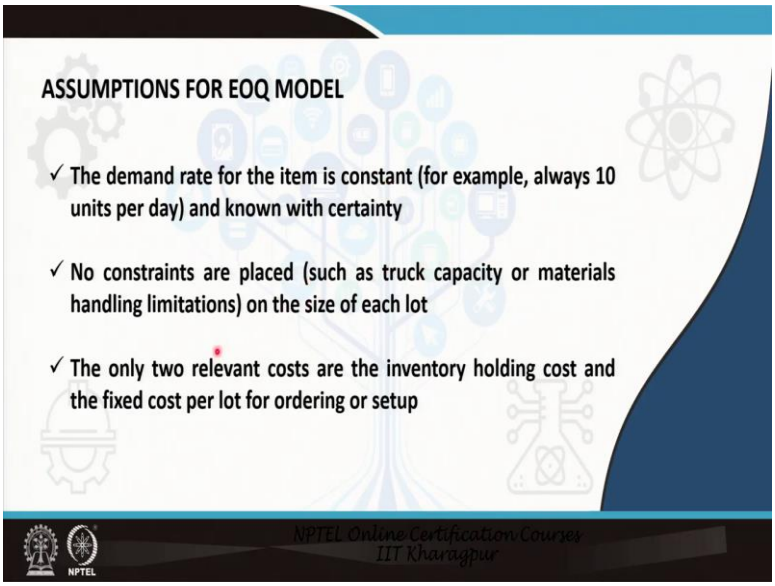
(Refer Slide Time: 23:54)



Now, inventory levels for EOQ model. Here in, we are trying to determine the lot size Q that minimizes the total annual inventory holding cost and ordering costs. So, here you see time is plotted along the x axis and along the y axis; we are basically plotting the on-hand inventory.

You see the stock comes here; the level of inventory goes up to the level Q, then the stock gets depleted at a constant rate and again, there is instantaneous replacement, the stock jumps up to Q. So, you see a seesaw pattern and the average inventory level is Q by 2 because the maximum inventory is Q in this model; minimum inventory is 0. So, Q plus 0 by 2 is Q by 2; which is the average inventory carried throughout the cycle.

(Refer Slide Time: 25:16)

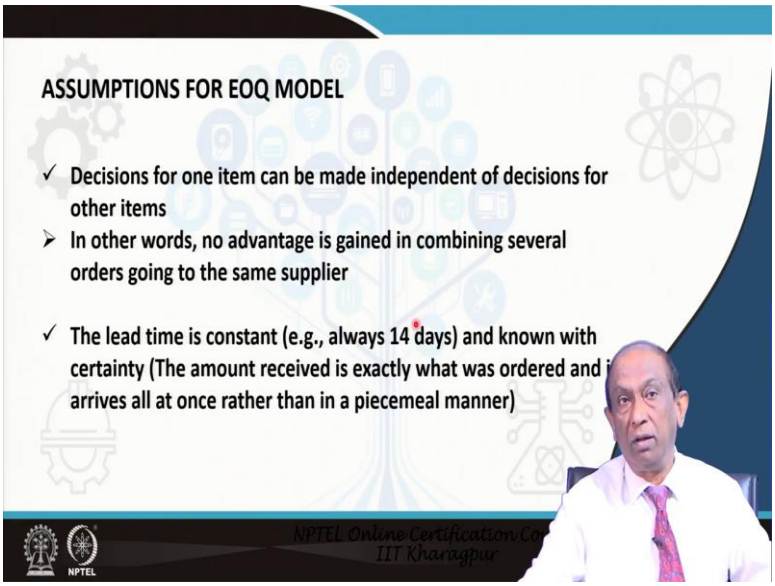


Now, the assumptions behind the EOQ model is that the demand rate for the item is constant; for example, always 10 units per day and known with certainty. No constraints are placed such as truck capacity or material handling limitations on the size of each lot and the only two relevant costs that will be considering in the simplest model are the inventory holding cost and the fixed cost per lot for ordering or setup.

Setup comes in a manufacturing situation when through the same machine, we are producing different products. And when we change from one product type to other product type, the dice and tools for the first product has to be dismantled and the dice for the second product needs to be fixed up, the tools have to be organized for the second product.

So, during this period of time, we are not able to make any production run and there is a cost involved for not producing during this time when this setup takes place, that is why this cost is like a ordering cost and known in a manufacturing environment as the setup cost.

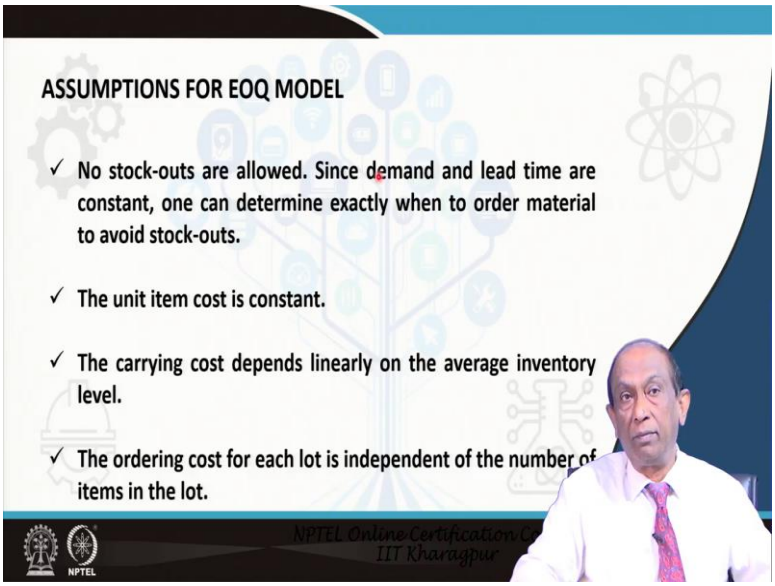
(Refer Slide Time: 26:44)



The other assumptions in the EOQ model are the decisions for one item can be made independent of decisions related to other items. In other words, no advantage is gained in combining several orders going to the same supplier for the purpose of this particular modeling or the discussion that follows. The most important assumptions related to this model is that the lead time is constant.

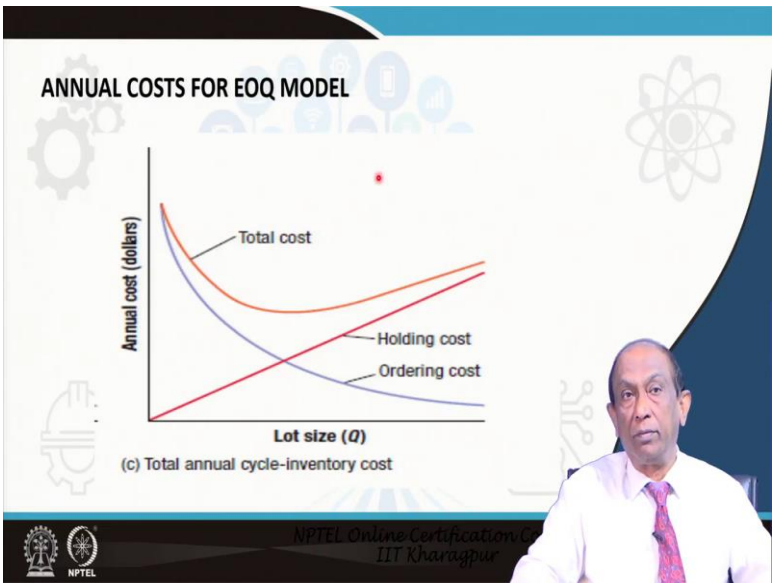
For example, always 14 days example and known with certainty and the lead time may be 0, when there is instantaneous replacement, may be in case of say vendor managed inventory or we talk about just in time inventory and things like that. And the other assumption is that the amount received from the supplier send is exactly what was ordered and it arrives all at once rather than in a piecemeal manner.

(Refer Slide Time: 28:03)



No stock-outs are allowed since demand and lead time are constant, one can determine exactly when to order material to avoid stock-outs. The unit item cost is constant is a very important assumption and the carrying cost that is inventory carrying cost, inventory holding cost depends linearly on the average inventory level; the ordering cost for each lot is independent of the number of items in the lot.

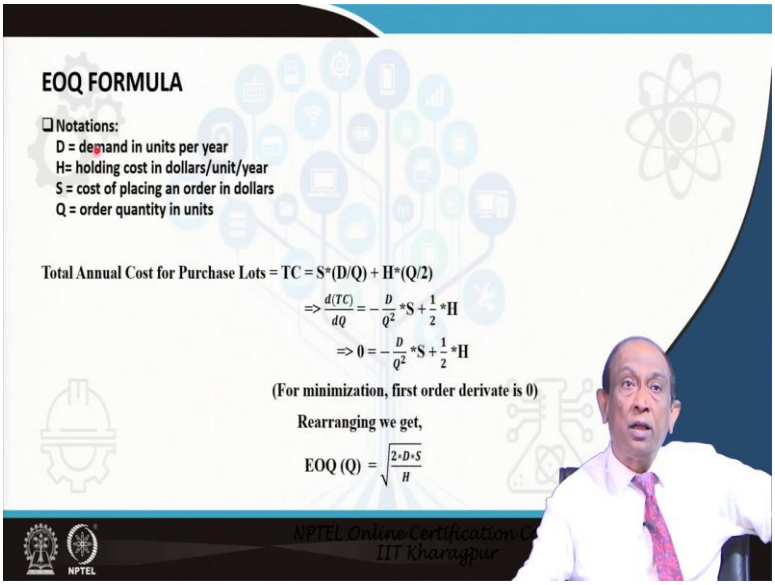
(Refer Slide Time: 28:52)



This is the total cost consisting of inventory holding cost, the linear function and the ordering cost decreases with the size of the order. The total cost curve is a u cost curve

and the optimum point somewhere lies here and there is a range within which the cost structure is flat.

(Refer Slide Time: 29:29)

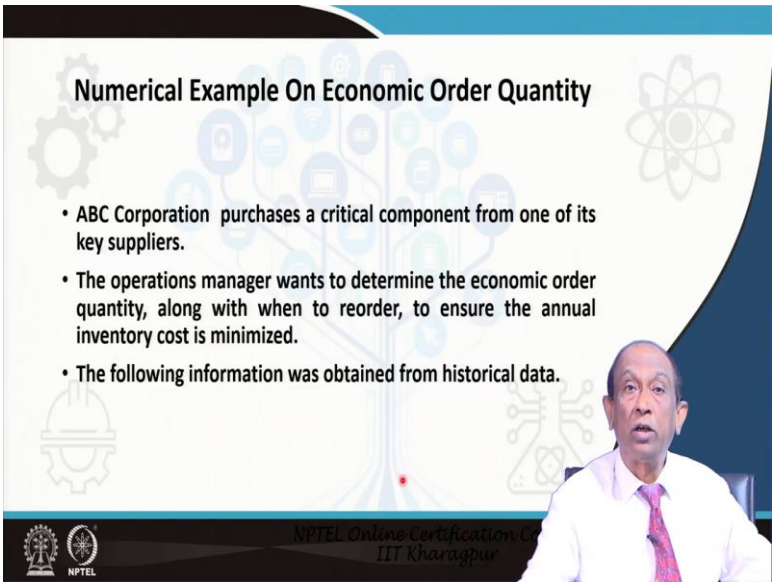


These are the notations that we will follow; D refers to the demand in units per year; H is the holding cost in dollars per unit per year; S is the cost of placing an order in dollars; Q is the order quantity in units. So, total annual cost for purchasing the lots is the setup cost is that is the cost of placing an order into the number of orders over the year that is D by Q. Q is the lot size; D is the total annual demand.

So, D divided by Q is the total number of orders in the year multiplied by the ordering cost per order that gives you the ordering cost component plus Q by 2 is the average inventory multiplied by H which is the holding cost. So, that gives the inventory carrying cost portion.

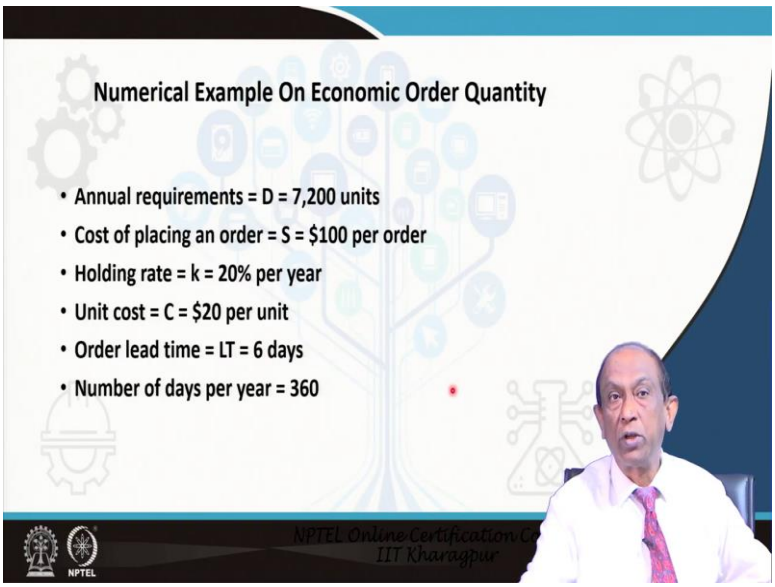
This total cost, first we must differentiate with respect to Q to minimize the total annual cost for purchasing the lots and equate it to 0, which gives minus D by Q square into S plus H by 2 equals 0 and for minimization. First order derivative is 0 and rearranging, we get the EOQ or the optimum order quantity equals root over 2 into annual demand into ordering cost by the holding cost.

(Refer Slide Time: 31:13)



And if you do the second order derivation, then it will become positive indicating that the cost is minimum. Let us look at one example. ABC corporation purchases a critical component from one of its key suppliers. The operations manager wants to determine the economic order of quantity along with when to reorder to ensure that the annual inventory cost is minimized.

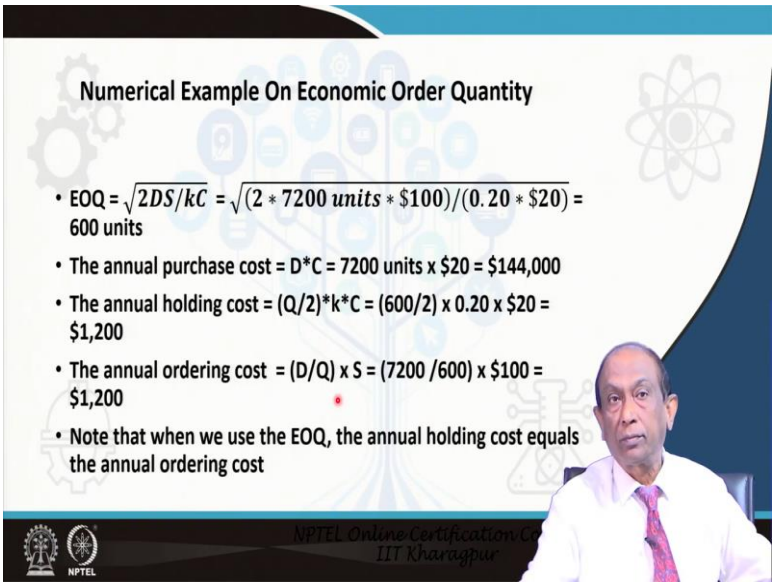
(Refer Slide Time: 31:55)



That means, we have to determine the optimum order size Q and the reorder point. The following information was obtained from historical data. Annual requirement 7,200

units. Cost of placing an order is dollar 100 per order. Holding rate is something like interest charge is 20 percent per year. Unit cost of the item is given as dollar 20 per unit. Ordering lead time is given as 6 days that is constant and the number of days per year, it is given in the problem as 360.

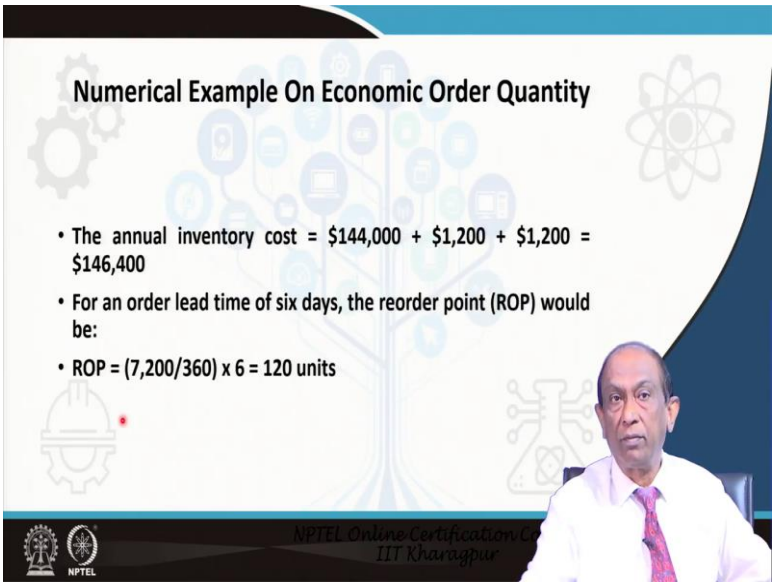
(Refer Slide Time: 32:28)



So, economic order quantity is root over twice D S by holding cost H which is equal to k into C; k is the interest rate or 20 percent that is given in the problem multiplied by the unit cost of that. We substitute the values and we determine EOQ at 600 units, the annual purchase cost which does not really get reflected in the model; but if you want to separately determine it, that is the total annual requirement multiplied by the unit cost of the item which is this much.

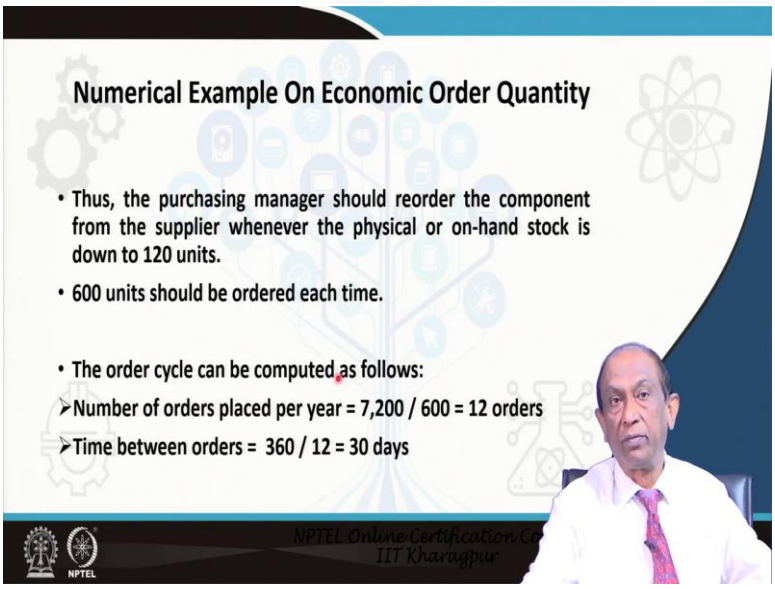
Annual holding cost equals average inventory multiplied by the interest rate into unit cost of the item is this much. Annual ordering cost the total number of orders in a year which is D by Q multiplied by the ordering cost per order is calculated to be this much and you note that when we use the EOQ, the annual holding cost equals the annual ordering cost.

(Refer Slide Time: 33:43)



The annual inventory cost is the sum of the three costs that we had determined just now, that is the annual purchase cost plus ordering cost plus holding cost. For an orderly time of 6 days in this case, the reorder point would be average daily consumption into multiplied by 6 days which is the lead time which is equal to 120 units.

(Refer Slide Time: 34:26)

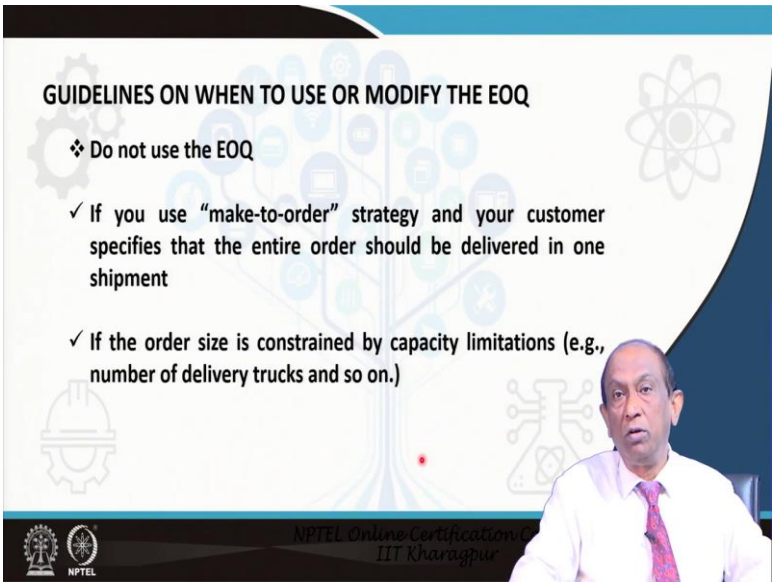


Thus, the purchasing manager should reorder the component from the supplier whenever the physical or on hand stock goes down to 120 units and every time he orders, he orders 600 units and the order cycle can be computed as follows. Number of orders placed per

year is 12 orders and time between orders is the number of working days in the year divided by the number of orders that is 30 days.

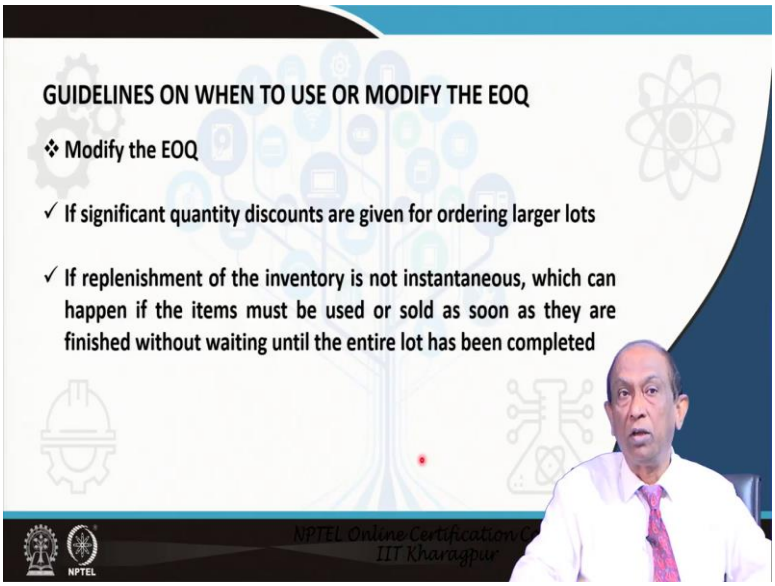
The simplest model which gets incorporated in the decision support systems and before taking the final decision, the results are shown to the decision managers. The materials managers, they see the implication of this order size and its impact on the annual inventory; if required, given the other operating parameters, the dynamics of the environment, they can change this order size and see the corresponding implications in an interactive manner and then finally, decide at the lot size for ordering. So, this is all for this first module.

(Refer Slide Time: 36:03)



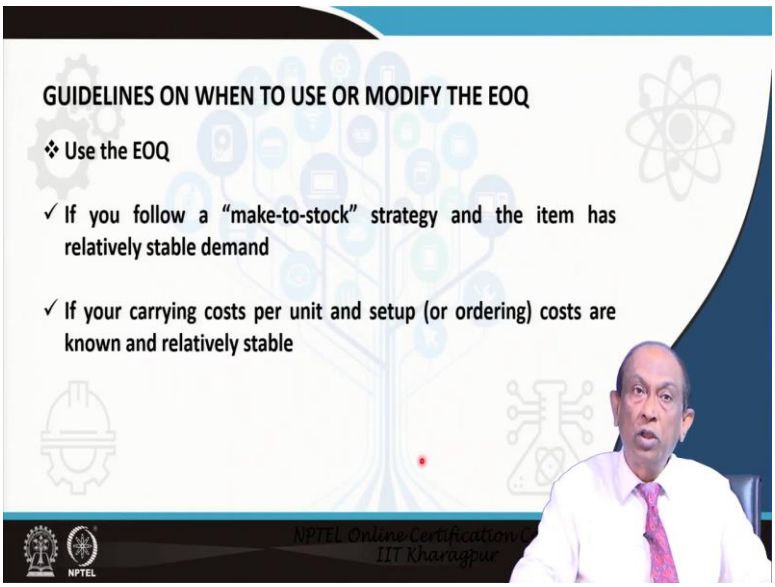
And only there are certain guidelines or when to use or modify the EOQ, if you use a make to order strategy and your customer specifies that the entire order should be delivered in one shipment, then you do not use EOQ and the second thing is if the order size is constrained by capacity limitations. For example, number of delivery trucks available size of the trucks and so on, then you do not use the EOQ model.

(Refer Slide Time: 36:41)



If significant quantity discounts are given for ordering larger lots, then this EOQ model needs certain modification. 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. Or if the lead time is not constant, then do not then, this EOQ model cannot be directly applied; but it requires certain modifications.

(Refer Slide Time: 37:17)



And you should use the EOQ, if you follow a make to stock strategy and the item has relatively stable demand. If you are carrying cost per unit and setup cost or ordering costs are known and relatively stable, then you use the EOQ model.

(Refer Slide Time: 37:35)

These are the references that I have used for preparing the lecture, particularly in preparing the problem. I have used that 'Wisner' book on 'Supply Chain Management: A Balanced Approach'.

Thank you all for your patience!