Principles of Industrial Engineering
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Lecture 38 – Inventory: Models lI

Hello, I welcome you all in this presentation related to the subject Principles of Industrial Engineering and we are talking about the inventory. Inventory is maintained in the organizations whether they are manufacturing or in the service sector, inventory is maintained so that they can provide the items as and when they are required and wherever they are required in the quantity as per the requirement. Now, this helps in reducing the cost, total cost at which the item can be produced, this reduces the possibility of the stock out situation, it helps to smoothen the production, so there are number of the secondary benefits.

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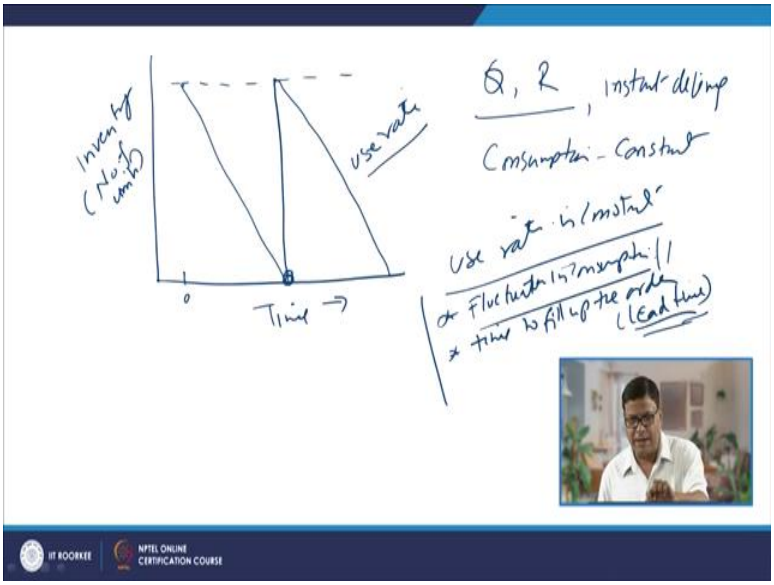

So, earlier we have talked about one of the simplest Q R model related with the inventory. In the simplest Q R model where the ordered quantity is fixed and the reorder point is also fixed. And the consumption rate or the demand rate, that is also constant and the delivery of the item as soon as order is placed is instant, so we can say instant delivery. About this model I have, we have talked earlier like say the model is in this case, the stock is full, so the consumption at 0 time stock level is this, so the consumption takes place at a constant rate like this and it continues, so the rate of consumption is fixed like this as a function of time.

So, here in x axis, we have time and the inventory y axis where here it is about basically the number of units, number of units in the inventory. As soon as the stock level is reduced to 0, the order is placed, so reorder point here is set at 0 level. Because the delivery is instant, so as soon as the order is placed, immediately the stock is replenished, stock is filled. And again, the consumption starts and it is at a constant rate. So, here we can say the use rate or the consumption rate is constant and the delivery is instant, reorder point is at 0, there is no safety stock in this case.

So, this is very simple model but we hardly have a situation where the use rate is constant, practically the use rate or that assumption rate may fluctuate that is one, so the fluctuation or the variation in consumption rate is very common phenomena. One day, 10 units are being consumed, another day maybe 12, another day maybe 8 number of units are being consumed for particular item, so it is very common. The second is, it is hardly, we find a situation where the delivery is instant. As soon as order is placed the entire quantity is supplied within no time.

So, hardly we have this situation. So, there is always some time, time to fill up the order or to get the supply. So, this time the moment order is placed and the moment when we get the supply, that time gap is known as lead time and during this lead time also, there will be some consumption, because the consumption is continuous, maybe at low or high rate. But in this model, it does not consider the lead time kind of things or the fluctuation in consumption.

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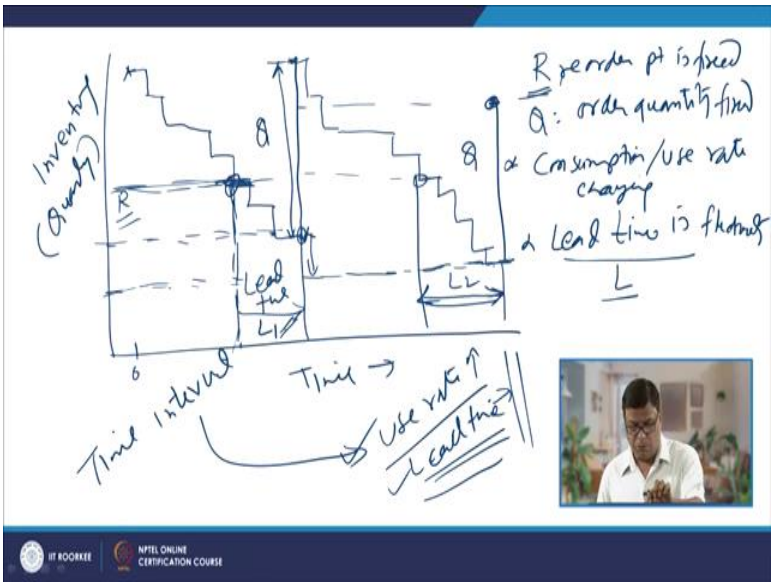

So, there is another model, where the rate of consumption fluctuates and there is a variation in lead time. So, in this case also the reorder point that number of units left in the inventory at which the order will be placed that is fixed, so the R point or the reorder point is fixed. And the quantity number of units for which order will be placed that is also constant, so Q order quantity is also fixed, is also constant, what is changing? The demand. So, the consumption or use rate is changing as a function of time, this is one new thing and there is a fluctuation in the lead time.

Once the order is placed and we get the delivery in two days, another time order is placed and we get the delivery after 3 days or 4 days. So, the lead time is fluctuating or changing. So, we have to consider this lead time and the variable consumption situation. Since the reorder point is fixed and the quantity for which order is placed is fixed, so how it will be changing? What, how the model will be shown? In the x axis we have the time, which will be showing the consumption as a function of time or the way by which the inventory will be depleted or items number of items in the inventory will be reduced, so here quantity or the items in the inventory.

So, here say (invent) at the 0 time the inventory is full, so the consumption rate is say fluctuating like this. Let us say reorder point is fixed at a particular level, this is the level at which, so in this kind of the inventory model, the record keeping personally keep on counting the number of items left in the inventory. And as soon as the number of items left in the inventory are reduced to or

brought down below certain level, the order is placed. So, here this is say reorder point, which is constant.

But once the order is placed thereafter, after some time delivery will be made, so this is the point at which the order, this is the time, this is the movement or the time when order is being placed. Because the items are being consumed and as soon as the stock is reduced below this level, below this R level, order is placed. So, the moment when order is placed is this. And we get the order after this much time. So, this is the time when the order is supplied, so this time we can say lead time say L1.

So, this is the moment when we get the order as supply is being made available against the order so it will be filled in, so the delivery is made for the items Q, for which order was placed. So, again the stock is filled, so that this quantity is Q. So, now our the stock has been refilled, again the consumption will be taking place and say like this. So, as soon as the stock reaches to a particular level, order is placed. Let us say in this case the consumption continues at a much higher rate and it is reduced to a significantly lower levels as compared to the earlier case, earlier we got the order at this movement of the inventory level and in this case, we got the stock or the supply at significantly lower level of the stock in the inventory.

And say this is the moment when order is received. Since the order was placed again of the quantity of the queue, so here this time it will be refilled by the same quantity, so if we see this is the same quantity for which order was placed earlier and the maximum stock level which reached is here, which will be lower than the earlier level of stock because we have consumed more during the lead time. So, here we see the lead time here is more, say this is the lead time L2, this lead time is greater than what we had in the earlier case like L1.

So, L2 is greater than L1 that is why our stock was reduced to the lower level, considering the same consumption rate or the higher convention rate, so there are 2 possibilities. If the either the use rate is high or the lead time is high, so both this is the fluctuation in use rate or fluctuation in the lead time, both will be leading to the change, leading to the time when order change in the time when order is placed. Reorder point is fixed, but the time interval between two orders, between two consecutive orders can change depending upon the kind of demand which is there, because it will be governing how fast it is reaching to the R level or the lead time.

If lead time is the longer, obviously the gap between the two consecutive orders will also be more. So, here but there is a possibility, there is a possibility of the stock-out situation if the consumption rate or the use rate is increased significantly and we are not left with the items in the inventory to deal with the demand during this lead time. So, if the lead time is significantly greater than the items available in the inventory then it will be leading to the stock out situation, so this is the another model.

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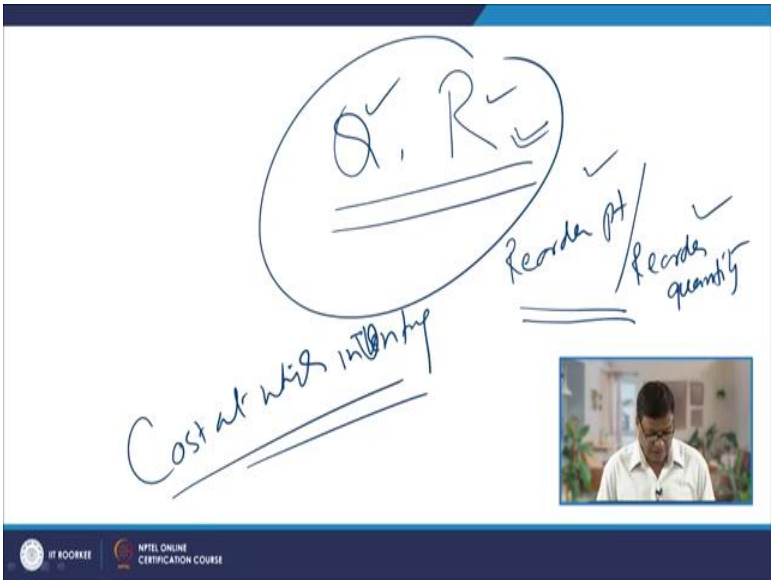

So, in both these cases if we see, the quantity for which order is being placed and the number of items which are left in an inventory deciding the R kind of the reorder point, the time when order is placed, again these two factors are the in the core of the inventory, maintenance, re-order point means the number of items left in the inventory when the order is placed or the reorder quantity means the number of items for which order will be placed.

Both these factors significantly affect the cost at which inventory is being maintained. So, the cost of maintaining the inventory significantly influenced by these two factors, so the how to optimize the order, reorder quantity or the reorder point, that becomes crucial towards minimizing the cost for maintaining the inventory.

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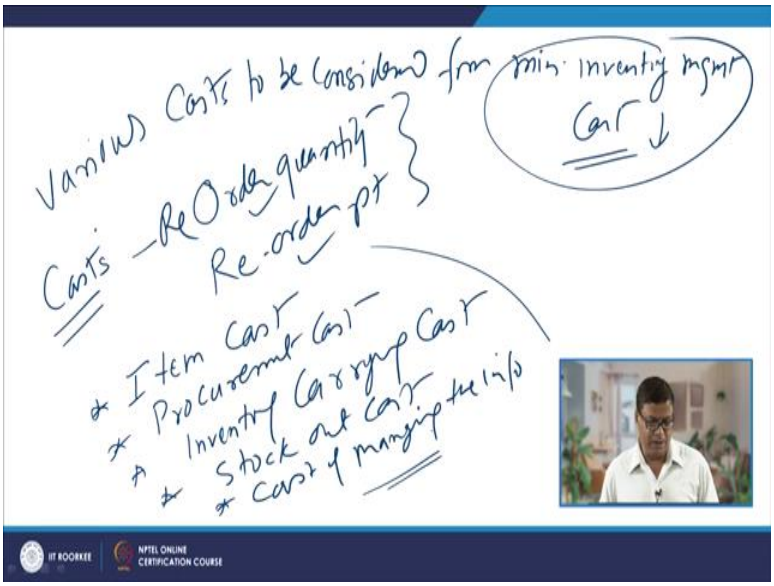

And therefore, it becomes important to understand what are the various costs that need to be considered for minimizing, costs to be considered for minimizing the inventory management cost, the total cost of managing the inventory that has to be minimized. So what are the, so this is important for having the inventory at the lowest possible cost. So, what are the various costs which are considered?

So, all there are various costs, but all those costs which will be affected by the order quantity or the reorder quantity or the re-order point, so the costs which are affected by these two things must be considered in optimization of the inventory or managing the inventory in such a way that the total cost is minimized. And what are the various costs? These, so the first one is here, the item cost, the cost of procuring the items, whether the 1,000 items are to be purchased in one go or we will be placing the 10 orders and each time we will be buying the 10, 100 items only.

So, the cost of items, then procurement cost, then inventory carrying cost, then we have the stock out cost, what if we are not left with the items in the inventory then what will be their losses which will be incurred on account of the stock out situation? And then cost of managing the information or information processing like maintaining the record of items available in the inventory and the way by which these are being consumed when the order is being placed when the deliveries are being received. So, maintaining all this information, will be falling in this cost

of, managing all this information will be falling under this last cost, cost of managing the information and information processing.

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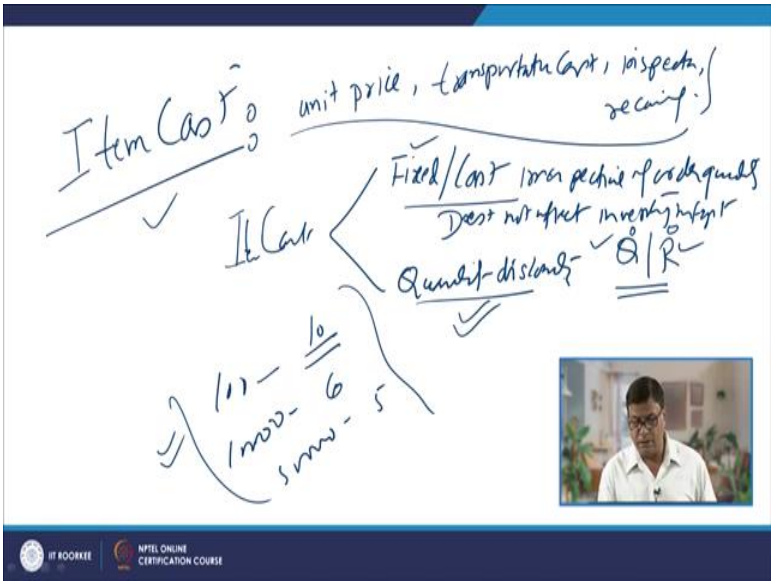

So, what are the various ingredients and the details related with these costs? So, the first is the item cost. So, obviously, the item cost there are two situations related with the item cost, so we will consider first what are the components or things which will fall under the item cost. First is the unit price, number 1, then the transportation cost, then inspection cost if any, then receiving cost, these are the costs which may change with the quantity for which order is being placed. So, there are two situations.

One, when the item cost is fixed or constant, irrespective of order quantity, so irrespective of the quantity for which order is being placed, there is no change in the price. If this is the case, then it does not affect the item cost, does not affect the inventory management aspect, means the order quantity or the reorder point, so the two are not affected if the item cost is fixed. But if there is a possibility of the quantity discount, means if the 100 items are placed, the unit price is 10 rupees.

But if the 10,000 items are placed, maybe units are available at means the unit price is 6 rupees or if the 50,000 items are purchased, then order is placed for 50,000, then maybe it is available at 5 rupees per unit. So, if this is the situation then certainly, it will be affecting the total inventory

cost or total inventory management cost. So accordingly, we have to see that Q and order reorder points are influenced by the item cost.

So, if there is a quantity discount possibility, then definitely Q and R points will be affected related with the item cost. So, item cost will be a factor in optimization of the order quantity and the reorder point if it fluctuates with the order quantity or the if the discount, quantity discount is available; otherwise, the item cost becomes irrelevant in optimization of the total inventory cost.

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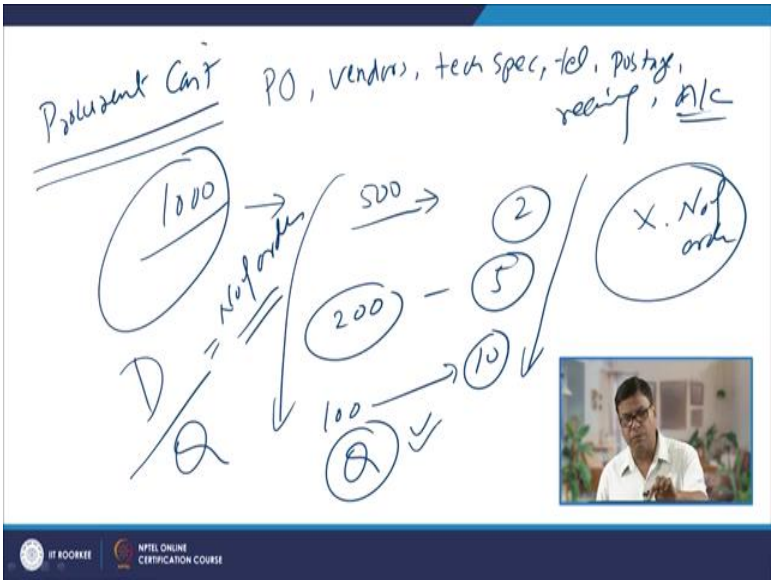

The second is the procurement cost, procurement cost is whatever actions are need, are required to be done for placing the order and for ensuring the procurement of a particular item, it may be required just once in a year or it will be required 10 times in year. So, depending upon the number of times for which procurement is to be made, that will be affecting the procurement cost directly. So, procurement cost considers like the cost of placing the order, preparing the purchase order and its placement, development of the vendors, development of the specifications, then telephones, postages, receiving the items.

So, these are the, these increase with the, procurement cost increases with the number of times for which order is placed, maintaining the accounts related with the procurement. Then we have, so this is directly affected by the order quantity, say annual demand for an item is 10,000, so if we place just the, if we place the order of the 500 quantities, then we have to place the two orders

in a year. If the order quantity we decide to be of 200 units, then we have to place the 5 orders in year or so depending upon the order quantity, if it is like 100 then we have to place 10 orders for fulfilling the annual demand.

So, procurement cost will directly be increasing with the number of orders which are being placed and that in turn will be governed by the order quantity, say the demand is D and the quantity for which order is being placed, this will determine the number of orders to be placed to fulfil the annual demand. And if the procurement cost is fixed, say x and then number of orders are there then we can directly determine the procurement cost. So, the Q directly affects the order quantity, directly effects the procurement cost, higher the order quantity, lesser will be the procurement cost and vice versa, like more lesser is the order quantity more will be the procurement cost.

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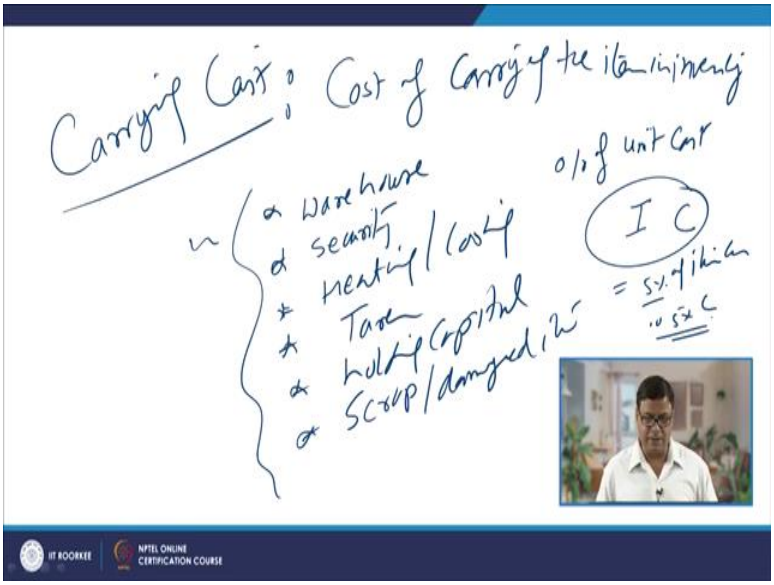

Next is the carrying cost, carrying cost is about cost of carrying the items in inventory, which means like we are holding just 50 units in a inventory on an average or we are holding the 500 units in inventory on an average in a year, so because if they are just 50 units, we need the less maintenance, the less space, less security, smaller warehouse, less lighting like that. And if many units are to be maintained then it will require lot of investments.

So, what are the various costs which are involved in maintaining the inventory under the carrying cost? So, that is what we will see, the among these the first one of carrying the inventory is the warehouse, items will be stocked somewhere, so some space is needed, few items small space or many items very large space will be needed. Then security, then as per the requirement there may be heating and cooling requirement, there will be taxes, there will be a holding of capital like we, if the capital is being held in large quantity, we will be losing the interest kind of thing.

There will always be some losses in form of breakage or scrap. So, scrap or damaged item, some percentage of items will be damaged. So, all these costs will be considered under the carrying cost. And how it is expressed? It is expressed as a percentage of unit cost, unit cost is say C and I is the percentage of the unit cost. So, I C will be leading to the carrying cost per unit. So, let us say it may be like 5 percent of the item cost, 5 percent of item cost. So, 0.05 into the C cost of item, that is how the carrying cost is expressed.

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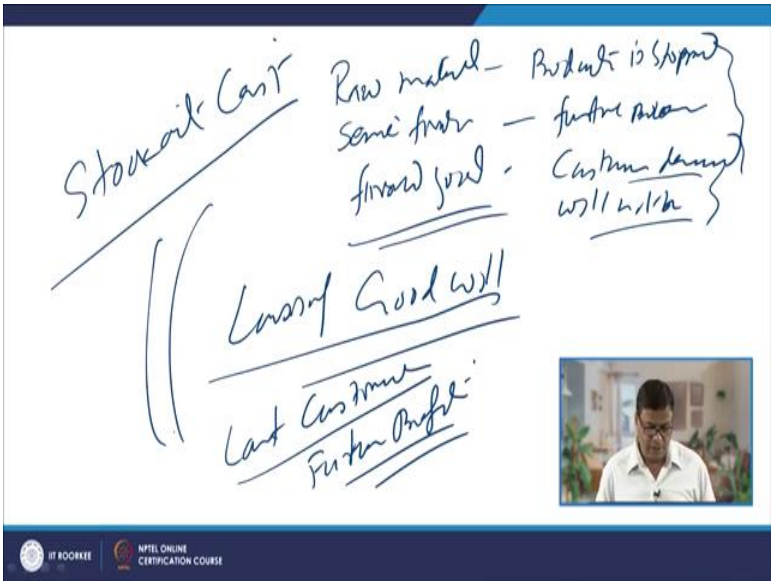

Then we have stock out cost. So, the stock out cost is really very undesirable situation, because this is the situation whether inventory of the raw material, if the raw material is not there then production is stopped, especially in mass production case the entire production system will be stopped. So, if there is a semi-finished product, then further processing of the product will be stopped. So, the production will be affected, if the finished goods are out of stock, then customer demand will not be met, so the customer will be dissatisfied.

And this situation so in the first two cases, you are suffering the production losses. In third case where the finished goods are out of stock, then the customer demand will not be fulfilled and this will be leading to the loss of goodwill. So, the loss of goodwill means the customer may switch over to some other product or they may look for some other client for their services. So, this may be leading to the not just lost customers, not just the lost customers, but the future profits are also lost, because customers may tend to switch over to somewhere else. So, the stock out really a not a good situation for the organizations and industry whether they are in manufacturing or in the service.

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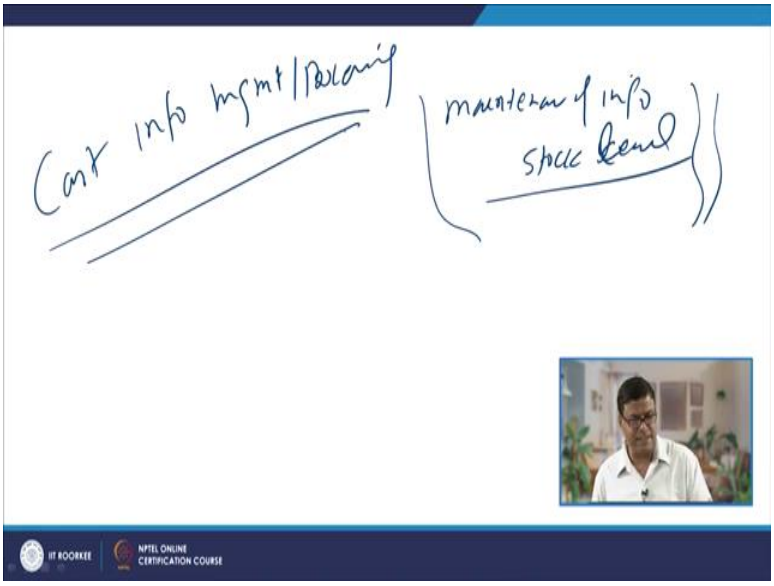

And then we have the cost related with the information management and processing. So, as I have said earlier, under this primarily the costs which are related with the maintenance of information related with the stock level, when the stock is being received how much it is being conclude, when the order is being pleased, so whatever is the situation related with the inventory stock that information is maintained and accordingly, the decisions are made. So some costs are involved with this also, but it does not affect the inventory total inventory cost directly. So, these were the different costs.

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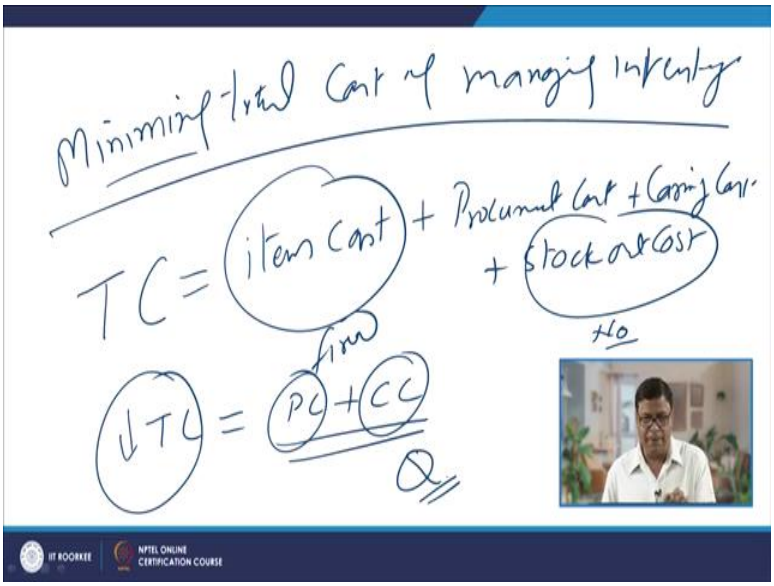

We are primarily interested in minimizing the total cost of managing inventory, this is the main factor. So, what we have seen, there were 4 costs basically, if we see the total cost TC some of the item cost plus the procurement cost plus inventory carrying cost plus the cost of stock out situation, stock out cost. If we assume that the cost of item is fixed and there is no stock out situation, no stock out situation and the fixed cost, then the problem of minimizing the total inventory cost is reduced to the optimization of the procurement cost and carrying cost in such a way that the total cost is reduced.

So, for minimizing the total cost we need to see that how the procurement cost and the carrying costs are dealt with so that the total cost is reduced. And interestingly, these two costs almost go in opposite manner and these are significantly governed by the order quantity or the quantity for which order is placed.

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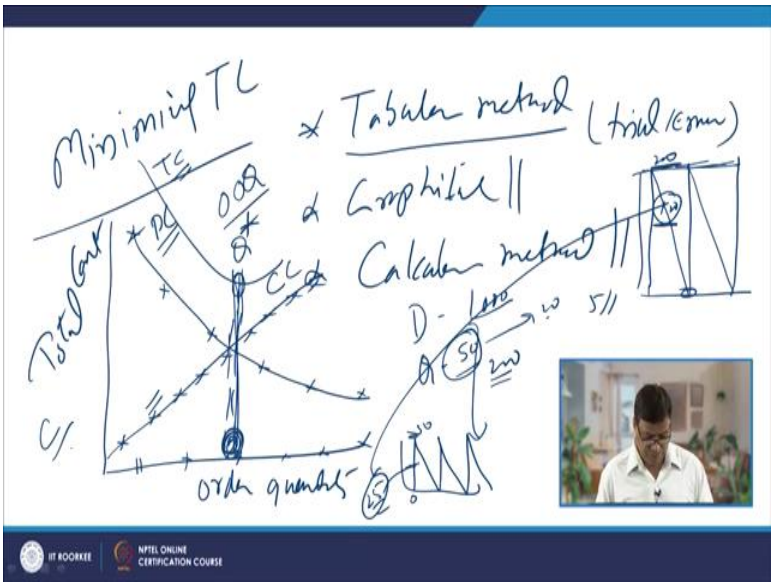

So, what are the methods which are used for minimizing the total costs? They are three methods basically, one is like say the Tabular method, this is just the trial and error method where various combinations are tried to see what will be the, if this is the order quantity what will be the procurement cost and what will the inventory cost for the given data. So, this is trial and error method. The next is the graphical method and third is the calculus method and this last one is the most commonly used method, this also is used and I will explain how it works in.

Let us say in this, this is basically a plot which is done between the, plot which is prepared between the total cost of maintaining the inventory and the order quantity. We know that for a given demand D say 10,000 units, if the order quantity Q is small like say 50 units, then we need to place 20 orders and if the for a given procurement cost per order, many orders means the higher procurement costs, so when our order quantity is less, our procurement cost is high. As the order quantity increases, procurement cost keeps on decreasing. So, this is what is related directly with the procurement cost, increasing the order quantity, procurement cost will keep on decreasing.

Because increasing the order quantity, fewer number of the orders are to be placed to fulfil the annual demand. Let us say here, instead of the order quantity 50, if we have the order quantity of 200, then instead of the 20 orders now we have to place just 5 orders, so it will require lesser cost. So, the procurement cost in short PC will be reducing with the increase of order quantity.

On the other hand, in the earlier case if we see, we were maintaining the inventory when we were placing the order for 50 units, for fulfilling the annual demand of 1000 units we were buying the 50 units and these order were being placed for 20 times.

So, like say in that case, our the fluctuations would have been like this. So, here maximum of 50 and minimum 0, so average inventory here was being maintained of just 25 units. On the other hand, if we are placing just two orders, five orders each of 200, so 200 units, for five times like this, so order quantity is 200, so maximum inventory level will be 200 and minimum is 0, so average inventory will be 100. So, here average inventory is five times, sorry four times, earlier it was 25, now it is 100.

So, we have to maintain the higher inventory levels when the order quantity is high. And that is why our cost of carrying the inventory will also be increasing. And therefore, when the order quantity is less, our inventory average inventory level is also less. As the order quantity increases, average number of units in the average number of units in the inventory will be increasing and accordingly, the cost of carrying the inventory will also be increasing. So, this is how it increases linearly, so the carrying cost increases linearly.

And some of these two will be giving us, some of these two will be giving us the total cost, so total cost will be coming like this. So, somewhere here, there will be a minimum total cost, which is sum of the procurement cost and carrying cost, so the total cost of carrying the inventory that will be somewhere here, so this will be giving us the minimum or optimum order quantity that will be giving us the minimum total cost of carrying the inventory.

And this total cost is nothing but just sum of the procurement cost and the carrying cost for a given order quantity. So, this is what will be giving us the optimum order quantity Q star, this is the graphical method of determining the minimum total cost while considering that the item cost C and there is no stock out situation, item cost is fixed and there is no stock out situation. So, now I will summarize this presentation. In this presentation, I have talked about one Q R model where the use rate was changing and the lead time was also changing and we have also talked about the various costs that we, that should be considered while optimizing the order quantity for minimizing the total cost of managing the inventory. Thank you for your attention.