Module 3: Inventory Management

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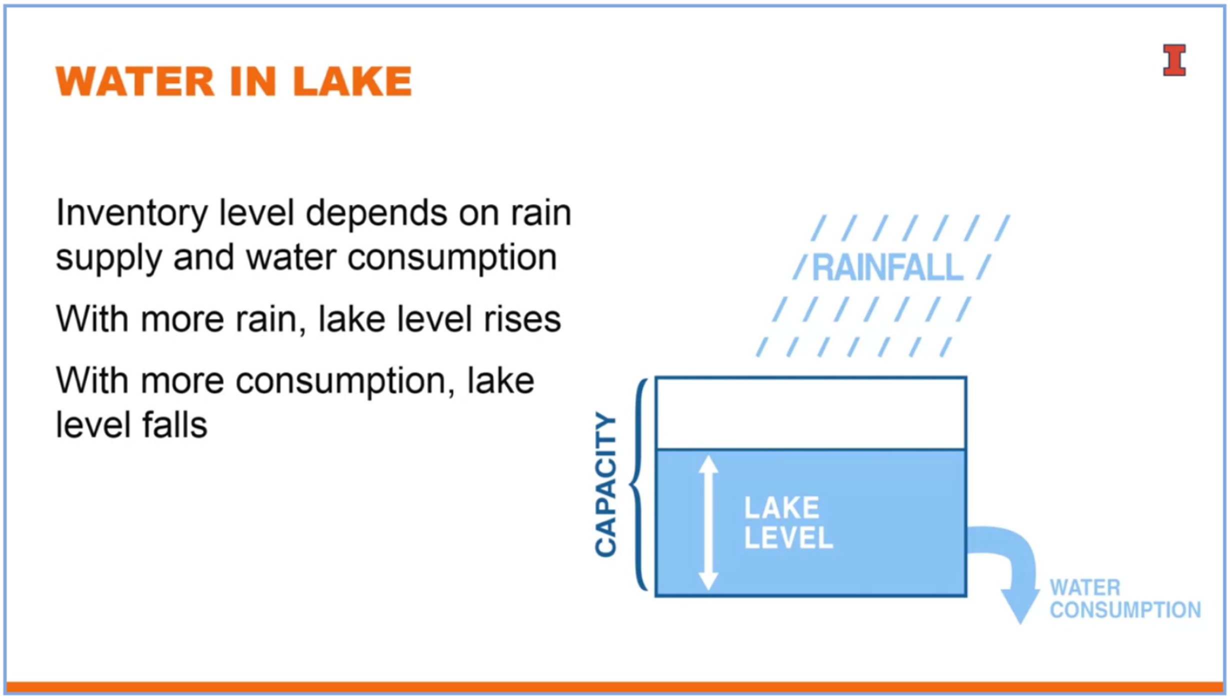
Lesson 3-1: Types of Inventory

Module 3.1.1 Reasons for Inventory

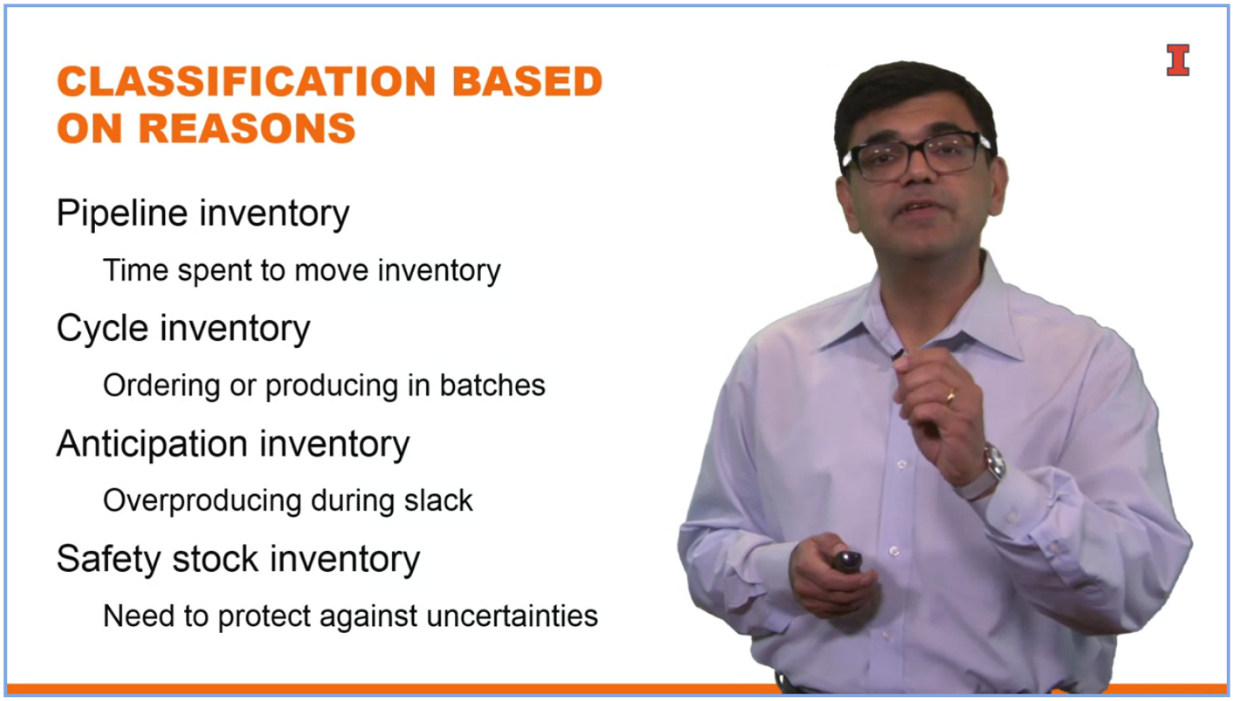
In this lesson, we're going to look at classifications of inventory. We're going to look at different types of inventory, and we're going to see how we can classify them based on importance as well as some other things. First, if you think about what is inventory, simple definition is it's whatever is kept in stock. Goods in stock is what we define as inventory. A lot of times we use the word stocks to denote inventory. The reason we, organizations keep inventory, or even as individuals, we keep inventory at home in our pantries and our refrigerators is to match supply with demand. You want to match the timing of when the demand occurs versus when you can get the supplies, and that's why you keep inventory. When we talk about organizations keeping inventory, you want to focus on internal as well as external customers. Within an organization, there may be sub-processes and the inventory might be for a customer that is within the organization for a sub-process. It can be internal customers, or it can be external customers and external customers are customers whose demand, there might be more uncertainty about when you compare that to internal customers. You have to think about it differently when you're talking about management of inventory. Finally, you want to think about businesses and individual customers, both, when you're talking about inventory, because a lot of companies have business to business relationships so they are making products to sell to a different business. Companies are outsourcing a lot of their production. A lot of components coming from different businesses, and you want to talk about inventory of that as well.



If you think about inventory and the idea of matching demand with supply, you can think about it from a perspective of a lake. The capacity of this lake is how much inventory you can store in your warehouse. The capacity of the warehouse in which you can store inventory. The level of the lake is the current level of inventory that you have. The rainfall is a supply, and the consumption of water is your demand. Put it this way. When the rainfall exceeds the consumption, the level of inventory is going to increase and it's going to get closer and closer to the capacity of your Warehouse, and when the consumption is more than the supply, the lake level is going to decrease. Inventory acts as the matching of demand and supply in this way, and we think about water consumption in a very similar fashion when we store water for our consumption in our households.

Let's take a look at why organizations have inventory, why they build inventory. The first reason you can think of is a lead time for supply. For example, if there is a supplier that is at a certain distance from the purchaser, from the buyer, it's going to take a long time or it's going to take some model time for the supplies to get there. There's transportation time, but there will also be lead time that the supplier might quote in terms of we're busy with other things, we'll take so much time to make your particular order, and that's going to get added to the lead time of the transportation time. As a buyer, you are going to have to plan for that lead time during which that it's going to take for your order to get to you so you're going to store some inventory for that lead time. Within a process, within a multi-activity process, you might have activities that are at different processing times. In fact, most times you're going to have activities that have unmatched processing times. For example, one activity could be running at the rate of 10 units an hour, and another activity might be running at the rate of 15 units an hour so one is faster than the other. Now, you're not going to run both of them at 100 percent, but what you're going to do is run the faster one and build up inventory, and pause until the slower one catches up. Different processing times will mean that you will need to have some inventory based on the different processing times of different activities. Economies of scale. You might have a setup time involved with doing changeovers from one type of product to another. In which case you're going to say, well, I'm going to make a large batch of this inventory before I change over to the next item that I make. In which case, you are going to build some inventory. Now, this reason is basically because you want to take your cost of that setup time and spread it over a larger quantity, and that's why you have a batch size. You're going after economies of scale. You could think of a similar reason for economies of scale when you're talking about getting supplies from an external supplier, in which case, you might be thinking about well, I want to get a full truckload in order to take the cost of all items and spread it over lesser number of deliveries. In that case, you're going for economies of scale for an external supplier that you're purchasing from and you are building inventory based on that. You get a big order and you build up inventory until that gets exhausted and then you get another big order. Seasonality. If you're making lawnmowers, they're not going to be sold at the same rate throughout the year. In order to build up inventory for the spring and summer seasons, you'll continue to run your manufacturing plant at a certain rate during the winter months in order to build up inventory for that season. Similarly, with other seasonal items, such as the festive items for Christmas or other festivals that you might build up. Variations of products. When you have many different types of products, you are not going to keep making all of them all the time simply because it may not be cost-effective so you'll make certain items and keep them in stock while you're running other items on your line. Sometimes you'll be keeping inventory on the basis of speculation of prices. You'll say, well, here's a discount that I'm able to get or I know that the price of oil is going to go up in the near future. If I'm an airline, I'm stocking up on how much fuel I'm purchasing, and that might be inventory. That comes in my name, even though it may not be delivered to me, I may be buying those future contracts, and that's inventory that's effectively being held by me. Availability might be an issue if you're expecting a shortage, you're trying to speculate and hold that item so that you have it available when you need it. That might be a reason for you to hold inventory. Finally, talk about uncertainties. Uncertainties in terms of demand, uncertainties in terms of supply, and uncertainties even in terms of the way your process is being run. If it's not running at 100 percent yield rate, you might keep excess inventory for what if it breaks down or what if I have a quality issue or what if I have a strike and my plant has to shut down. I might keep inventory for those purposes to cover for those uncertainties. That's why organizations keep inventory.

Module 3.2.1 Classifications of Inventory



Now, you can think of inventory and classify it based on the reasons that organizations keep inventory. Now keep in mind that this classification is not something that you can directly apply to a piece of inventory that you might see. You might not be able to say that this piece of inventory is pipeline or cycle, or anticipation. These are reasons on the basis of which you can classify inventory. Pipeline inventory is the time that inventory is in transit in any process. You order from a supplier that's distant from you during the time that it's in the pipeline to get to you, it's pipeline inventory. Cycle inventory is based on batch sizes. Let's say I run a batch of 10,000 units of one type of product, product X before I move to product Y? That cycle, when I'm making those 10,000 units, is going to start from zero and build up all the way to 10,000 units and I'll have 10,000 units of inventory before I send it off to the next task or to my customer, and that's going to be my cycle inventory. I'm building up that inventory during that production cycle. Anticipation inventory is something that we referred to earlier. You are overproducing when you do have the time or you're overproducing in anticipation of demand that you're expecting in the future. Then safety stock inventory is inventory that you hold for any kind of uncertainty. It might be uncertainty to do with production rates. It might be uncertainty to do with demand. It might be uncertainty to do with lead times. It may take five days for this product to get to me, or it might take eight days. I have to keep some buffer in order to allow for that uncertainty. That's what is classified as safety stock inventory. These are the main reasons that organizations keep inventory.

Now here's a classification that you can actually point out and say, this inventory is raw material inventory or work in process inventory or finished goods. In any organization, you'll be able to say raw material inventory is whatever has been purchased from outside. Whatever has been purchased from an external party is going to be raw material inventory. The work in process inventory is inventory that is being worked on. Whether it's waiting to be worked on within the process boundaries, or whether it's actually being worked on in the process. Whether it's in the machine, whether it's bread that's being baked in the oven, or it's in a machine that requires a certain amount of time for something to get cured. It's going to be work-in-process inventory. Finally, finished goods inventory is anything that's ready from that organization's perspective, that's ready to go to the customer to get delivered to the customer. It's at the loading dock waiting to get on that truck to go to the customer, that's going to be your finished goods inventory.

IN-VIDEO QUESTION

Identify raw materials, work in process, and finished goods inventory for two types of businesses.

Bakery

Grocery Store or Sandwich Shop

Top: (Waltzer, 2005) Bottom: (flickr.com/Infrogmation, 1936)

Now that we have this classification of inventory, what I'd like you to do is apply this classification to two simple kinds of businesses. The first business is a bakery, and the second business is in the same stream of products. It's a grocery store or a sandwich shop. It's a sandwich shop that uses the bread to make sandwiches. You have a bakery and a sandwich shop. What I'd like you to think about is, what are the raw materials? What is the work in process that would be the case for the bakery or the sandwich shop. Finally, what are the finished goods that these two types of businesses would have? Give that a minute and think about it, and then we'll come back and talk about the implications of this classification for these two different types of businesses.

IN-VIDEO INSIGHTS

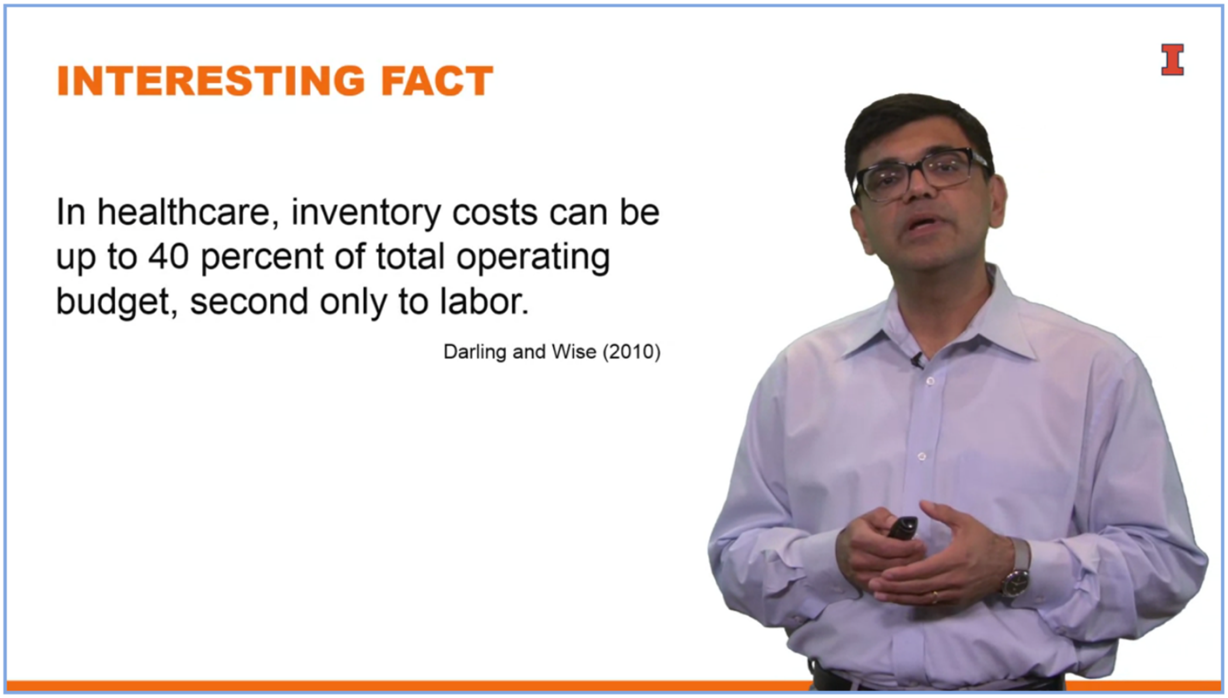
Identify raw materials, work in process, and finished goods inventory for two types of businesses.

Bakery

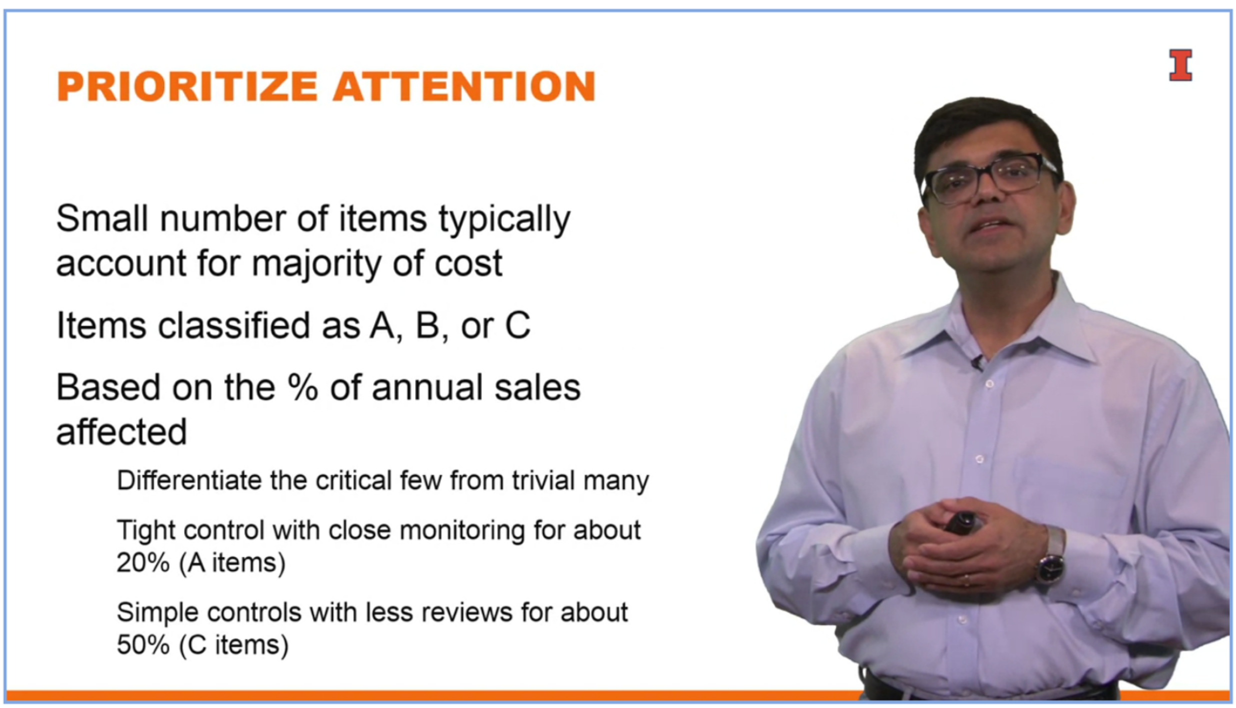
Grocery Store or Sandwich Shop

We were classifying the raw materials, the work in process, and the finished goods for bakeries and sandwich shops. For a bakery, you may have thought of flour, you may have thought of water, yeast. Those are the things that go into making bread. Those would be raw materials that they would be purchasing from outside, that they would be acquiring from outside. The work in process is going to be anything that's kept, that is in the process. If it's baking for a certain amount of time, it's working process inventory. If it's dough that's kept to mature before they start baking the bread from it, that's going to be work-in process inventory. Finally, the finished goods are going to be the loaves of bread that come out, that get on the truck to get delivered to customers. Raw material, work in process and finished goods for a bakery. For a sandwich shop, their raw material would include the bread that they're going to buy from that bakery. The raw material for them is going to be the finished goods for the bakery. Then they're work in process inventory is going to be some of the probably the sliced bread that they keep or they might be able to do some processing of sandwiches and keep them ready for customers. Then the finished goods are going to be the ready sandwiches that are being delivered to customers. What you can see from here is that what is one organization's finished goods is going to be raw materials from a different organization's perspective. Even though we have this classification, it'll be based on the usage and the position of that organization in this whole chain that is making products for the ultimate customer.

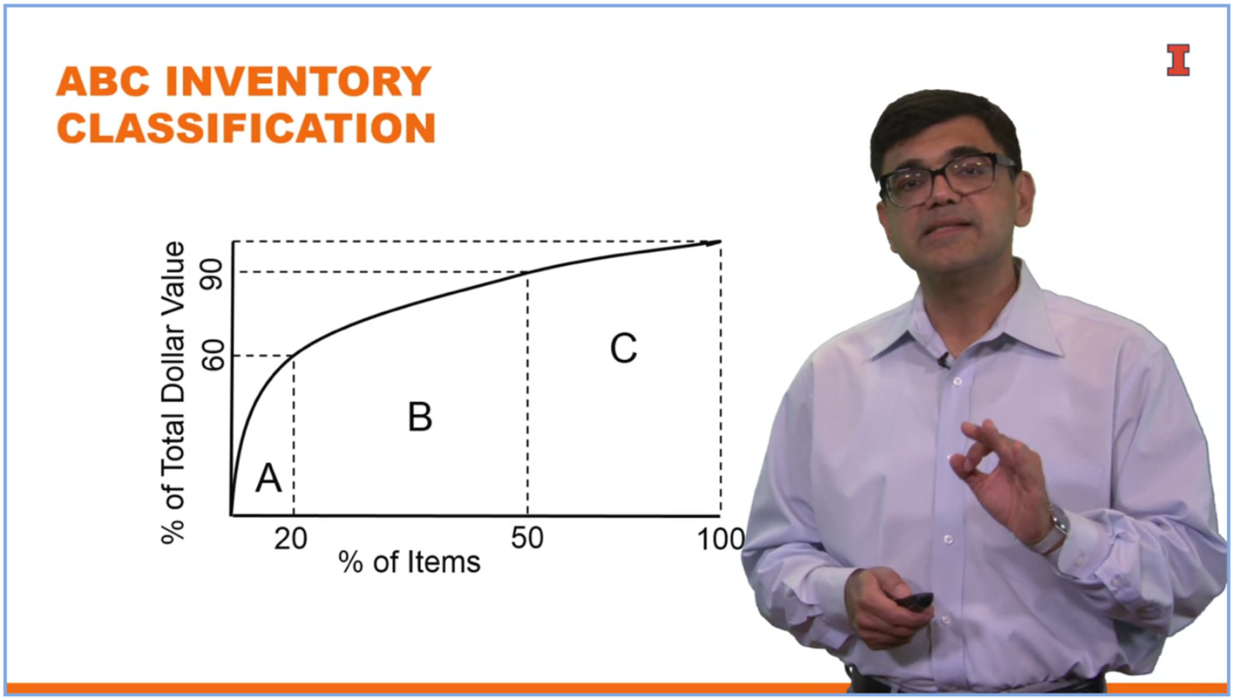
When we think about inventory, we normally think about manufacturing businesses. We say, well, in services, you can't hold inventory. It's something that you make for a customer and you cannot really keep that in stock. We think about capacity of the service as being the inventory that we hold. But if you think about it, even services such as hospitals, restaurants, and hotels have to keep inventory. They have to keep inventory of different things that are needed for them to do their business correctly. Hospitals need drugs, they need surgical instruments. Restaurants need different things to serve their food. They need different things to manufacture their food. Hotels are going to need different things that they need to stock in the rooms. They're going to need different linens to be able to use them in the different rooms. Even their inventory is going to be important and to give you an interesting fact about inventory in services.



In healthcare, inventory costs can be up to 40 percent of the total operating cost. The cost of holding, and using inventory is about 40 percent of total cost. This cost, by the way, is second only to labor costs, which is obviously not surprisingly, the highest proportion of cost for a healthcare business. Inventory is pretty important even for services.



Now let's look at a different way of classifying inventory. This is based on which items in inventory need more attention versus which items need less attention. This is called an ABC analysis. It's based on what you may be familiar with as the 80/20 rule. You have 20 percent of your items that account for 80 percent of the value. That's the idea between the ABC analysis is that you want to focus on those really important A items in terms of controlling the inventory, you want to keep a close eye on them. Then the C items, you may not follow as closely. You may not care as much about them in terms of keeping a close eye on them, and spending your resources keeping a close eye on them.



The idea is simple. You have 20 percent of your items are responsible for 60 percent of the dollar value. The next 30 percent of the items are responsible for 30 percent of your monetary value. Then the next 50 percent of the items are responsible for the top 10 percent of your dollar value. You have the A, B, and C that is telling you which are the more important items to keep an eye on.

IN-VIDEO QUESTION
LET'S DO THE NUMBERS

Locoplane Automobile Parts Inc. has compiled data on annual unit sales for their seven products. This data along with the selling price for the items is provided. Please help Locoplane management identify the A, B, and C items for inventory control.

(Dugdale, 2010)

Let's take this ABC classification, and apply it to an example. Here's an example of a company that is making automobile parts and we have data on their annual unit sales that you're going to see in the next couple of slides. They want help in identifying the A, B, and C items.

DATA ON INVENTORIES

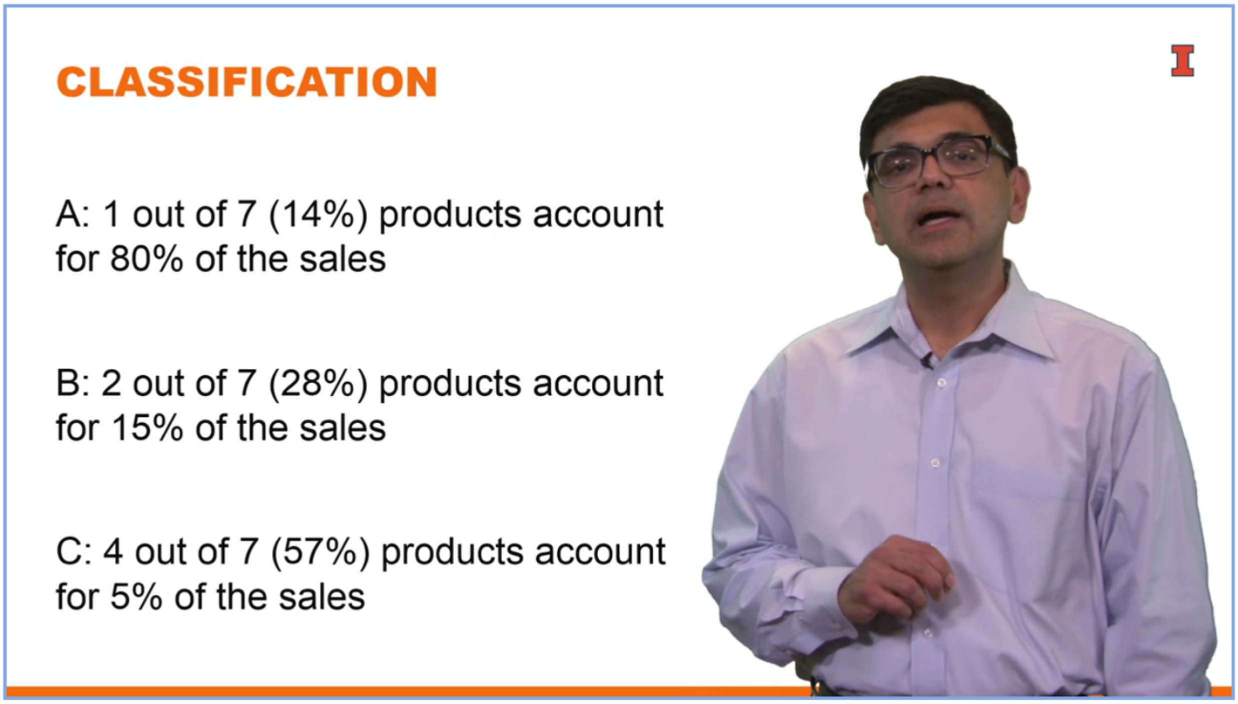
Item identifier	Annual sales (units)	Unit price ($)
1	75	80
2	150,000	0.9
3	500	3.0
4	18,000	0.20
5	3,000	0.30
6	20,000	0.10
7	10,000	2

Here you have the numbers to do the ABC analysis for local plane automotive parts. What you can see is the first column is just the identifier, the second column gives you the annual sales in units, and the third column is giving you the unit price. Take a minute, digest this information, and think about how you would go about converting this into an ABC analysis telling you which items you should be focusing on, spending more time on in terms of inventory control, which item's next, in terms of an ABC analysis.

COMPUTATIONS FOR ABC RANKINGS

Item identifier	Annual sales (units)	Unit price ($)	Annual sales ($)	Sales %	Rank
1	75	80	6,000	3.55	3
2	150,000	0.9	135,000	79.88	1
3	500	3.0	1,500	0.89	6
4	18,000	0.20	3,600	2.13	4
5	3,000	0.30	900	0.53	7
6	20,000	0.10	2,000	1.18	5
7	10,000	2	20,000	11.83	2
			169,000	100.00	

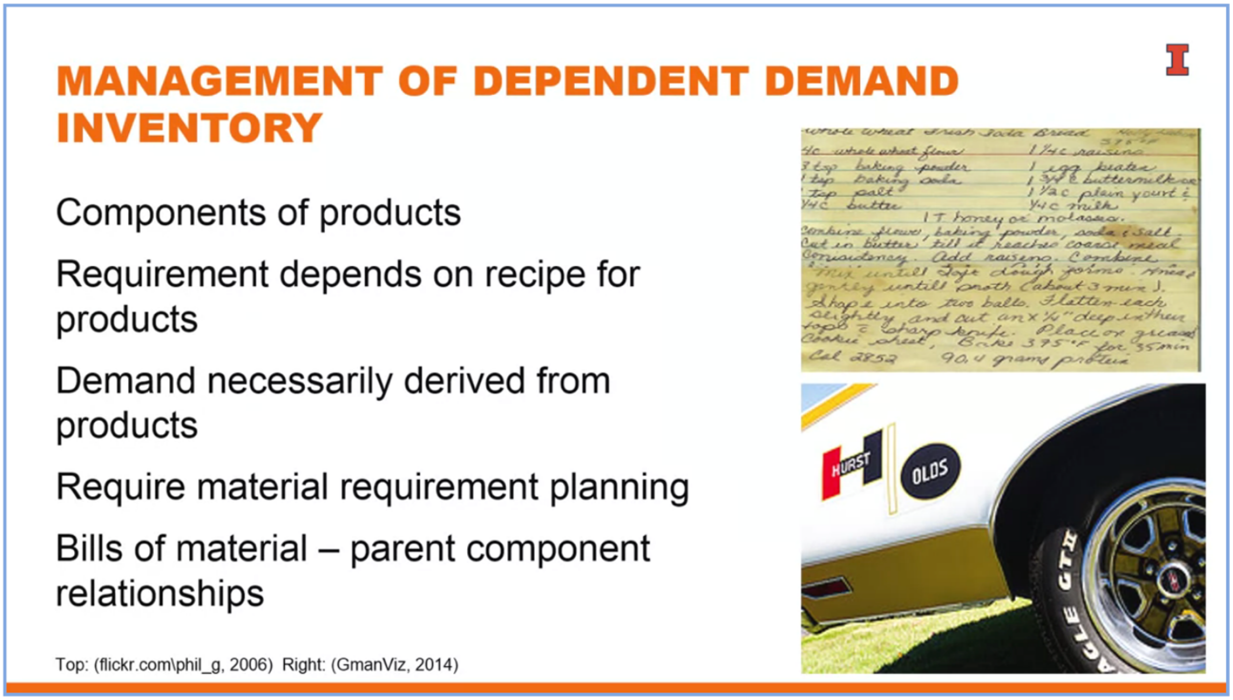
Here you see the result of this analysis. We've run through the numbers here. What we've simply done is converted the annual sales quantities into annual sales monetary values here, dollars, and we see that we have annual sales, a total of 169,000. Once you have that, you can convert into percentage of total sales. That's what we've done. In the next column we have the percentage of sales. What you can see right from there is item Number 2, which is responsible for 80 percent of the monetary value of the sales. That would be obviously an item to focus on. It's one out of seven items that is responsible for 80 percent of their sales and that's going to be the prime item to focus on. This analysis can give you a sense of which items to focus on next, and which items to focus on the least.



As a result, what you can see is you have this classification of one out of seven products accounting for 80 percent of the sales. That one item that we saw earlier, the next in line, the next in sequence in terms of percentage of dollar value are two items that account for 50 percent of the total monetary value of sales. Then out of the total of seven items, the last four account for only five percent of the total value of sales. What we've seen from this is that you can classify inventory based on many different ways. ABC classification is one of them which focuses on the importance of inventory management for different items in inventory. Earlier we saw a classification of raw material work in process and finished goods. Then earlier than that we saw why do different companies store inventory, and we saw classification based on that.

Lesson 3-2: Inventory Decision – How much?

Module 3.2.1 How Much and When



In this lesson, you're going to learn how to determine how much quantity of inventory to order based on some different costs of ordering and holding inventory. But before we get to the idea of calculating how much you need to order, let's look at inventory from two different perspectives. These two perspectives are dependent demand inventory and independent demand inventory. Now what do we mean by dependent demand inventory? A dependent demand inventory basically means, it's the inventory for the parts that you are going to make in-house. Here, for example, you see a recipe for making a certain bread. Now, once you know how much quantity of bread you would like to make, the dependent demand inventory is going to be determined by the recipe. It tells you how many eggs are needed, how much salt is needed, how much flour is needed, how much water is needed. It's going to be determined by the demand for that finished product. That's going to tell you how much of the dependent demand inventory you need to take care of. Another example you can think of is, once you decide how many cars are going to get manufactured, you can look at the recipe, the bill of material that you have for making that car, and you can see what are the different parts that will be needed. To give a very basic idea, you're going to need four of the tires, four wheels for the main ones, and then one for the spare. That's going to get determined by the independent demand inventory. Dependent demand inventory, you manage it using manufacturing resource planning systems, which take your parent item demand, and divide it up into its different components and tell you how much is needed. That's what you see mainly in ERP systems, Enterprise Resource Planning systems, and Manufacturing Resource Planning system. What those systems do, is they take your parent item demand and convert it into the dependent demand for all the parts that you're going to use.

What we're going to focus on in this lesson is going to be your independent demand inventory. It's the inventory of items that you sell to customers. It's the inventory that is coming from outside the organization. This could be a B2B customers so you could be selling parts to a car manufacturer or you could be selling cars as a dealership to ultimate customers. You could be selling bread to many different stores. It's a B2B relationship, or it could be a store that's selling bread to ultimate customers. The independent demand item is going to be different based on where you are in that big supply chain.

IN-VIDEO QUESTION

You or someone else buys groceries for your home. Take any one regular grocery item such as milk. What are some considerations when deciding how much of that item to stock at home?

Before we get into the calculation of how much you should order, what I'd like you to do is think about the things that you consider when you go out and get groceries. Take any one regular item that you purchase and I say milk over here, for example. What are some of the considerations that you have when you decide how much quantity you're going to buy during this trip to the grocery store? Whether you're going to buy a gallon, two gallons, how much you're going to get from the grocery store? What are some of the things that go through your mind, when making that particular decision.

IN-VIDEO INSIGHTS

Considerations when deciding how much milk to stock at home

- Consumption
- Cost
- Price discount
- Storage space
- Spoilage
- Next trip to store

We're talking about going to the grocery store and getting milk. Some of the things that would have gone through your mind would have been things like, how much do you have in your refrigerator, how much do you have at home, and how much do you consume on average? Your average demand rate of your household for that item. Here we said milk, but you could be thinking about any grocery item, and how much you consume on a daily basis. The other thing that might go through your mind is, how much does it cost from the perspective of, if you have to think about the investment that you're going to make. It might not be much for milk, but if it's a more expensive item, you're thinking, should I be investing so much of my money in purchasing milk for future consumption? You might think about a price discount and you might be tempted to buy more, if there's a price discount available, or if you anticipate a price discount that's coming up, you might purchase less based on that upcoming price discount that you're expecting. Storage space is going to be a huge consideration, whether you have a spare refrigerator or you don't, and how much space do you have in your refrigerator for storing the milk that you're purchasing. Expiration date on the milk and how much you use versus when it's going to get spoilt, is another thing that you might consider. Finally, you're going to think about when you're going to go to the store next. If you're planning to not go for a couple of weeks and you're thinking, I need to get enough for a couple of weeks, and then there might be some uncertainty involved in how much you consume in that couple of weeks, so you might get a little bit extra based on what if guests come or what if your family consumes more than they normally do in that particular period of time when you're planning to go to the store next. These are the things that you think about, when you decide how much to purchase in terms of groceries for your household. Companies, organizations go through very similar decision-making when they are deciding how much to purchase.

COSTS OF INVENTORY FOR BUSINESSES

Capital and insurance

Storage and handling

Spoilage and rework

Devaluation and obsolescence

The things that they're thinking about is, how much capital investment there's going to be, how much storage space is going to be required, whether it's an item that's going to need handling, it's going to have to be stored in different places and moved around, whether there's going to be refrigeration needed, if there's some cost involved with that. They're also thinking about spoilage. Is there going to be something that expires over time? If it's something in which there might be a fluctuation in demand, it might get obsolete. People might not want that particular product. If you're thinking about a fashion goods store, you are concerned about the items going out of style and not being able to be sold and that's when you would have to discount them. Those are the things that companies are thinking about when they're thinking about how much inventory they want to purchase.

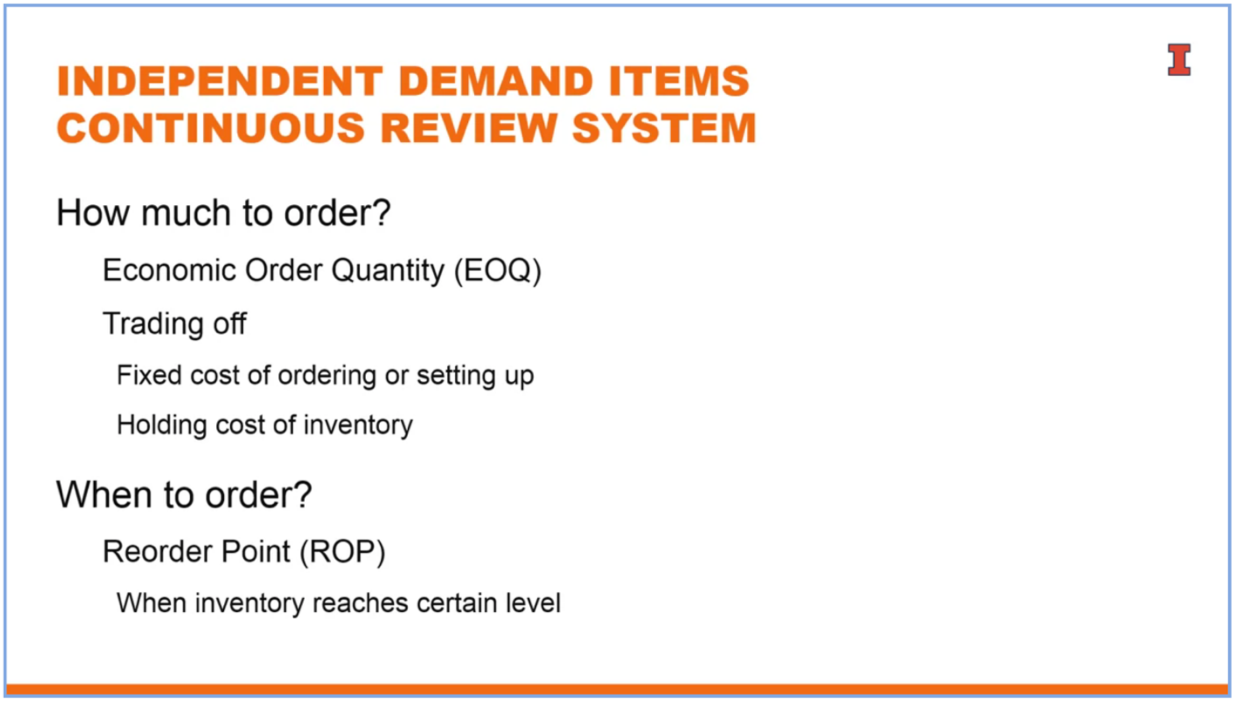
INVENTORY MANAGEMENT
TWO MAIN QUESTIONS

How much to order?

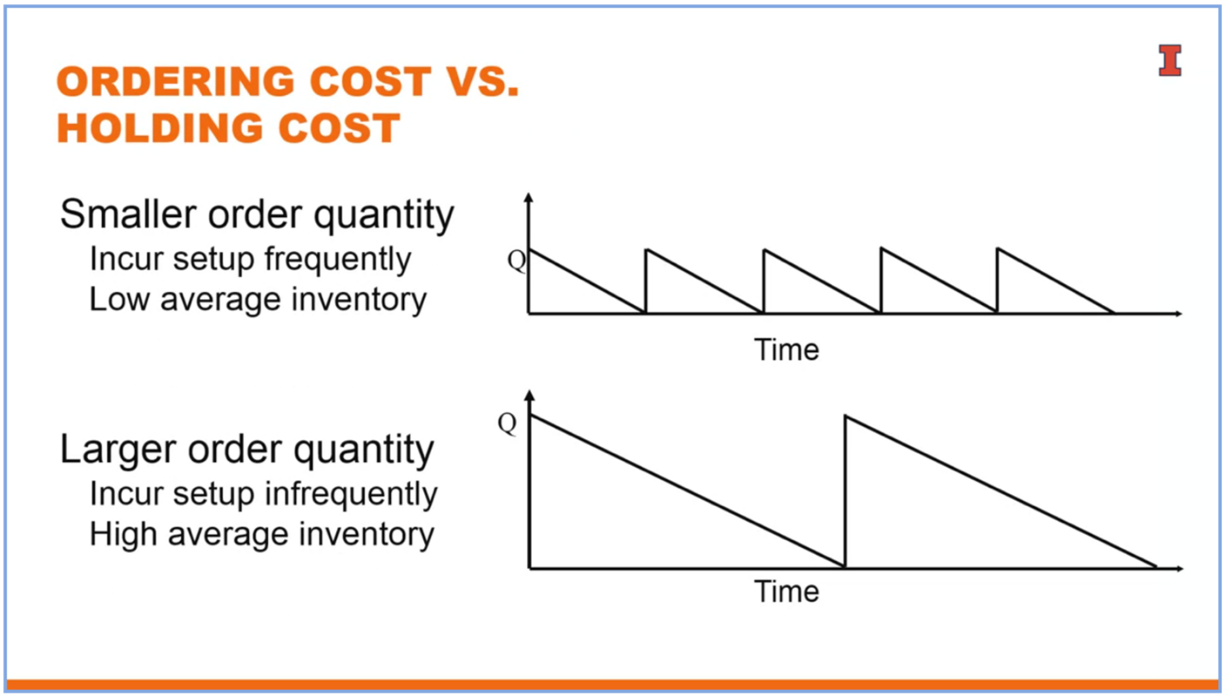
When to order?

When you think about inventory management decisions, there are two basic decisions that companies are making. One is, how much to order and the other one is, when to order. When should they place the order? These are going to be based on different considerations of the things that we talked about a little bit earlier.

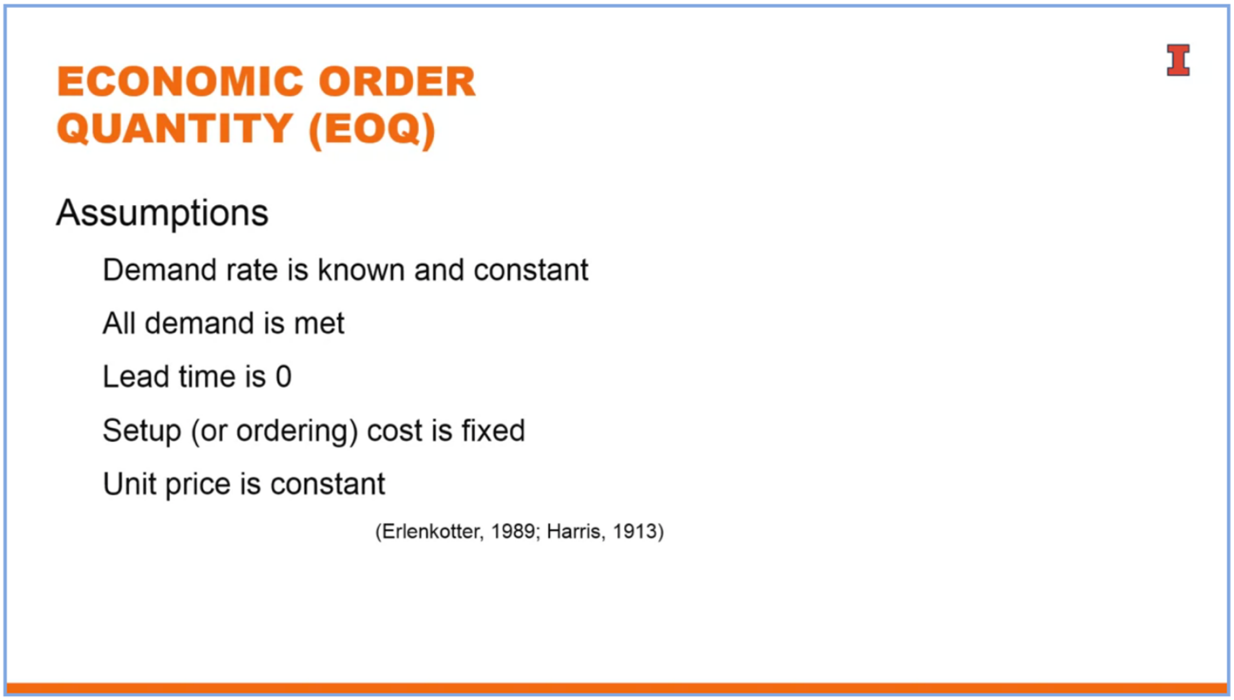
Module 3.2.2 Economic Order Quantity



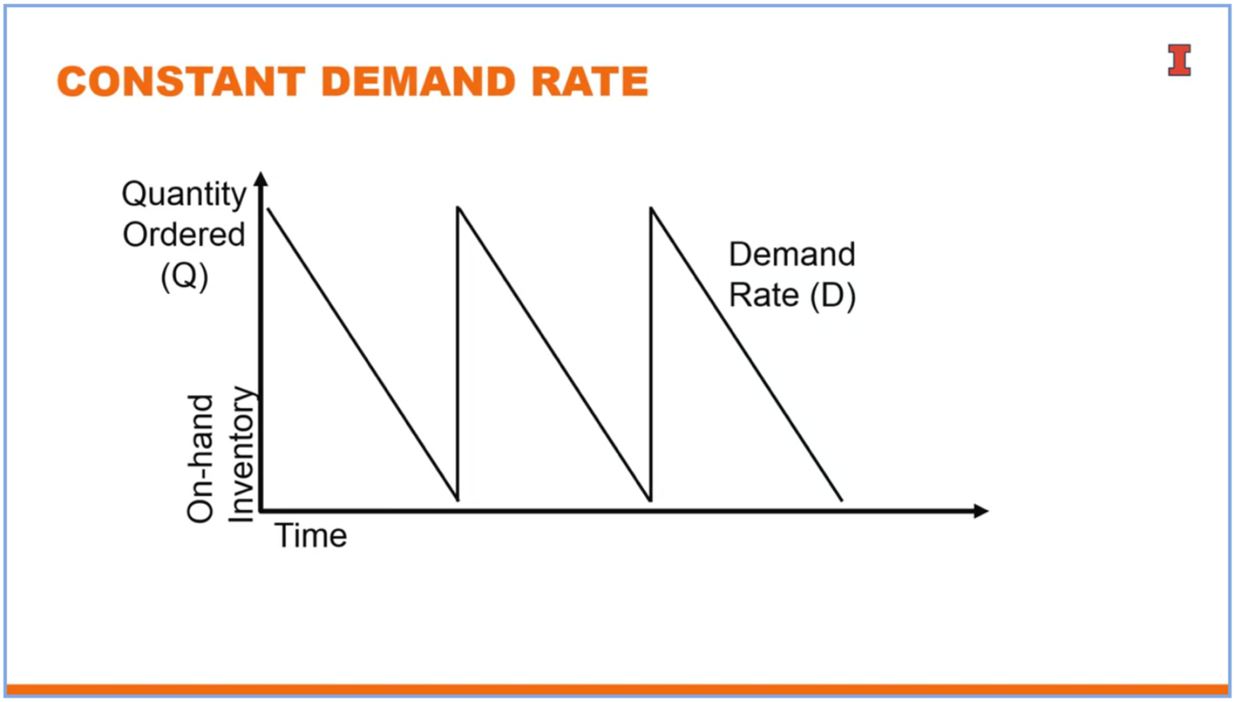
Remember we're focusing on independent demand items here, items that a company would purchase from a supplier that's coming from outside. And how much to order is typically based on this model that is very popular called the economic order quantity. So this is a model for calculating the amount of inventory in terms of how much you want to order. Now, this model is based on the principle of trading off of two different costs. One of these costs is the cost of ordering. So if you think about the cost of ordering, if you're thinking about that trip to the grocery store, it's the cost of the time that you're spending to go to the grocery store, it's the cost of of the gas that you might be consuming to get to that distant grocery store. For a company, it might be order processing costs, it might be cost of transportation, it's the cost of getting a truckload and that might be a fixed cost, whether you get a full truckload or you get a quarter of a truckload, it might be a fixed cost based on that. So that would get counted under your ordering cost, right? So it's based on the number of orders that you have in a year, you're going to have an annual ordering costs from that. The other cost that companies are principally concerned about and that gets incorporated into this economic order quantity model is the cost of holding inventory. So if you think about the cost of finance that's being invested in this inventory, the insurance that you're paying on that warehouse, the opportunity cost of the space in your warehouse, all those things are figured into the holding cost for inventory. And when you think about the economic order quantity model, what you'll see is you'll see that it's trying to trade off these two different costs, right? And we'll see in terms of how it's trying to trade off these two different costs. Now, we are also going to talk about when to order and we'll talk about that in a different lesson. In this lesson, we're going to focus on how much to order. But when to order is going to be based on a reorder point. So it's going to be based on when the inventory reaches a certain level. There's going to be a point that will be determined based on some analysis that we'll do that will say when it reaches a certain level of inventory, that's when you place an order. The question that we're trying to address here in this lesson is how much to order? And that's going to be your economic order quantity. So let's take a look at some of the things that that get incorporated into this economic order quantity model.



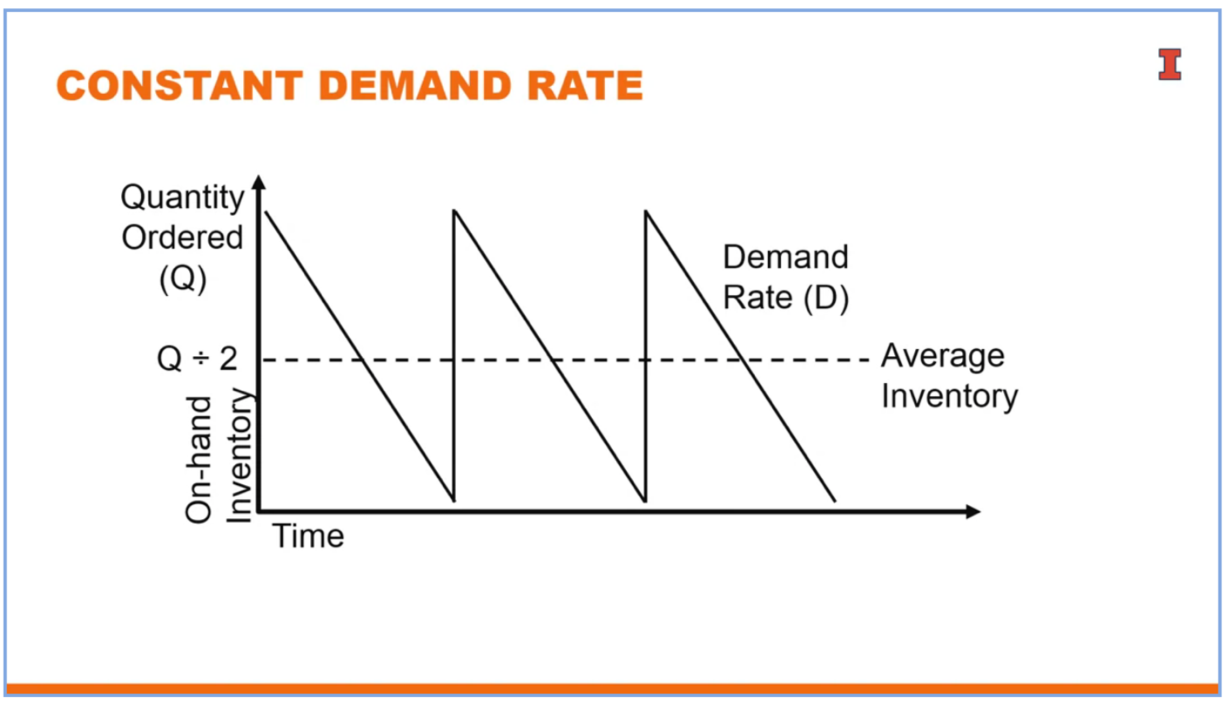
So the first thing that you want to get a perspective of is the trade off between ordering and holding cost. So if you think about this from the perspective of annual quantity that's being ordered, if you order in smaller quantities, you are going to order many more times if you have the same annual quantity right? You will order more frequently and you will have many more orders. So if you have a fixed ordering cost, your annual ordering cost will be very high because you've ordered many many times. Now contrast this with the idea of ordering a large quantity at a time. So here, in this extreme example, if this was the time of the year and you've ordered only two times in the year, you order six months worth in a year, your annual ordering cost is going to be based on just two orders. It's going to be very small. However, the cost of holding inventory, the cost of how much investment you have in that inventory, how much risk you're taking about that inventory getting obsolete or getting spoiled is going to be much higher because you're buying six months worth at a time. So that's the idea of ordering costs and holding costs. And you can get some sense of a trade off between these two costs, right? And that's what we're going to use in order to derive what is called the economic order quantity in order to calculate what is called the economic order quantity. Now, the economic order quantity model is based on certain restrictive assumptions. It's a simple model and whenever you have a simple model, it's probably going to have restrictive assumptions that are simplifying it in order to get the calculations done quickly. So what are the assumptions here? The assumptions are that the demand rate is known and it's constant, annual demand is something that we know we can forecast very well.



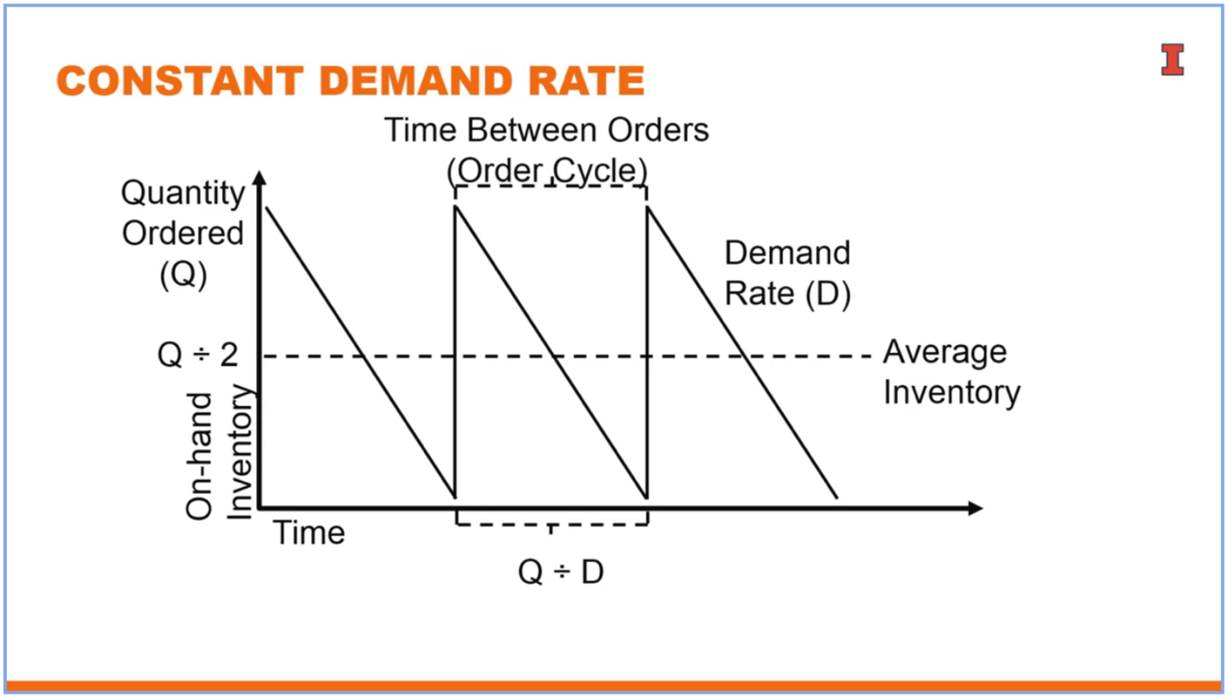
That's what we're assuming here however unrealistic it maybe. And we're also assuming that all demand is met, that you're never telling a customer don't have enough. All demand is being met. We're assuming a lead time of 0 at this point, right? When we get to reorder point, well, we'll talk about incorporating lead time in the reorder point. But for the economic order quantity, we're assuming a lead time of 0. So there's instantaneous replenishment, you place an order and you get the quantity delivered to you right on that day, right? So you're never worried about about running short. The setup cost is fixed regardless of the quantity you order. So again, whether it's a realistic or not, what we're saying is that every time you place an order, you incur a fixed cost. Whether that order is for a very small quantity or a very large quantity, the cost of ordering is going to be based on simply the fact that you placed an order. So it's a cost per order. The unit price is constant over the years. So over the period that you're calculating the economic order quantity, the unit price remains constant. And and we're starting off with the model that does not involve discounts of any sort. So the unit price is constant in this case.



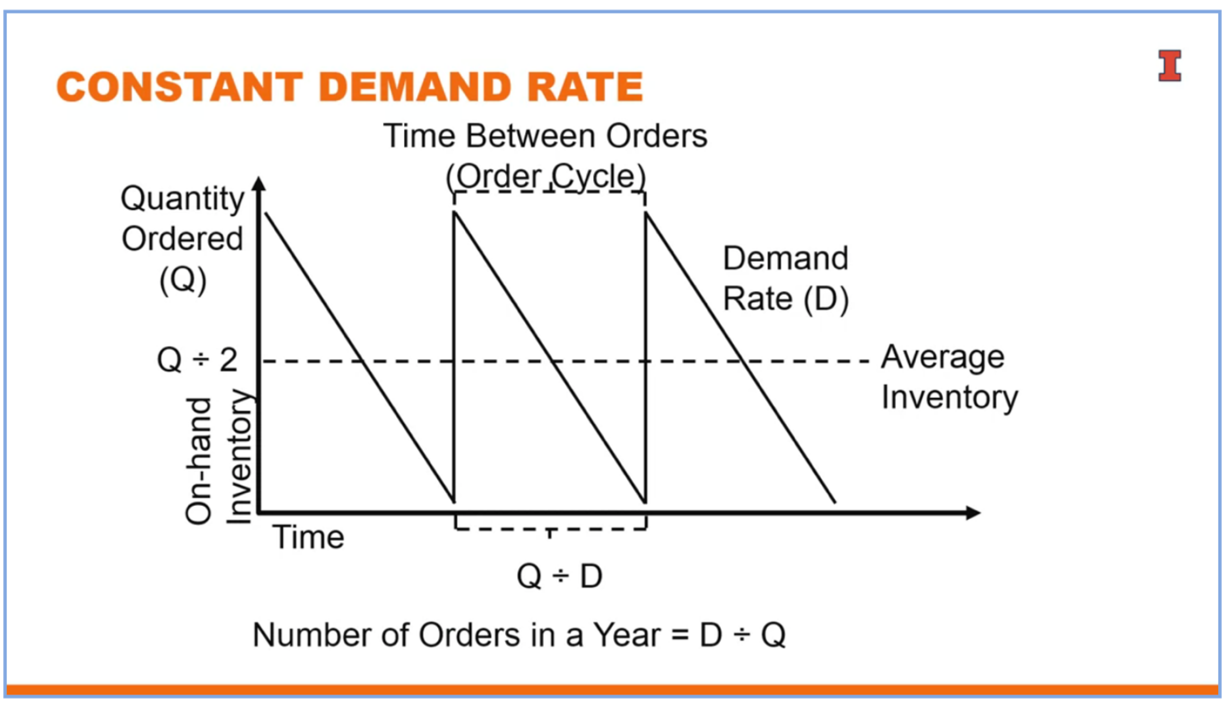
So, let's work towards coming up with the economic order quantity here. So we said it's a constant demand rate. On the x axis, you have time, on the y axis, you have the quantity that's being ordered.



So when you have a constant demand rate and an annual demand of D, your average inventory that you have at any point in time is going to be based on Q divide by 2. So if you're ordering q at a time, your inventory is going to be based on Q divide by 2. Simply because you start off with Q, it goes down to zero, starting and ending inventory, are Q and zero and the average is Q divide by 2.



Right. So the next thing that you want to see is that the time between orders is going to be determined by the quantity that you order every time you place an order divide by the annual demand or D.



And if you take the opposite perspective of this, the number of orders in a year is going to be based on the annual demand divided by the quantity that you order every time you place an order. So simply stated, what this is saying is that if you have an annual demand of 10,000 units and you order 2000 at a time, you basically ordering five times in the year. So that's number of orders is five in a year based on 10,000 being the annual demand and 2000 being the order that you order every time you place an order. So that's reflecting, this picture is reflecting the assumption of there being instantaneous replenishment, there being a constant demand rate. And we're keeping these assumptions in mind going forward.

TOTAL COST OF INVENTORY MANAGEMENT (1 OF 2)

TC = Total annual cost of managing inventory
D = Annual demand (units per year)
Q = Order quantity (units)
S = Cost of ordering or setting up ($)
H = Annual inventory holding cost ($ / unit / year)

So before we get to the economic order quantity, let's take the perspective of ordering costs. And holding costs as being the only two costs that we have and calculate what would be the total annual cost of managing the inventory. So we're keeping the cost of the item aside. We're not taking that into account. We're simply looking at the total cost of managing the inventory. So, when you look at the total cost of managing inventory, it's going to be based on two components. One of them is the ordering costs. So what you need is the number of orders, right?

TOTAL COST OF INVENTORY MANAGEMENT (1 OF 2)

TC = Total annual cost of managing inventory
D = Annual demand (units per year)
Q = Order quantity (units)
S = Cost of ordering or setting up ($)
H = Annual inventory holding cost ($ / unit / year)

Orders $= \frac{D}{Q} \rightarrow$ Ordering cost

Average Inventory $= Q/2 \rightarrow$ Holding cost

You need the number of orders in a year and the number of orders in the year is going to be determined by the annual demand divided by the quantity that you order every time you place an order. And that's going to give you your annual cost of ordering. Now, on the other hand you need you're holding cost. Your holding cost is going to be determined by how much you hold at any point in time. So your average inventory which is Q/2 is going to determine your holding cost. So the ordering cost is going to come from the number of orders so that's your one component and the other main component is going to be the holding cost. And that is going to be determined by the average inventory that is held based on the fact that you're ordering Q at a time.

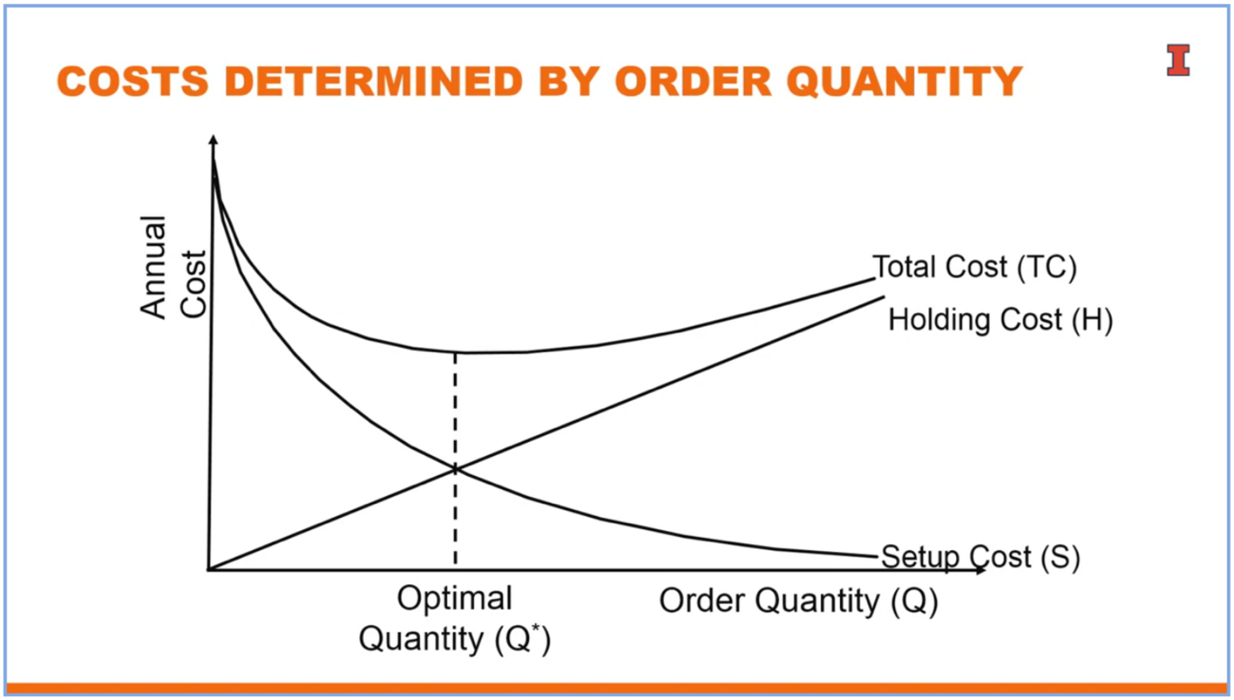
TOTAL COST OF INVENTORY MANAGEMENT (1 OF 2)

TC = Total annual cost
D = Annual demand (units per year)
Q = Order quantity (units)
S = Cost of ordering or setting up ($)
H = Annual inventory holding cost ($ / unit / year)

Total Annual Cost of Inventory Management = Annual Ordering Cost + Annual Holding Cost

$$TC = \underbrace{(D \div Q)}_{\text{Number of orders in a year}} * S + \underbrace{(Q \div 2)}_{\text{Average inventory level}} * H$$

So, if you were to take those two components and try to come up with the total cost, you have the total number of orders in a year. You multiply that by the cost of ordering every time you place an order and we call that S here because S stands for ordering costs or set up cost, right? It could be setting up your machinery to make an item in which case you're going to call it your setup costs, it could be the setup cost of your supplier, in which case you're going to use setup costs as the cost of ordering. And on the other side you have the holding rate. So that's going to be like an interest rate. That's going to be calculated like an interest rate but it's going to have some more components than simply the investment. It's going to have some component of how much percentage do you expect to be added for product to get spoiled? To get obsolete? And those sorts of things might go into a holding rate. So that would give you the total cost of holding inventory and ordering inventory coming up with a total cost of inventory management.



So if you take these two costs and and you look at the trade off between these two costs, that's what's being represented on this picture over here. On the x axis, you have order quantity as the order quantity goes from left to right as it increases. So the more you order at a time, the holding costs, the straight line going from left to right and diagnose is your holding costs. That increases the more you order at a time. At the same time, the costs of ordering or set up costs go down. And that's the curve that's going down from left to right showing that the setup cost is going to be less if you order more at a time simply because you have fewer orders. And the total cost curve which is a combination of the holding costs and the setup cost, the total cost of the combination of those two is giving you the total cost based on adding up both of these costs. So the optimal quantity Q star is what you want. It's the quantity at which your your total cost is going to be at its absolute minimum. There's going to be a unique minimum for this in terms of total cost. And that unique minimum of total cost is going to come from a optimal quantity Q star which can be computed based on this economic order quantity formula.

SIMPLE FORM OF EOQ

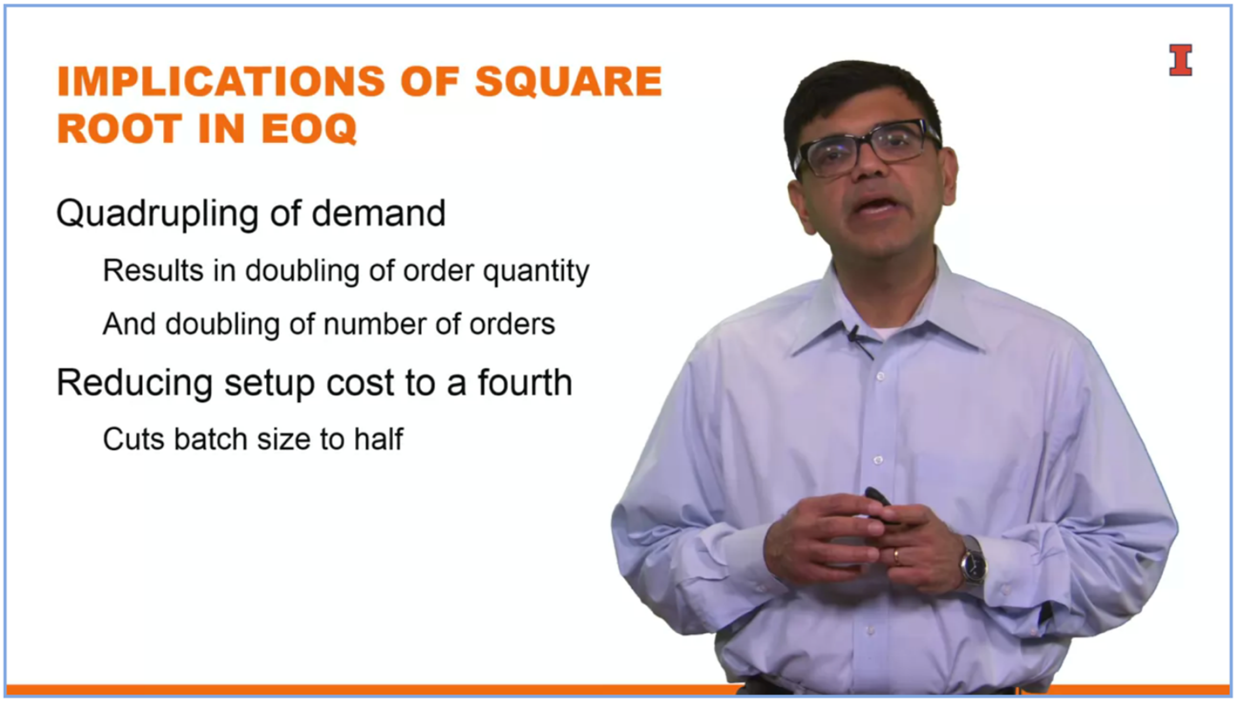
$$Q^* = \sqrt{\frac{2\,\overbrace{D}^{\text{Annual Requirement}}\,\overbrace{S}^{\text{Setup Cost}}}{\underbrace{H}_{\text{Holding Cost}}}}$$

Total Annual Cost using EOQ:

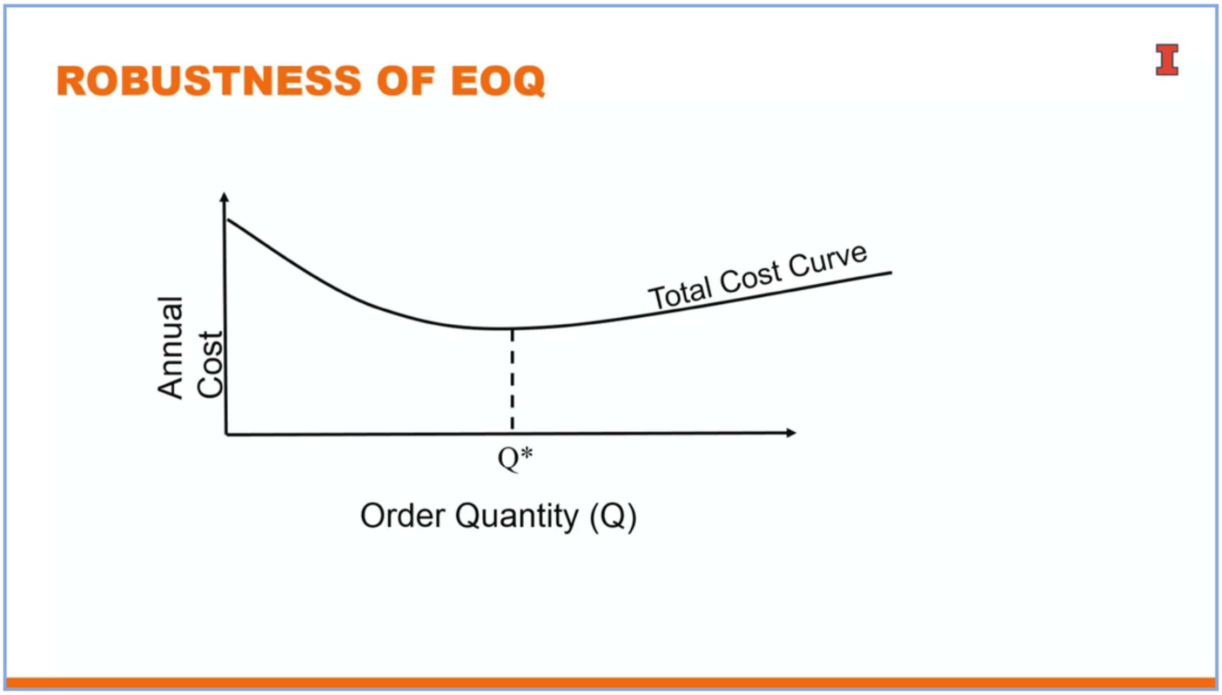
$$TC\,(Q^*) = \sqrt{2\,D\,S\,H}$$

It's EOQ or Q star is the square root of your total demand or annual demand times you're ordering cost, multiply that by 2, divide that by holding cost and take the square root. And that gives you your EOQ. Once you have your EOQ given to you by Q star, your total annual cost using that EOQ can be calculated by the formula that you have on the bottom of the screen square root of 2 times annual demand times set up costs for every time you place an order times the holding rate that you have for your item. So that's the way you would be calculating your total annual cost if you were using EOQ.

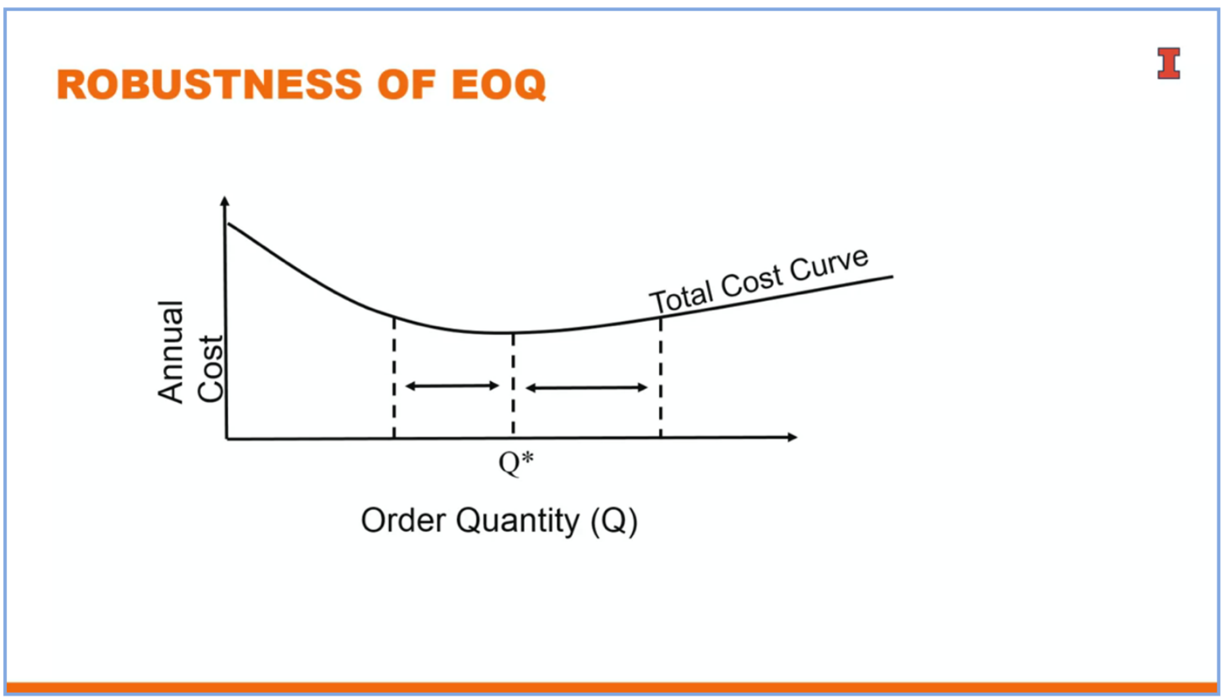
Module 3.2.3 Calculating How Much to Order



So you see that the EOQ formula, the formula for the optimal order quantity has a square root in it. And what are the implications of the square root in terms of what can happen when demand changes? So if you think about it, if the demand quadruples it becomes four times what it is. What will happen is it will result in doubling of the order quantity simply because the square root of four is two. And it will also result in the doubling of the number of orders, doubling of quantity. And the number of orders in the year would get doubled if the demand is quadrupled. On the other hand, the setup cost, which is also in the numerator of this formula, if the setup cost becomes a fourth of itself, the batch size is cut to have. So this gives you an idea of if you want to reduce the batch size to a half, you need to reduce the setup costs. Which is where a lot of companies put their attention in terms of reducing ordering costs, reducing setup cost. If you can reduce that to a fourth of its original then the batch size is cut to half.

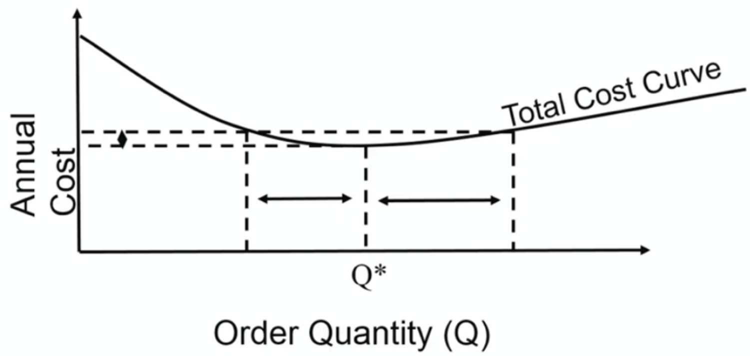


The other thing about the EOQ is that you can see that the total cost curve is pretty flat at the optimal point. At the point at which the total cost is at its minimum at Q star the total cost curve is pretty flat, what do we mean by that?



If you move to the left or if you move to the right of Q star even by a substantial amount.

ROBUSTNESS OF EOQ



The annual cost doesn't go much higher than the lowest cost by too much. So it's robust to any misestimations that might result in getting an incorrect Q star. So if you were to miss estimate the holding cost or the setup cost which results in a misestimation of the optimal order quantity. You would have to misestimate it by quite a bit for the annual cost to be substantially higher than what would have been based on the optimal order quantity.

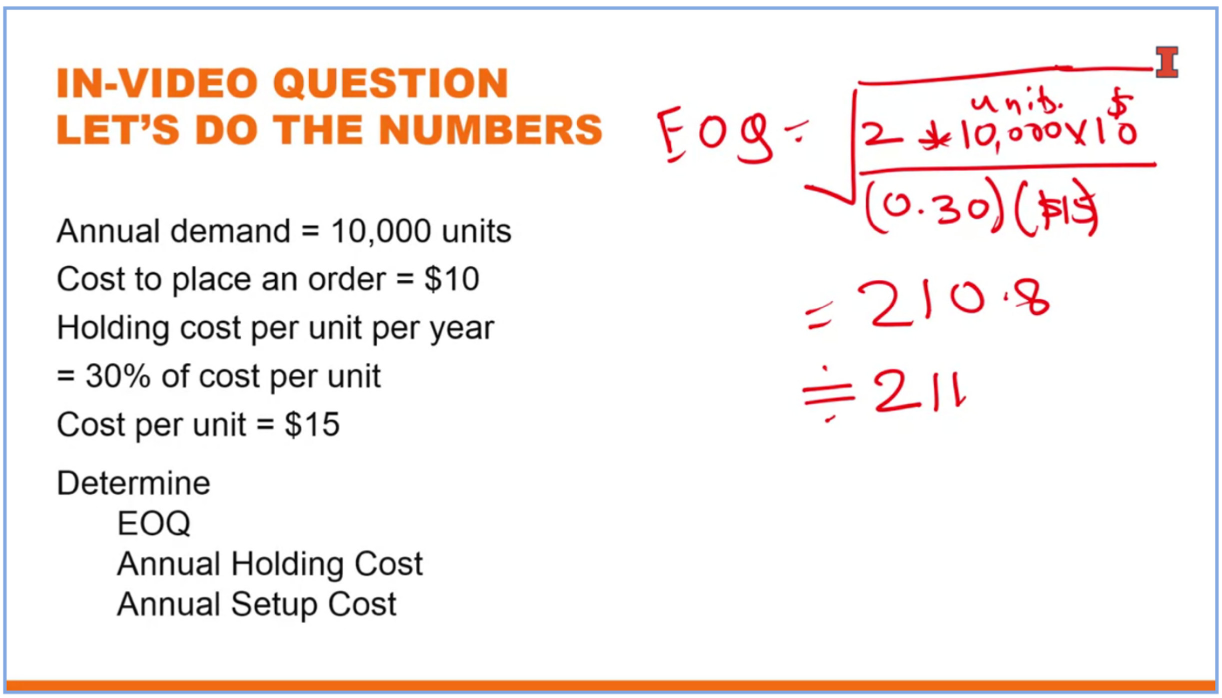
IN-VIDEO QUESTION
LET'S DO THE NUMBERS

Annual demand = 10,000 units
Cost to place an order = $10
Holding cost per unit per year
= 30% of cost per unit
Cost per unit = $15

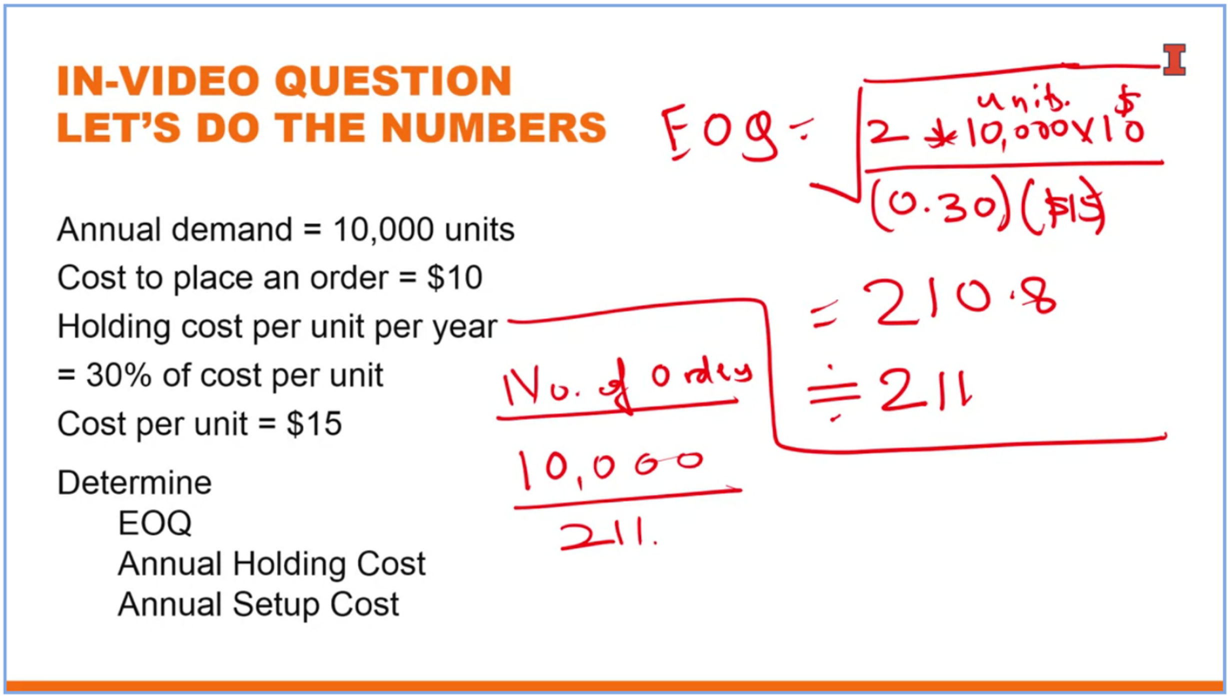
Determine
- EOQ
- Annual Holding Cost
- Annual Setup Cost

(Dugdale, 2010)

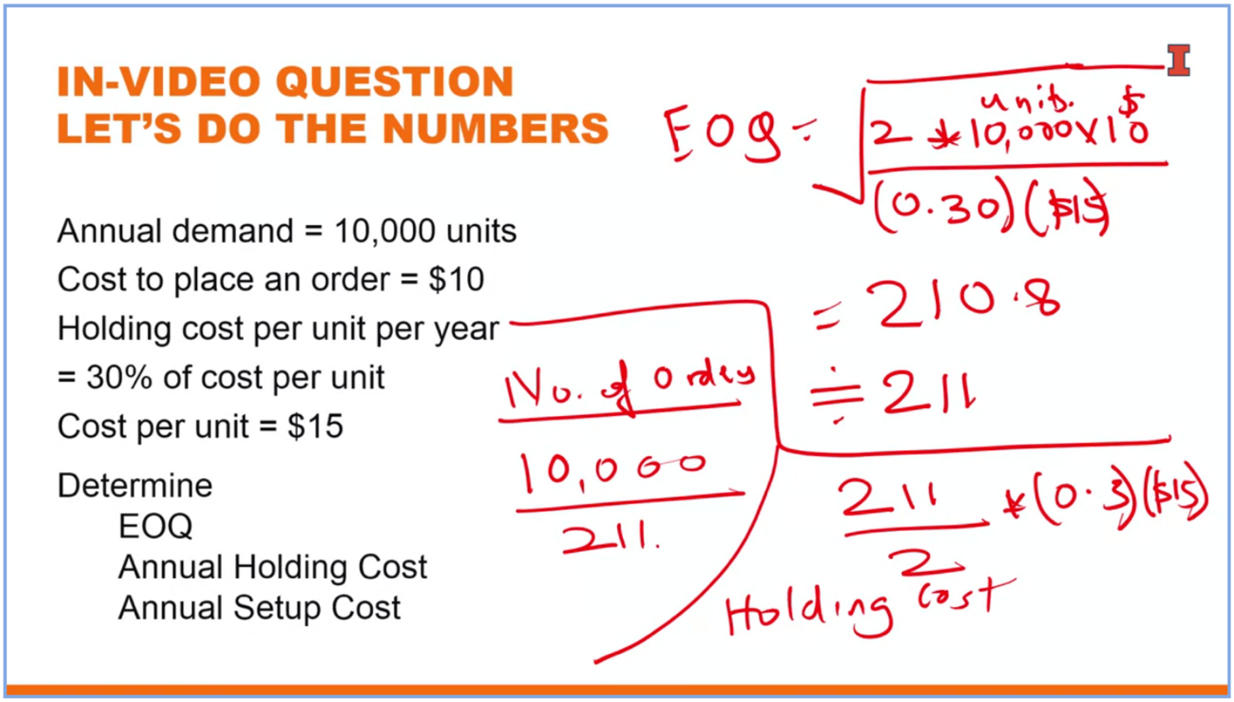
All right, now let's take all that we have learned in terms of the EOQ. And apply that to see the mechanics of how you would calculate the EOQ for a particular company. So let's practice this calculation based on this problem that we have here, annual demand 10,000 units. Cost to place an order $10, every time you place an order you incur a cost of $10, holding cost is 30% of cost per unit. Obviously this includes more than the interest of investment that you have an inventory. So it's got a little bit more than that, that's why it's a 30%, the cost per unit is $15. So what we're going to do here is determine the economic order quantity. And then we'll go back and check the annual holding cost and the annual set up cost and we'll see what we can find there. And then you can also check based on the formula that we saw earlier, the total cost even without calculating the holding and setup costs separately. So take a minute and work through these calculations and then we'll come back and see if we can match what you found with what we'll be doing here.



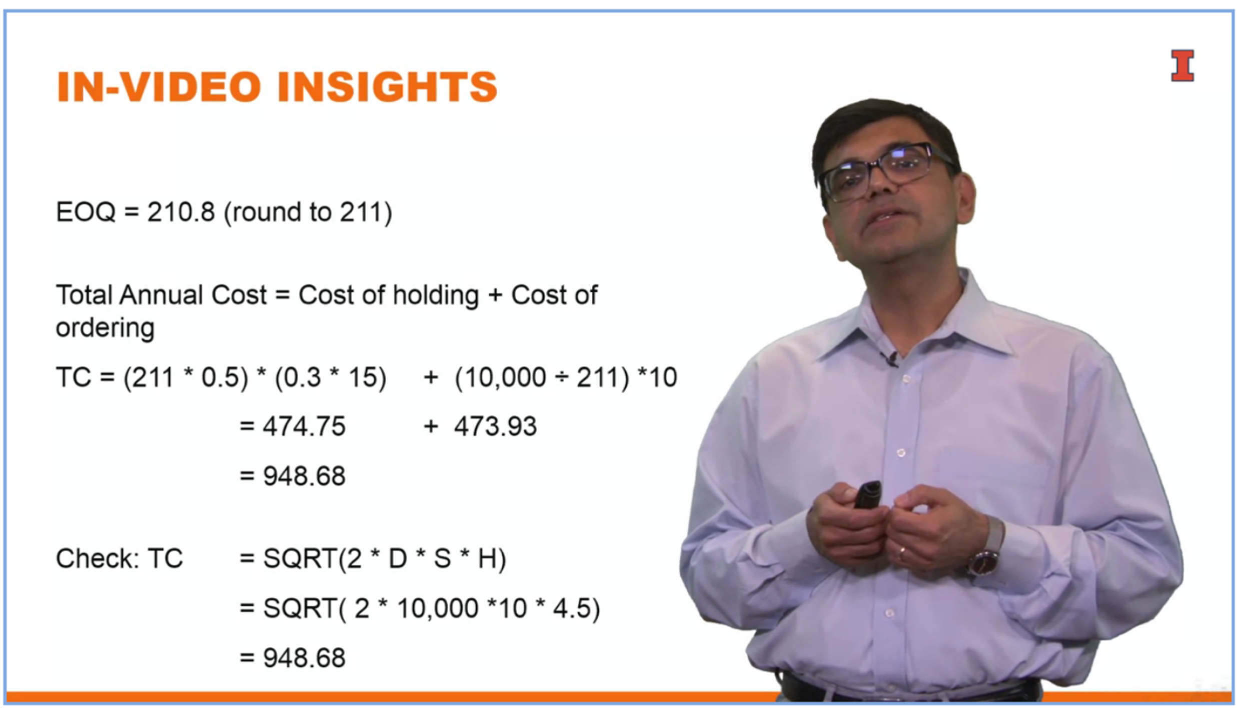
All right, so let's first do the calculation of the EOQ here. So the EOQ here is going to be determined by that formula that we looked at earlier. So it's 2 times the annual demand which in this case is 10,000 units, the ordering cost or the setup cost is $10. So this is in units, the 10 is in dollars, so it's $10 here and then we have 30% holding rate. So that's a percentage and you're multiplying that by the cost per unit which is $15. And that gives us an EOQ calculated exactly that works out to 210.8, so you would round it up. And since we know that the EOQ is robust to a little bit of misestimation to the left or right, we're going to call it 211. Right, this also tells you that if the packaging size is approximately close to 210, that that would be okay that you could order 200 at a time. If that's the packaging size of that's what's convenient and you would still be very close to getting the best total annual cost. Now let's go to the components of calculating the total annual cost for ordering and the total annual costs for holding.



So total annual costs for ordering, number of orders is going to be based on the annual demand. So that's 10,000 units of annual demand, you order 211 at a time, this will give you the number of orders. And let's separate this over here, and on the basis of this number of orders and multiplying it with the cost to place an order of $10. You can work out the annual cost of ordering for this quantity, for holding costs, you would take the Q which is 211. You would divide that by 2 to get an average, so here we are talking about holding costs.



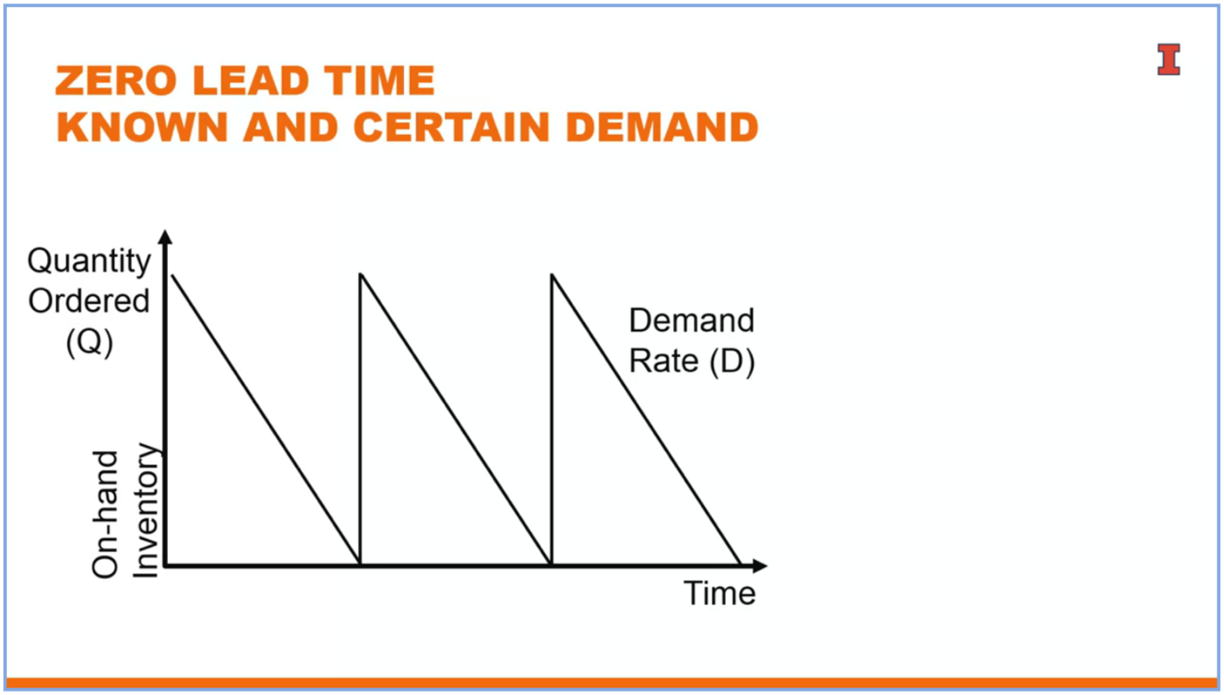
And this is annual holding cost 211 divided by 2, is the average inventory multiply that with 0.3. And you multiply that with the $15 of the cost of the item and that should give you the annual holding cost. So if you were to work through these numbers, what you find is that the total cost works out to $948 and change.



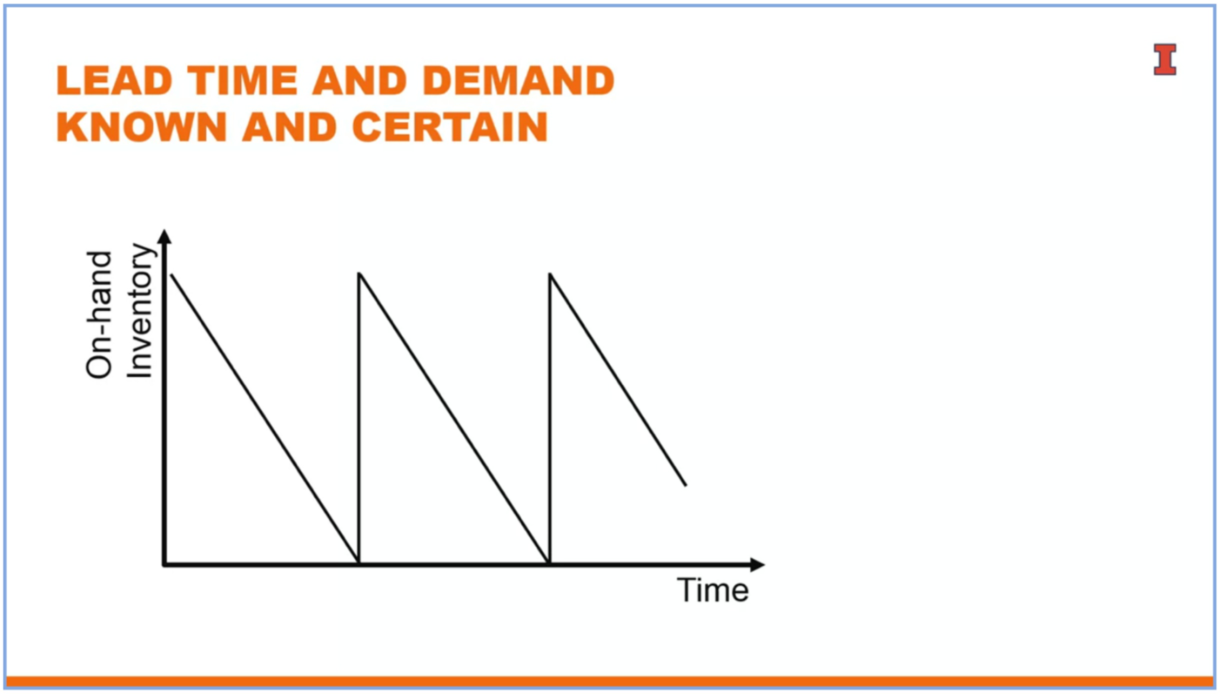
And what you would notice from looking at the calculations for the cost of holding and cost of ordering is that they approximately equal each other. So you have $474.75 for the cost of holding and you have 473.93 cents for the cost of ordering. And of course this is not by accident because the economic order quantity that we calculated is based on trading off these two costs. So it's the point at which the total cost of ordering for the year and the total cost of ordering of holding for the year are equal to each other. So that's what we found. Now you could use the formula that we looked at earlier for total cost. And check your work in terms of finding out what the total cost would be and you would find that it would be exactly the same. So here we have the EOQ being used to calculate how much to order. The other part of the decision for inventory management is going to be when to order. And that's going to be based on calculating a reorder point and that's what we'll look at next.

Lesson 3-3: Inventory Decision – When?

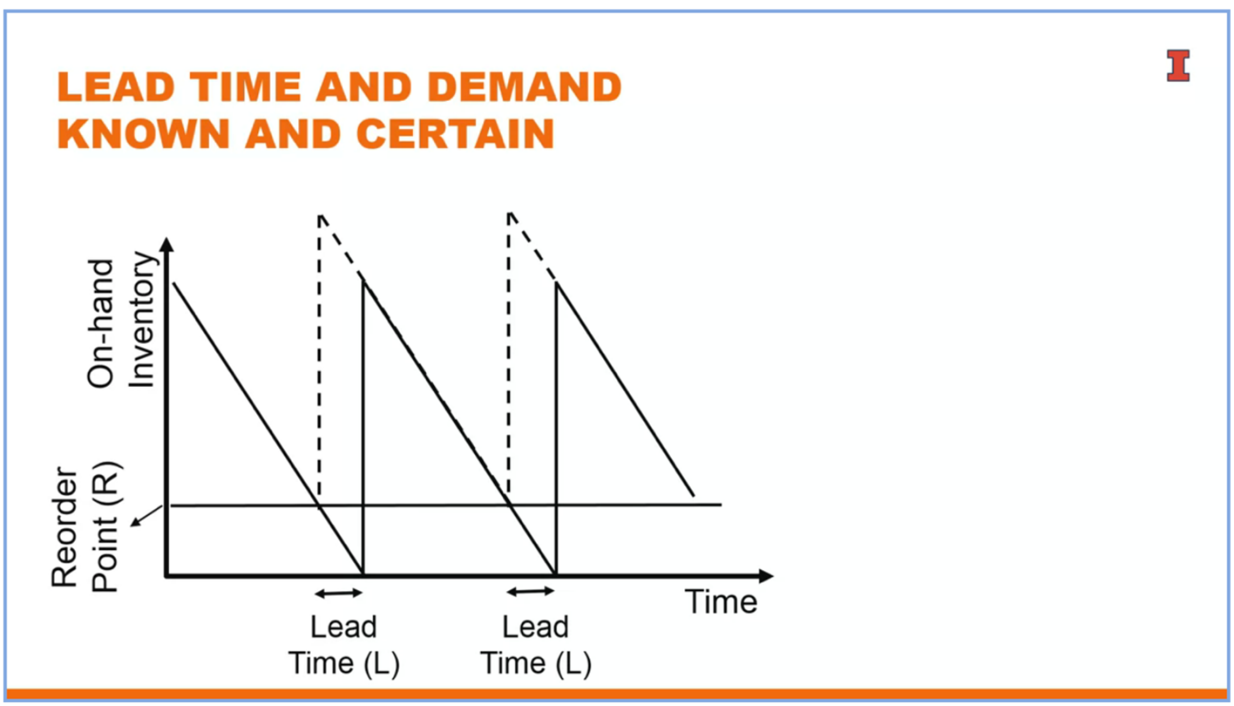
Module 3.3.1 Reorder Point for Continuous Replenishment or Review



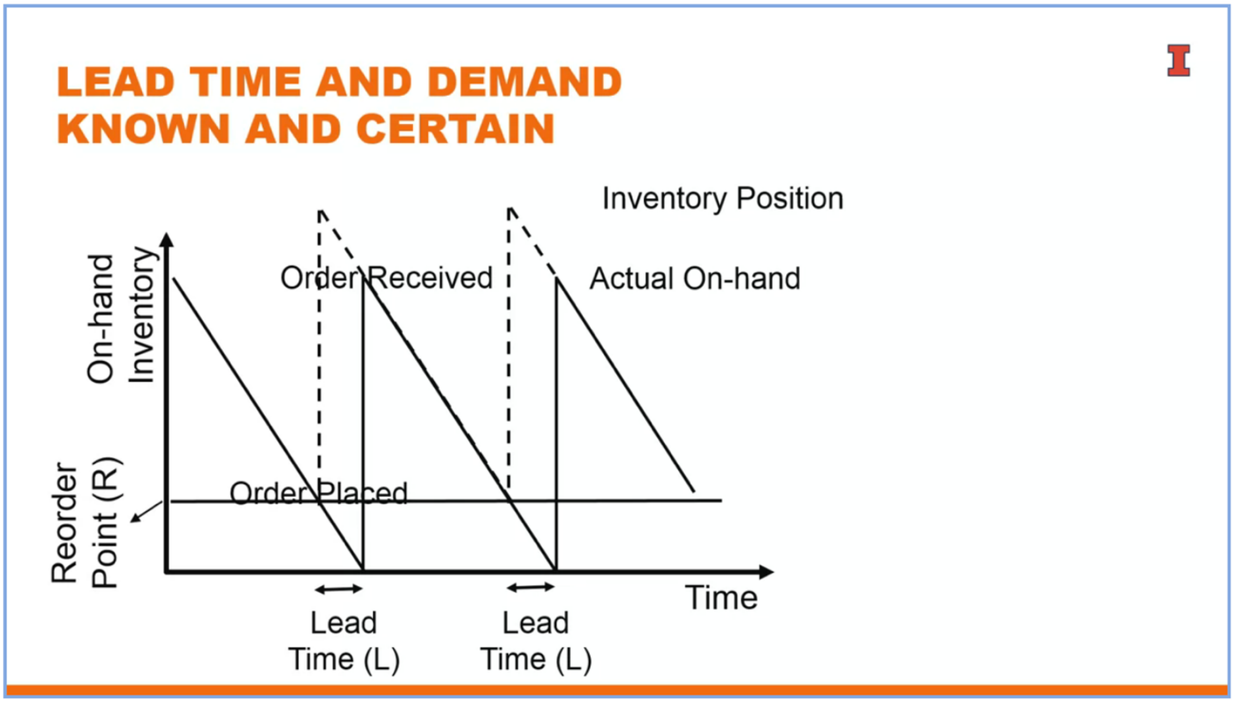
In this session we're continuing to talk about inventory management decisions. Earlier we've talked about the idea of how much to order and we came up with the EOQ as being the optimal order quantity that makes our inventory management costs the lowest. Here what we're going to talk about is, when to place an order. The EOQ is how much to order and reorder point will give us a sense of when to place an order. Before we get started, you want to keep in mind that what we're talking about here is the continuous review system of inventory management. You are continually reviewing your inventory. You are keeping an eye on how much inventory you have, and then when it reaches a certain level you are placing an order. In order to get started with the mechanics of how you would calculate a reorder point for a continuous review inventory management system, let's start with a system for when you have zero lead time. The picture that you have here shows that you order Q at a certain point in time, you use up all of that inventory. It goes to zero, you place an order, and you have instantaneous replenishment. However unrealistic that is, we're saying that there's zero lead time, so there's instantaneous replenishment whenever you go down to zero, and there's a constant demand rate. You are utilizing the material at the same rate. You can see the nice similar triangles across time which are showing that there's a constant rate of usage of that item. When would you place an order here? The answer is obvious, when the inventory goes down to zero, you place an order. Reorder point here is, whenever inventory is zero.



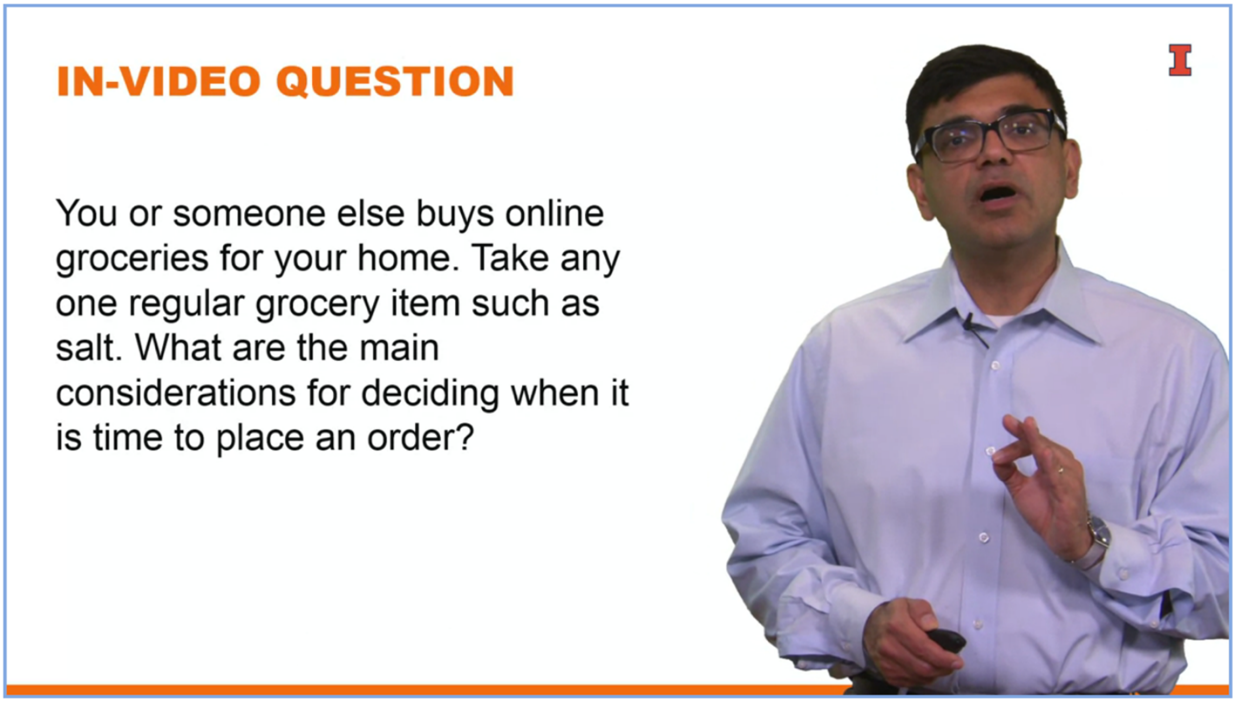
However, in reality what's going to happen is, there's going to be a lead time for when you place the order to when you receive it from your supplier.



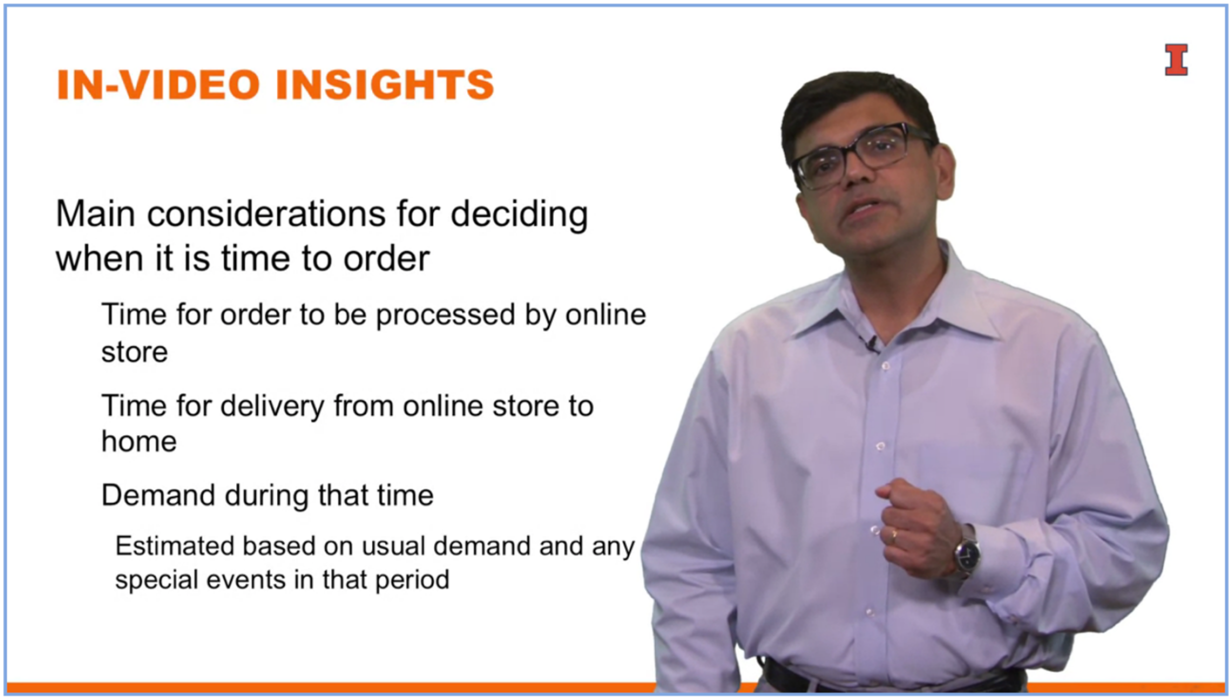
Let's incorporate some type of a lead time into the same system, and then what we're saying here is that depending on the lead time, let's say that you have a lead time of five days, you're going to say when I have five days worth of inventory left with me, I'm going to place an order. That's what is represented over here by that horizontal line above the x-axis which is showing that the reorder point is incorporating that lead time which is the time that it'll take for the material to get to you. What you have is, once it reaches that reorder point, remember you're continually reviewing your inventory.



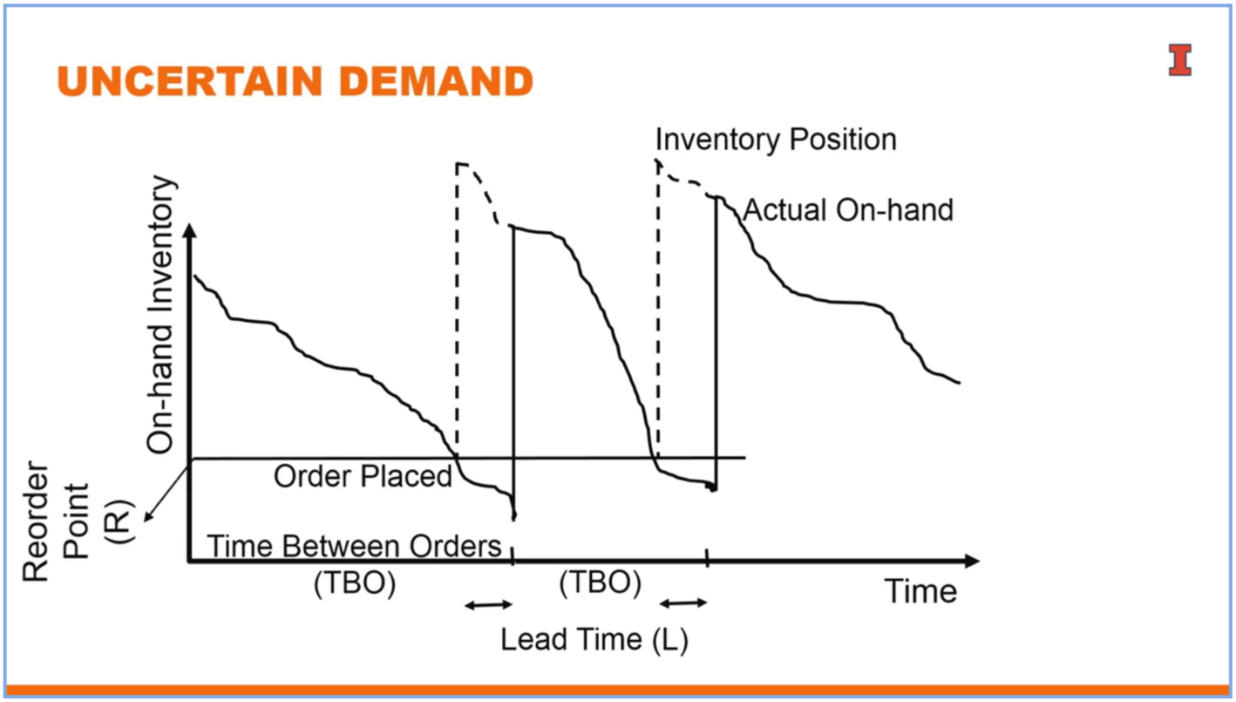
Once it reaches that reorder point, you will place an order and then you will have an inventory position that will show up. You'll keep track of that, that'll be the inventory position you placed an order. Now it'll take some time for that order to get to you. By the time that order gets to you, your actual inventory position has reached zero. On the day that it has reached zero, you receive an order of Q which in the continuous review system is the EOQ, so you receive that order of Q on the day that your inventory position has become zero.



Now, before we move on to the actual mechanics of the reorder point for the continuous review system, what I'd like you to do is in order to relate this whole idea to something that we do on a day-to-day basis in our routine lives, think about this decision that you would have to make. Let's say, however unlikely it is that you buy your groceries online. You have some lead time for when they get to you. You order your groceries online and then they get to you, so take any regular item and here I say salt because that's something that you might order online and receive it from your online supplier. What would be the main consideration for you to decide when it is time for you to place an order. What would be your main considerations in coming up with a reorder point? When would you say I should place an order now so that I receive this salt in time. Take a moment and think about that and we'll come back and relate it to the idea of reorder point under the continuous review system.

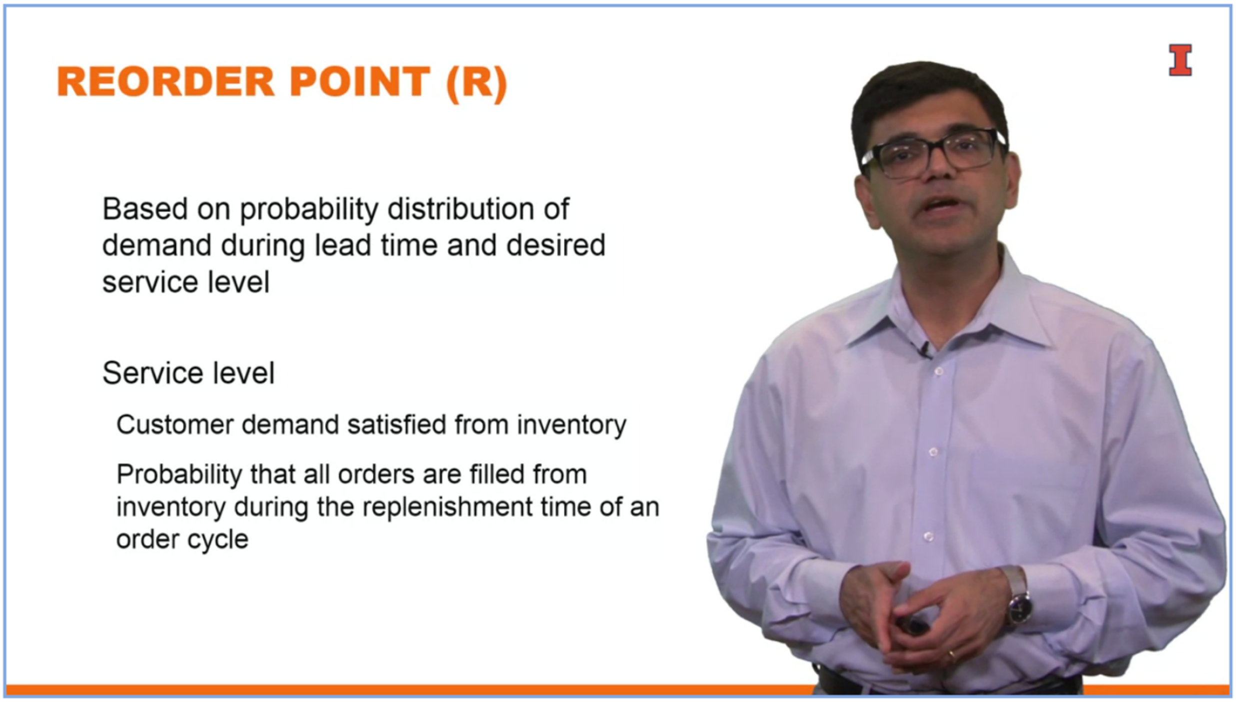


When you place orders from an online grocery store, you're probably thinking about the time that they're going to take to process the order. They're going to receive the order, they might not process the order immediately. There's going to be some lead time involved there. There's going to be that lead time for them to mail your product to you, to send it, to clear it to you, and that's going to factor into the time that it's going to take from when you place the order to when you received it, and we call that the whole thing lead time. Now, what you're concerned about is your demand for that product during that lead time, how much salt you consume during that lead time. What we're saying here is that if it takes five days for that grocery store to deliver the salt to you, you place an order when you have five days worth of salt left in your pantry and you still continue to consume over the five days, it goes down to zero, and by the time you've received the order from that online grocery store at your doorstep, so you're in good shape. However, you don't know exactly what the consumption of that salt is going to be in those five days, so you may be concerned about some uncertainty in that consumption of salt over those five days. It's the same thing that companies are thinking about when they're thinking about a reorder point. They are thinking about how much of a lead time there is and how much buffer they should have for any misestimation for their own consumption during that lead time. Whether we're going to have a more consumption than what we expected. If it's lower, that's not going to be a problem because there's going to be access, but if it's a higher consumption than what you anticipated, then you're going to run short in that lead time, so you basically want coverage for that lead time for the product to get to you.

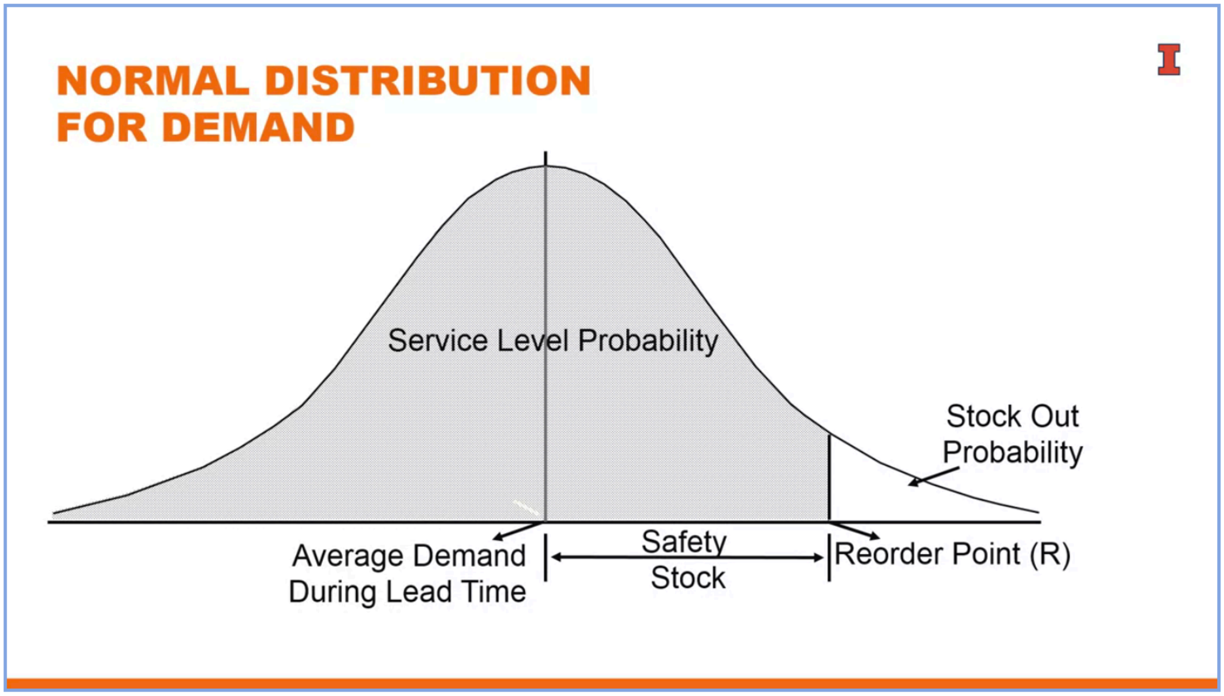


When you figure in the uncertainty in demand into the same type of picture that we were looking at earlier, another picture doesn't look as neat as it looked before. It doesn't have the straight lines that we were looking at in terms of depletion of inventory.
It's not going down in a straight line. Here we have crooked lines that are telling us that the inventory is being consumed at a different rate. You can see the reorder point. The reorder point here is bumped up from just being what you need for the lead time based on an average. You are saying that we expect certain consumption during lead time, but you also bumping it up based on the uncertainty saying that what if we run out, let's have some extra. That's the extra that you're adding in there that is bumping up the reorder point to it being higher than what you saw in the other picture, which was based on just the average demand there being no uncertainty.

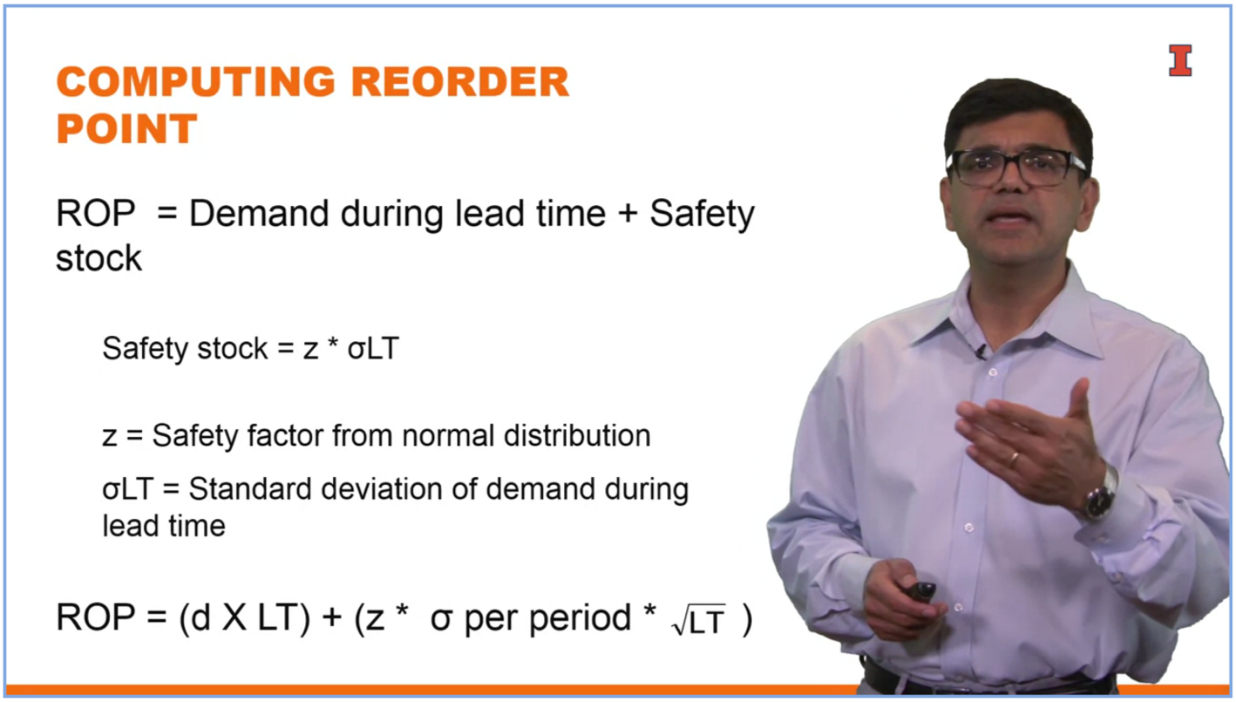
Module 3.3.2 Calculating When to Order



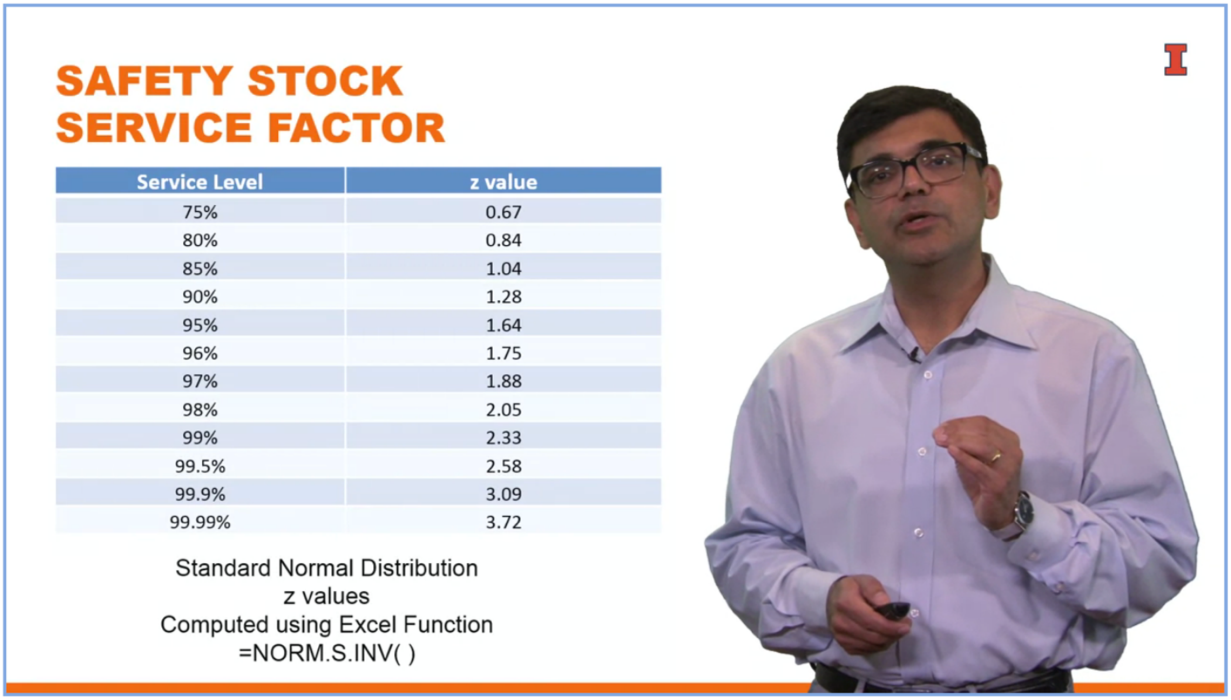
The reorder point is going to be based on two essential things that you're going to figure in. One is going to be the probability distribution of demand. What does that mean? It means that you're going to figure in the standard deviation of demand. You're going to say, well, I expect my demand during the lead time to be 40 units, but it could be as high as 50 or 60 units, so that's what I want to cover because my demand during lead time could be between 40 and 50 or 60 units, so I want to cover all the way up to 60 units. The other thing that you want to figure in is what service level do you want to give your customers. What that means in terms of inventory, is how much are you okay with running out at any point in time? Are you okay to run out 10 percent of the time? In which case you are saying you want a 90 percent service level. You don't run out for approximately 90 percent of the time, but you're okay with running out 10 percent of the time, and if you want a 95 percent service level, by what you're saying is that you are okay with running out five percent of the time. That's the managerial decision that you have to make. What is the service level that you want to maintain? Then you have to incorporate the probability distribution of demand and come up with a reorder point based on that. Two things we're going to include in coming up with a reorder point.



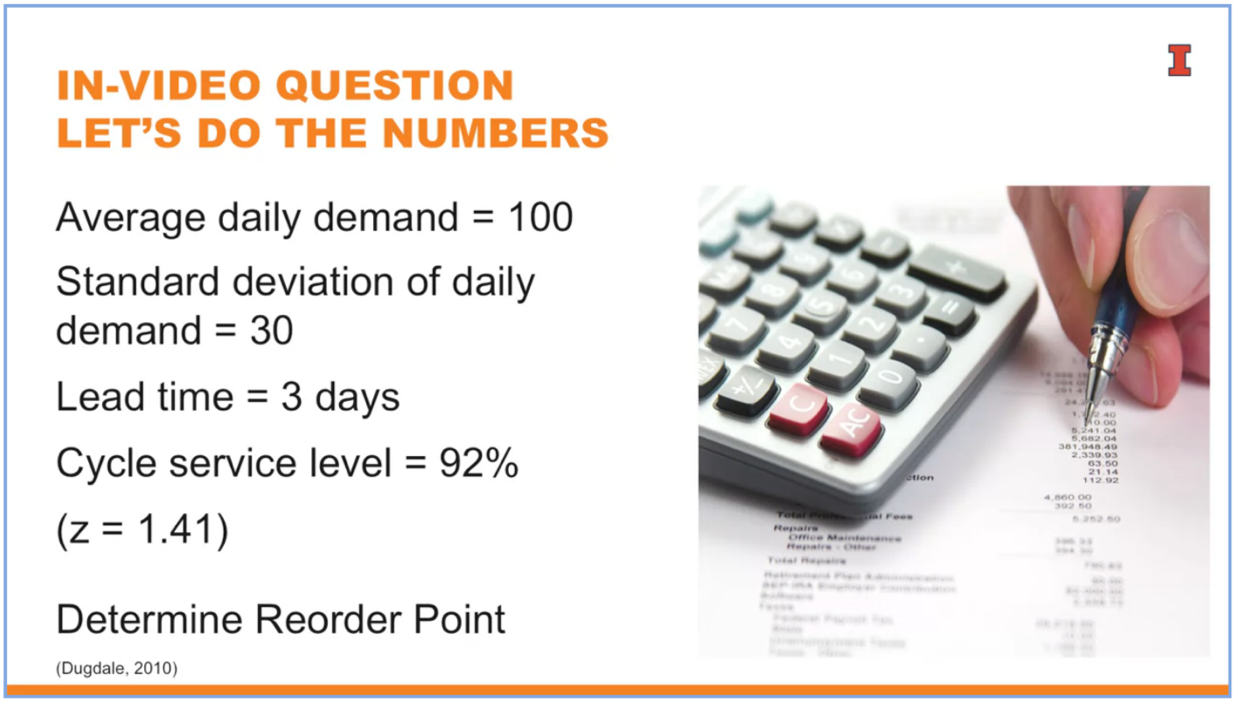
You have the service level for the customer on the basis of which you have a stock out probability, and then you also have the probability distribution of demand. What you see over here, is what is used a lot when you're using any statistical calculations, and this is your normal distribution. We're going to base the calculation of the reorder point on the normal distribution. We're going to take the properties of the normal distribution and use it to come up with a reorder point. You have a certain stock out probability, you have the average demand during lead time, which is going to be the center of this distribution which is basically saying, if you maintain inventory at this average level, you are saying you're okay with running out 50 percent of the time, because 50 percent of the data in this distribution is to the left and 50 percent of the data is to the right.
If you keeping average demand, you're okay with running out 50 percent of the time. But if you're not okay with running out 50 percent of the time, you are adding some safety stock, and that's going to be based on your stock out probability and the standard deviation of demand that you would have got from that data that you have on your demand.



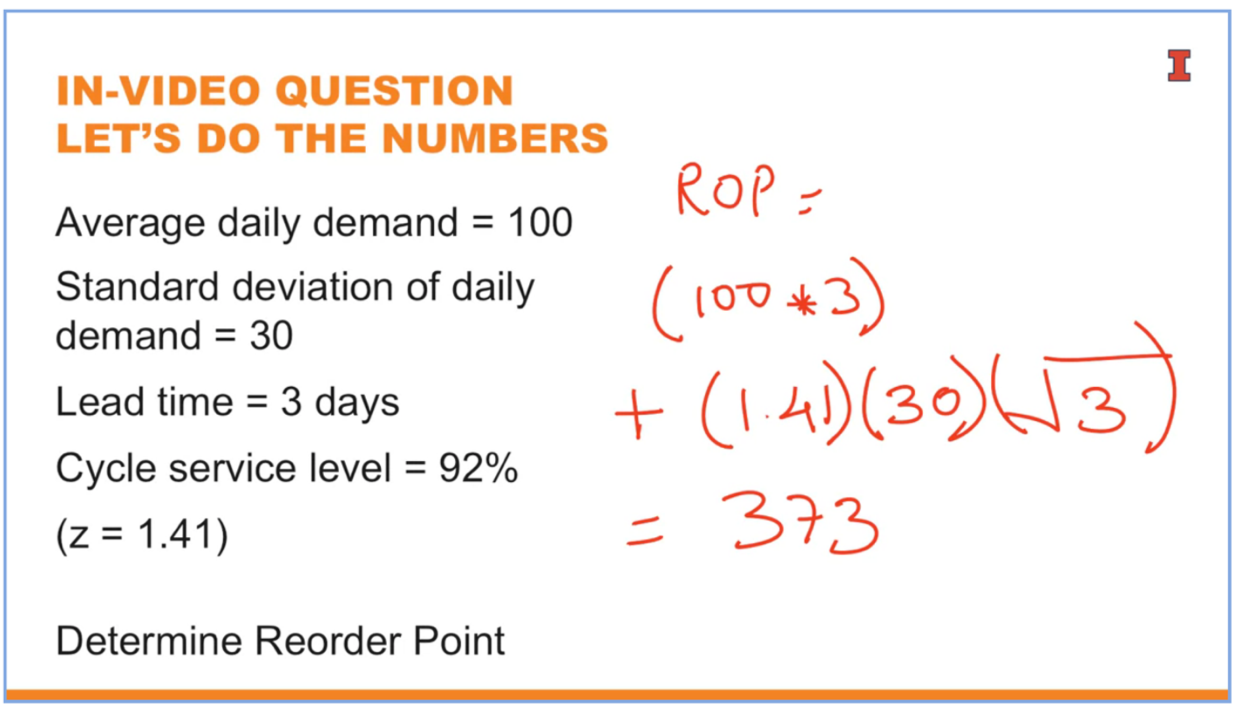
Let's go through the calculations for reorder point here and then we'll go through an example to see how this works out. Reorder point is based on the demand during lead time, which if we didn't have any safety stock, it would simply be, let's take whatever lead time we have. Let's calculate the demand for that and that gives us demand during lead time. The safety stock is based on something that we call a z score. Now, if you remember this from statistics, a z-score comes from a standard normal distribution, and it's based on the probability that is to the left and the right of that point. We'll take the z-score based on that, and in the case of this lesson, what we'll do is we'll just look at a table that's going to give us the different z-scores for different probabilities running out. We'll take a look at that in a minute, for now let's just call it a z-score. Then we multiply it by the standard deviation of demand during lead time. We might have a standard deviation per period and we convert it to a standard deviation for demand during lead time, and what you see on the bottom of the screen there is, you're calculating the standard deviation for demand during lead time by taking the standard deviation per period, multiplying it by the square root of the lead times square root of LT is the square root of lead time, and that's giving you your standard deviation for demand during lead time.



I promised you that we would see a table that's giving you all the different factors of a service and all the different z-values for those factors of service. Here you have that table which says 75 percent service level translates into a 0.67 z-value, going all the way up to 99.99 percent, translates into a z-value for 3.72. What this is saying is that if you want a certain service level, you enter the z-value, the corresponding z-value from this table, and for those of you who are familiar with statistics, this is something that can be calculated or taken easily from an Excel Function based on norms inverse. You put in the probability into that function and you get the z-value based on that. You can do this easily for any probability that you want to look at.

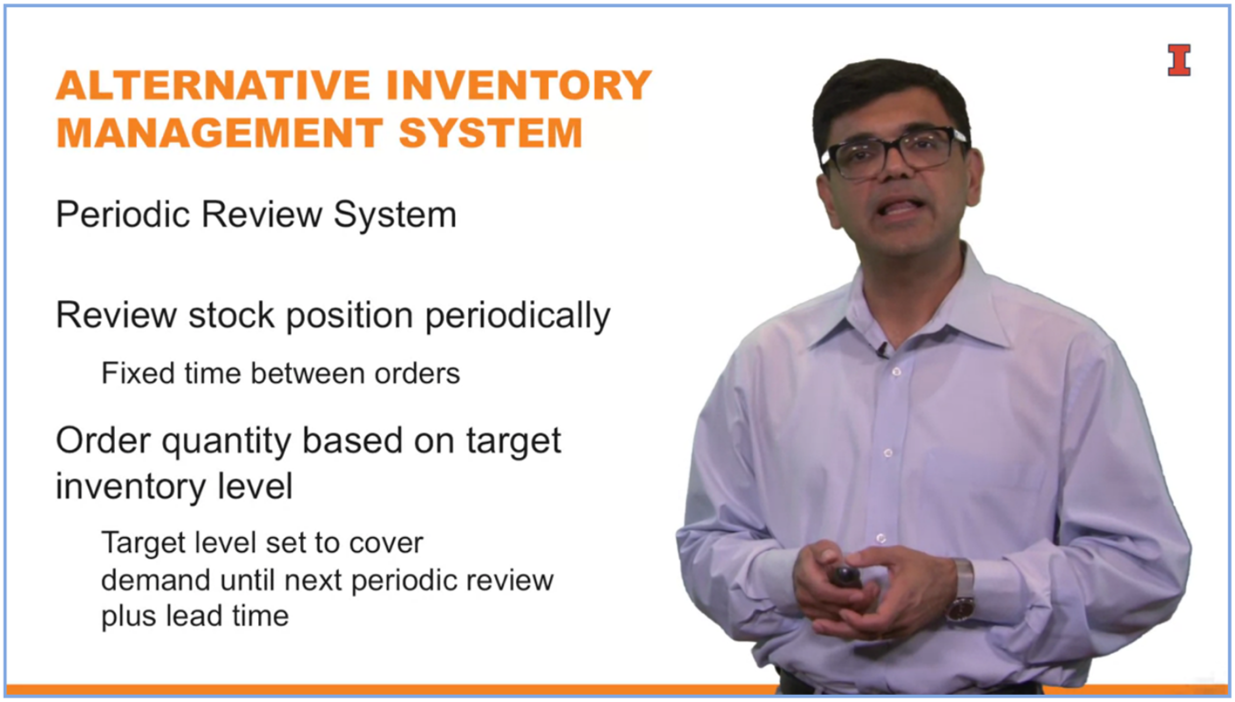


Now, let's take this idea of reorder point and apply it in an example. What you have here is average daily demand of a 100 units, standard deviation of 30, lead time of three days. The cycle service level that is expected is 92 percent. You're okay with running out eight percent of the time. The z-value is given to you as 1.41 for that service level, and you're asked to compute the reorder point. Go ahead and use the formulation that we had earlier to compute the reorder point and we'll come back and see what you find.



The reorder point is going to be based on the demand during lead time, and then the safety stock factor, which is going to be based on the standard deviation, the z-score that you're going to get based on the service level., and we can calculate the standard deviation based on the square root of lead time that we're going to multiply it with. Here's your reorder point for this particular problem is going to be 100 units of average demand per day times three days of lead time, to that we will add the z-score, which is 1.41, multiplied that by 30, which is the standard deviation and multiply that by the square root of 3 in order to convert the standard deviation into standard deviation for lead time, and this gives us a reorder point of 373. What is this telling us? It's telling us that every time your inventory reaches a level of 373, if you are using the continuous replenishment system for inventory management, you will place an order which is going to be equal to the economic order quantity. You reach a level of 373, you place an order of economic order quantity. Here you have the complete solution given to you in clear type, so 373 is your reorder point.

Module 3.3.3 Other Inventory Management Systems



Now we looked at what is called a continuous replenishment system as the system that we focused on for the calculations. There is however an alternative system that you can use. You may be familiar with the system, when we describe it, you'll probably see that you're familiar with the system. It's called a periodic review system. The main difference there is that in the periodic review system, the time between replenishments is fixed. When I said you may be familiar with this, let's think of the vending machine that you might have in your building, in your office building or in your school, that is being replenished at fixed intervals. There's somebody who comes there every week or every four days, whatever that fixed period is, and replenishes the inventory in there. What you'll also notice about that replenishment system is that the time period is fixed, but the quantity that needs to be replenished for every product is going to be different every time it gets replenished. If you have 10 slots for M&M candies in that particular machine, on some days that the person comes back to replenish, all of those slots might be empty, in which case the replenishment quantity becomes 10 units. Some days only two of those might have been used up so the replenishment quantity becomes two. Some days, none of those might have been used up and the quantity is zero. To contrast this with what we learned about in the continuous replenishment system, in the continuous replenishment system, you are having a fixed order quantity. We came up with the EOQ, that was a fixed order quantity. The time between orders is going to be different based on when you reach the reorder point. In the periodic review system, the time between orders is fixed, the quantity is not fixed. It's based on that particular target inventory level. It's the number of slots for the M&M's that you have in that machine that becomes the target inventory level. You want to build it up to 10, and that determines how much quantity you would be replenishing at any point in time. These are the two main types of inventory replenishment systems that get commonly used in all your inventory systems. These are in place when you look at a larger ERP system that's making decisions for inventory. These are the basic ideas that are in place there. This basic EOQ formula that we learned about in the basic continuous replenishment system that we learned about can be looked at from a more sophisticated perspective if you were to relax some of the assumptions. If you remember, we started off with saying, there are no discounts for any item in terms of the price, the annual demand is constant. We can take all of those restrictions and relax them and gets to be a more and more complex model for which the calculations obviously get more complex. But this is the model that we did look at, is the basic model on which all of those other models are based.