# **MGT 8803 SUPPLY CHAIN MODULE**

# **Week 9 TRANSCRIPTS**

## Lean Operations

>> Right, welcome back. So in this session, we will look at something I hope that you've heard of, right? And hopefully I'll go a little bit deeper for you. And that's lean operations, or lean manufacturing, whatever phrase that you may have heard or comfortable with. So our learning objectives here is first, I just wanna kind of give you the origin, where did this thing come from if you don't already know.

And I wanna make sure that we're all very clear on what the philosophy of lean is. Cuz this is something I see routinely that people have a misconception about. And then I wanna kind of at a very high level, kind of rotate through some of the most common tools and techniques, we won't go deep into them.

But just kinda lay them out and then what you'll see is in the next session we'll take one of them and we'll go a little bit further, okay? So here's my opening question. You've got the answer there, right? But lean itself, and by the way I'll back up even further, lean actually got its roots in something called the Toyota Production System, right?

So lean really originated with Toyota, that's where it came from. And I find that just kind of interesting because if you think of Toyota, Japanese company, Japan, right? Is a small landlocked country, so what that means to me anyway then is that space is a premium. So you have a company in a country where space is important.

In the back of my mind, I'm thinking that probably was a good motivation for them to adopt what have now become known as lean, okay. And here's what's interesting though, the philosophy of lean. What do you think the philosophy of lean is? Cuz a lot of people when I ask them this question, they'll say, the philosophy of lean is that product arrives just in time, it's JIT, just in time, okay.

Turns out that the core philosophy behind lean is elimination of waste. Now, the tie into the misconception is gonna be, that lean views inventory as waste, because inventory has all kind of bad things that can be associated with like it becomes obsolete. If it's in a big warehouse, people take it home.

Right, or it deteriorates all kinds of things, right? But here me, the philosophy of lean is the elimination of waste. All right, so why has lean over the years gone with so much attention? I won't name the company but instead we'll just give you a look at some changes with a company that was a traditional US company was operating a certain way for many years.

And then decided to embarked on this journey to adopt basically the principle of the Toyota production system. What was now called lean, right? And here you can just see some of the changes that have occurred as a result, right? So it turned out that in the current environment, it was taking them three to four years to do r&d to come up with a new product, right.

By the time they got lean fully going and implemented, they got that down to one year, that's huge, all right? Employee hours required for a machine, they cut it in half, all right? So quicker development time, less employ hours needed to monitor/maintain a machine. Not only that, but the amount of space they needed for machines was cut almost in half, all right?

They went from 100 square foot needed down to 55. And look at this, the number of defects went down by a whole order of magnitude, it went from eight to point eight, right? The amount of money that the company had in work in process, that's WIP, and finished goods, two types of inventory, right?

So you're thinking JIT, if that's the thought process, you're thinking, okay, it should go down. And indeed it did, $2.6 million down to 1.9, that's $700,000 right there, right. In Bali, throughput time will quickly think is, if I introduce a raw material into my manufacturing facility, how long does it take it to go all through all the steps and come out as a finished good?

16 weeks, can you imagine? Applying lean principles 14 hours to five days, what a difference, okay. I was by the way, and then you get this last thing, right. The lead time that they would quote to customers, right. Customer places order, how long til they get it, right?

It used to be four to 20 weeks, lean brought them down to one to four weeks, right. Pretty clear why lean has been talked about as much as it has, okay. So what are the principles, and what are some of the high level tools then? And this is gonna be done, and it's done here.

And it's shown in a circular kinda fashion, because the idea is, you keep doing this continuously. But really, with lean, right, the idea, first and foremost, is to identify value. And by the way, value is defined by your customer, not by you. And then often, in going on this journey to become a more lean organization, the next thing you'll wanna do is want to map the value stream.

And so I've got off to the side here VSM, this is called Value Stream Mapping. This is an exercise where you go through and you map out all of the product flows and the information flows at you company. And while we won't get into it here, but the idea ends up being trying to find areas where no value is being added.

By the way, no value equals waste. Philosophy again of lean is to eliminate waste. Now you'll see why that tools used, right? Third principle here in this flow diagram for getting to a lean environment is to create flow. They call it Create Flow. And a big tool is used here is something called 5S, you can look 5S up.

It's all around creating in a manufacturing environment, right, creating a very orderly kinda look. It should be clean, everything should have its place, it should be put away. Things should not be left out, right, Create flow. Fourth step is to establish Pull, okay? One of the big things about lean is it is what's called a pull system, and we'll get to that in the next session.

Most lean companies make heavy use of something called Kanban to help them. And then the fifth principle behind lean is Seeking Perfection. And the tool used here is something called Kaizen. It's this notion of coming in and doing, they'll call it a Kaizen blitz to come in and seek to improve a particular operation or process.

So understand this, I've given you a very high level, a very quick fly by of this thing called lean, and it's a pretty big thing. And I promise you there is way more down in this thing called lean. Literally, you could have a whole class on this, right.

But again I just wanted to give you as high level fly by and in the next section what I wanna do, session, is I wanna talk a little bit deeper about this notion of pole. And how that differs from traditional manufacturing.

## Push vs. Pull

>> So let's go a little bit further in this session into this notion of a pull method, as employed by Lean manufacturing. And so our learning objectives here are going to be not only to discuss pull versus traditional push method. But also to explore the use of what are called Kanban cards and this technique around Kanban.

So if we go back to the prior session, we talked about the five principles of Lean, showed them in this circle, right? And what we're gonna do here in this next session is I wanna zoom in on number 4, establishing pull. So look at this notion a pull and again using this technique or tool called Kanban.

So are you ready for this? Where do you think Toyota got the idea for what's called Kanban? And you're gonna love this. Turns out the idea came when one of them was on a visit to the US and they went to, yeah, I'm not kidding, Piggly Wiggly. And they saw, this is a supermarket by the way, okay?

And in the supermarket they saw that Piggly Wiggly was using these little cards on the shelf to help them know when to restock items on the shelf. So, there you go. So let's compare and contrast a traditional push environment with a more Lean methodology, which would be a pull environment.

And what I've got here on this graph, on the top is what a push environment would look like. And this is a nice, simple, three step kind of operation. You got two steps and then a final assembly. And so what you have here is, you've got step one right here, with some space for inventory in front of it.

They'll do, I don't know, whatever the step is. Move on, and you could have got inventory storage in front of the second step. And then you have final assembly. And then what I've labeled here FGI is finished goods inventory, okay? And in a push manufacturing environment, and by the way, this is very common and still, in some cases companies do this.

The idea is as they have raw material in the facility to work on. The ideas is as quickly as you can, let's get that raw material pushed in, and let's start processing it. And let's keep going. And let's keep going. And make as much as we can with the raw material we have.

So you literally think of pushing that raw material through. In contrast, all right, a pull environment works differently. And really the key difference, you hopefully can still see on this graph, is it's with respect to information. Okay, in a pull system what happens is you've got raw material, okay.

You've got some raw material here but that don't necessarily mean that you move it and you start doing this first step right here. You may have some working process here, but that doesn't mean that you automatically begin processing at step two. What happens in a pull system is as customers buy or order from you and in a sense they're pulling out of this finished goods inventory.

That becomes the information signal to assemble more, which then becomes the information signal for step two to do more. And as step two does more, that becomes the information signal for step one to do more. And as step one does more, that becomes the information signal to restock raw material into here.

So let me talk about it verbally. So I've kinda tried to show it pictorially, but verbally, right? In a traditional push system, right, the idea is that every worker's going to try to continually be busy, maximize their own output, make as much as they can. The more stuff they see in front of them here and ready to go, inputs, the more they wanna produce outputs, right?

The idea here is you're right you're focusing on keeping the individual operators and workstations busy. Problem of course with that is it doesn't necessarily mean that they are actually making something that somebody's going to buy. They could literally be making something that's going to get stopped for a while.

They may produce volumes of defective work. That you don't find for a while, right? And what's interesting is what happens in that push kind of system. What you'll see, and plenty of studies done on this and research done, is throughput time. So time for that raw material inventory to make its way all the way through actually gets higher.

And you have a lot of work in process. I mean, I've seen this. I literally at one point here locally where I'm at, I visited a company that makes carpet and they were absolutely in a push environment. And as I walked through, I literally saw rolls of partially finished carpet.

It didn't have the backing on yet or it didn't have the Scotch Guard on the top. Right, they had so much work in process they literally were piling these things up in the corners of the warehouse of the manufacturing facility. Right, because what they were doing is literally, as they got yarn in, let's get this yarn colored and let's push through and let's make carpet.

Other things you see with a push system is you can, you're going to see bottlenecks. You will see again inventories of unfinished product, all right? And because throughput time gets bigger, by the way, lead time will get bigger and it becomes harder in a push system to respond to special last minute orders or changes.

You can trash that with a pull system, okay? Pull system ends up, again, pulling from finished goods. It's controlled by the last operation. They'll use these things called Kanban cards in order to control work in process, in order to control inventory at these intermediate steps. Right, so in a pull system, you literally are preventing, in essence, those rolls of partially finished carpet from collecting up in the corners and the sides of the warehouse, or from piling up around a bottleneck, right?

In a pull system, the idea is to keep the material busy. You're not concerned as much about the operator moving and doing something 24/7, or at least something production oriented, all right? Now If problems arise, right, you get there's no slack in this kind of system. So there is one slight con here.

And by the way, taken at a higher level if you look back several years when there was a issue in Fukushima with one of the nuclear power plants, okay? What happened is in this pull system, production stopped at a lot of places. And that downstream effect in terms of those inputs going to other companies, the lack of material coming from, say source plants around Fukushima, caused these other plants to within a matter of two weeks start to run out of material.

And they run out and they stop. But on the plus side, throughput time and WIP are decreased. You're able to react faster. You catch defects quicker, and usually there's less opportunity create them. So let me touch on this Kanban. And I mentioned this word Kanban. And I wanna kinda show you what this might look like, and again I'll go back to pictorially, okay?

But here and as before we had a square to denote that something was happening. The circle denoted inventory. So the truth is in this example I'm doing here this is like the circle from that prior graph, okay, that's storage. The way Kanban works, okay, is again this is a pull, so things will start from this end down here.

It's a pull system. And so what will happen is when Work Center B has work to do what they would do is they would go and they would go to into storage and they would take material out which is input for them. And they will pull out or they would what they call withdraw Kanban.

They would put a card down that says hey, I just took a batch of raw materials or intermediate goods from the storage area, okay. And what would happen is when they do that and they take that and they go back with that, what happens then is that Work Center A sees okay.

And by the way, Kanban is, you also may hear the word container or you'll wanna figure out the size, how big it is. Well, just for argument's sake we'll say that for them a Kanban is 4 units. So they'll pull these 4 units, they'll go back to Work Center B.

They'll begin to process those 4 units. And a production card then goes to Work Center A. That says, hey, a container of 4 units was just removed from storage. Work Center A, you need to produce 4 more, produce 4 more, take that card back and put it back in here when you get done.

And then by the way, as soon as you do that, stop, Work Center A. Don't do any more until you see another card. So mechanistically right, this is kinda of how Kanban would operate. And so you can see now you take this and go to have Work Center A, B, C, D, E and so on.

And each of them having, flow these Kanban cards between them. And you can see how it operates. So we just took here now a quick look at how pull flow differs from push, all right? And then how, in Lean manufacturing, they make use of something called Kanban cards to help control inventory.

And so if you start to put all of this together more, and you go, okay, they're controlling inventory, why are they trying to control work in process, and particularly inventory? And it's because they view inventory as wasteful. And again, the philosophy of Lean is to try and eliminate waste.

## Sales & Operations Planning (S&OP)

>> Hey welcome to this lesson on Supply and Operations Planning or also known as S and OP. Our objectives here, are there gonna be to talk about both internal to a company and external to a company mechanisms that they use to try to match supply of the product with or service with demand for that product or service.

So many companies have a formal process where they try to take sales forecast or business plans, and they try to take and determine production plans and labor schedules that will be required to meet those forecasts. So for supply chain, what you're trying to do is you want to minimize the cost incurred to your company to provide or supply their product or service.

So again, how do we match up demand, which will come from the sales group, with our ability to supply, which will come from the supply chain group, right? And given an aggregated which means collected all together overall demand forecast. So if you have multiple products, aggregate is the demand for each individual one all put together.

How do we minimize again that total cost over plan horizon that you use here, to plan out for what force level is inventory levels and production levels. So when coming up with a quote production plan or when doing production planing, right? There's information that turns out that's gonna come externally to the firm or the company.

And then there'll be information that you'll take that will come within the company. And you'll take all these together to synthesize, rather, that plan. So externally, and outside of the company, they're gonna take a look at what is the current economic conditions. Whether we're in a recession or we're in a growing economy.

What is the market demand for our different products. Do we have any issues or is the raw materials or the inputs that we need, are they readily available? What are our competitors doing, right? And if we had to find external sources of capacity, what are those external sources and how much?

And then internally to the company, we'll look at what is our current inventory levels versus, what where we need to get to, right? What is the current workforce level? How much can they do in translating and in terms of that, what is our current physical capacity? How much could we produce over a given time, period, right?

And then are there any other activities that may be required maybe component parts or other things that have to happen for production? And you'll take all of those together to come up with an operations plan or production plan. Now, it turns out that there are different strategies or levers, one can use or a company can use to match again, match supply with demand.

Cuz in general, they don't equal, right? One or the other will tend to be higher, either they'll have more supply than demand is asking for, or demand will be greater than supply. So then the question becomes, once you've done this whole production planning, what kind of levers do we wanna pull to try to match these two up, right?

And from in within the company, most of the levers you see use or more supply chain or capacity related type of strategies, right? So they include things like if demand is going to be higher than supply, I will get or hire, H-I-R-E, right. Hire more employees. And when demand is lower, I may just fire more employees to bring supply down to match demand.

Another strategy you can use is to is to hire temporary workers, right? And this is a very by the way, very common strategy here in the US around December, around Christmas time each year. Many companies probably get 30, 40 if not more percent of their yearly sales in that busy Christmas period.

And the way that they handle it, the way that they can handle supplying that increased demand, is they have temporary workers for the holiday season. And when the holiday season is over, they let them go, right? Another lever you can use again, to get demand to match up with supply is give your employees overtime.

So give them extra over above regular pay to work hours beyond the traditional 40 hour work week and in times of low demand, may be reduced or hours from 40 down to 35, whatever it is. Fourth strategy is, if there are other companies that can do what you want done, you can subcontract a piece or all of a given activity to somebody else.

Fifth strategy is looking at having, what it was labelled here excess inventory. And what this is, and what this means is, that during periods of the year where demand is lower, you actually produce more than you need, and you store that away. Much like a squirrel does in the fall, right?

They go around collecting nuts. They're collecting way more than they need to eat in the fall. Because come winter, there will be no food, they begin to then use that excess inventory. It's the same analogy here, where a company builds more than they need, say maybe in the summer months, so that when winter comes along and demand is greater than capacity, they can begin to reach into that excess inventory that they built up.

Next strategy is you just kinda live with it, you're gonna have a backlog, right? You know you're behind, you're gonna have a backlog and just continue to work through it. And during the lean time periods, you'll get caught up. And then the last one is having the flexibility if you have it, to change your production rates.

Externally to a company, there's other levers that one can pursue. And these tend to be more along the lines of when you have a mismatch between here's demand for your product and here's the supply you have, right. The ones we talked about in the prior slide will ways to move the supply up to match demand.

Well you get it. The other option is, if supply is here, your ability to supply at this level, there are things that you can do to try to influence demand and try to move demand to match. And so those are things like changing the price of your product or service, right.

As you know, if you increase the price, demand should go down, right? So if I'm in this kind of situation, here's my supply and here's demand, if I increase the price, I would expect demand to drop. On the other side of the coin if I'm like this, I can put forth promotions.

The idea of promotions is to increase demand. The idea with advertising, increased demand, right. Bundling or packaging offers, increase in demand. Going this way again, no, it's a choice. I'm not saying it's a great strategy, but it is a strategy, is if supply is here and demand is up here, I could choose to just turn down some orders, this amount I gotta turn down.

And then the last one, pre-orders or reservations. So that's a real quick look at supply and operations planning or S and OP as it's often called. What I wanna do on the next lesson is I wanna dig in deeper into one of these levers we had here which was building of inventory.

We call it excess inventory. And so in the next lesson I wanna go on a little bit deeper. How do you actually manage or how can you manage that inventory that you keep.

## Inventory Management (Part 1)

>> Welcome back. So in this first of three lessons, I wanna dig into the topic of inventory management. Now, learning objectives for this first lesson is I wanna start out by talking about inventory just in general terms. What are the benefits of having inventory and what are the costs or maybe disbenefits, if you wanna call it of having inventory?

And then I want some key decisions and really what it comes to in coming up with an inventory management policy. So let's start with what is inventory and we've got a nice picture graph here to look at, right? And I'm gonna define inventory, right, it's basically, it's really any raw material, component part, work in process or finished goods that are held at some location at supply chain.

And so you could see here, we've got is raw materials. It can be whatever you want. It could be literally trees, paper. It can be rock. It can be metal, right? It's a raw material and it ends up being an input into a company or a process, okay?

And that company takes it in it transforms it and does something to it, and makes it a work in process. So here's an example if I were a company that was making carpet, okay? The raw material may be cotton, right, or yarn and the process that goes on here is that yarn is then taken it is woven on something to make the beginning of a carpet.

It's a working process at that point. Working processes is an item is not totally complete, okay? And so in my example here, the not complete part about the carpet now is it doesn't have any backing on the back of it to keep the carpet together. And let's say if it's commercial carpet and it's actually cut into squares, it's not been cut into squares yet.

I have a big wall right now and there's been no scotch guard put on the top of the carpet to help prevent stains and spills, right? It's literally just yarn that has been woven on some type of backing or material, okay? It's a work in process, right? So you got raw material working process.

And in some cases, you may have external parts that you buy from somebody else. Let's just say that the sticker that goes back on the back of a roll of carpet company buys from somebody else. So maybe process to what happens is that sticker gets put on the back, back and gets put on Scott's car.

It's put on and then out of that process, you have we'll call it finished goods. All right, it is in that case as well, the cuts square. So you have finished goods and then those can go off to maybe to various warehouses. Again, what I want you to get here is there's different types of inventory, right?

There's raw material inventory at the very beginning. There's work in process. There's components and then theirs the notion of finished goods. So why might a company want to keep inventory or keep stock, keep extra of raw material, work in process or finished goods, right, or let me put it in a different way.

Why does this matter in the context of supply chain? And so just some facts that I have up on here for you. All right And the biggie right out of the gate is inventory turns out to be one of a company's biggest assets. Meaning, it's one of things that companies have a lot of money invested in, right?

In the US, investment inventory is over $1.25 trillion according to the US Department of Commerce and it accounts for almost 25% of our gross national product. This is a lot tied up in inventory, right? So why do companies keep inventory? There has to be a benefit for it, right?

There's gonna be a reason companies do it, right? And at a high-level, right, the benefits of having inventory, so having finished goods already done, ready to go or having raw material already there ready to go. Is it provides for the company a hedge against uncertain demand? And in particular, where demand goes up unexpectedly?

If I get a big order all of a sudden and I have inventory finished goods, I can immediately fill that order. All right, it also, by the way, in terms of raw material, if you think about it, inventory can be a hedge against unsupported, sorry, uncertain supply. If I have suppliers whose lead times aren't exactly constant or I can always count on them to supply me, if I keep extra supply of my raw materials, if the order doesn't show up say on a given day, I can still continue to produce.

All right, you may have seen this. And this by the way, you probably seen your own life and a great way to look at inventory management is just to think about yourself and buying a food, right? So this third one here is benefit of inventories to economize. Ordering and a larger lots can give you a lower unit cost, and then fourth benefit is it can help with smoothing of production.

So while there's benefits to having inventory, there's also got to be in companies keep inventory. There's also got to be a reason why they don't keep unlimited amounts. There's got to be something on the other side that's limiting how much inventory a company would want to have and those would be the costs of having inventory, right?

Costs of having inventory puts pressure on companies to want to lower the amount of inventory and those costs include things such as holding costs, right? Those are cost to have a warehouse for of staff. You have to pay people to count what's in the warehouse. You have to for the warehouse, to cool the warehouse, right, to have someone patrol and make sure things don't go, taken from the ware house, have insurance.

So there's cost to holding and keeping inventory. There can also be obsolescence cost, right? You keep a lot of something, I'll give you an example. When I'm a student and by the way, this a long time ago, right, and I come to school at some place actually here and I buy a top of the line computer.

And this top of the line computer cost us $2,000 back in 1987, right? If I as a budding entrepreneur say, well, I think I can make a lot of money selling computers and I were to buy a whole warehouse full of $2,000 computers, right? How much would those computers be worth today?

And the answer is $0, right? Because that computer that I paid $2,000 for back in 1987, okay, had a 20-meg hard drive. Not gig, meg hard drive, okay? It didn't even have a Pentium chip yet, okay? And the point I'm trying to make here, right, is that if I thought I was gonna buy a whole bunch of those, and make a lot of money, right?

The rate of change of computers and processing power, and speed quickly makes the current model obsolete. So if I'm in an industry where product life cycles are short and the technology is changing rapidly, I run the risk that if I keep a lot of inventory, so that I can meet those orders that it can become obsolete.

All right, In a kind of similar way, if it's food or a perishable item that I'm talking about, you run the risk of spoils, right? And this will be the reason why grocery stores don't keep a huge stock of bananas. Why do they limit? What's gonna go bad if it doesn't sell?

So you wanna keep it down, right? Other costs of having inventory is if you have to rework, because something's wrong with it. You don't find out til you look at it. For three reasons, shrinkage. This is the notion that if you have a warehouse full of stuff over time, guess what happens to the quantity of that stuff?

It gets smaller magically gets smaller as employees take it home. It happens, right? It will shrink, right? And then of course, there's opportunity costs. If you put money down on inventory, that's money that your company is not using elsewhere and there's an opportunity costs associated with putting it on into inventory.

So here's the deal. At the end of the day when it comes to inventory management, you can boil it all down an inventory management policy is really about just two things. It's really it. Okay, when I wanna order more replenish my inventory, how much should I order? And when I need to order more, when should I order?

Those two things alone, how much to order when I order more and when to order constitute really a complete inventory management policy.

## Inventory Management (Part 2)

>> So welcome to our second lesson on inventory management. And here what I wanna do is again, I wanna answer the question of how much to order, and when to order in the context of an inventory policy. And as you're about to see how much to order, we're gonna use a classical theory called economic order quantity and then when to order, is gonna become from what we call the reorder point.

So when it comes to how much should we order in developing this notion or this concept called economic order quantity, I wanna first layout some variables and then also lay out some assumptions that go into this. Because this thing called economic order quantity does have several assumptions that go into it, okay?

And so what I've got here we'll have a retailer in the middle who gets something, a product, whatever it is from a supplier, and then on the right side you have demand for your product, okay? And so what we'll use is we're gonna use the variable D to denote demand.

And by the way, D is gonna be how many units people are buying per year. And when it comes to assumptions, then we're gonna use at this point and that can get relaxed later but the assumption we're gonna make right now is that the demand for this product is known constant, okay?

We also here are going to have something called an ordering cost, there will be a cost S for the retailer to get more of this item from the supplier, okay? And the supplier is able to replenish it totally given lead time, okay? We're gonna use the variable H to denote the annual holding costs.

So the cost to hold 1 item for 1 year. By the way, in many cases when you see holding costs, it's expressed as a percentage of the value or the cost of material, you can convert that from a percentage into $1 amount. And then the fourth thing we're gonna assume is that only ordering costs and holding costs or inventory costs and calling inventory but holding costs, these are the only two relevant costs, okay?

So if we make these assumptions and D, S and H for the variables that we're gonna define and look at here, right? I wanna go further and I'm gonna say, hey, if ordering cost and inventory were holding cost or the only cost that were relevant, then the total cost I incur for my inventory it's gonna be these two added together.

And then furthermore my ordering cost my total ordering cost for the whole year is gonna be that S value, cost per order times how many times the number of orders per year I make. That will give me totally ordering cost. And then my inventory cost would be, what's my holding cost per unit per year times the average amount of inventory I have.

So now what I'm drawing out here is this is gonna be a graph of time okay? Along the X axis we have time and along the Y axis is gonna be a quantity amount and the idea here is gonna be right that get the start our inventory is right here our inventory levels Q.

And because demand is known and constant, as time passes this way, right? Because demand is known and cost of the quantity of a product we have goes down in a linear fashion and their line here is much better than my blue line, okay? And ideally what we would do is once we got down to where there was no inventory left, we would place an order, that would replenish us back up to here and we would place an order for Q more from our supplier.

And then the same thing happens again, okay? And it goes down literally, right? Because demand is constant, and when we got to zero we placed an order for more, we replenish it back up to Q, and repeat, okay? All right, so these triangles represent the inventory, right? The average inventory for each period, all right?

And so you can do some simple math that average inventory I would just tell you is gonna be Q/2. Over the course of the year, if you're ordering in an amount of Q, whatever Q is, and demand is now under constant and you're ordering such that right when you get to zero you get a replacement order to bring you back up to Q, right?

Over the course of the year this writing here is gonna be the amount of inventory you have overall is half of Q, is what it is. Half of Q which is Q / 2, okay? So keep that in mind, our average inventory is Q / 2. We're gonna use that here in a second, and we're gonna use it right here, right?

Because we said, hey, inventory cost is gonna be our average inventory, which we just came up to say is Q / 2, times holding cost, which is, right? Cost a whole one item per one year, that will give us the total. And then taking the ordering cost now come back up here ordering cost right?

Number of orders per year, if demand per year is D, total demand is D and I divide by how big my order size is, right? So if demand is a hundred per year and my Q, the amount that I will reach time I place an order is 5, right?

100/5, then I'm going to make 20 orders per year, right? 100 divided by 5 is 20. Number of orders per year, and if I multiply that right? Number of orders I make over the course of a year times the cost to make one order, I will get the total ordering cost, okay?

So you see what we're doing here, we're taking these words and then translating them into equations. All right, now if I take that holding cost that we just defined, right? Which was Q / 2 times S and I were to plot it, you get that if Q is 0, if my size of order is 0, I'd have no holding cost.

As I began to order larger and larger amounts each time, my overall holding cost goes up and it goes up literally, okay? The ordering cost, right? So this was Q / 2 times H, the order and costs we defined is D / Q times S, and it looks like this red line.

If I order each time a small amount, I'm gonna have a lot of orders and my total ordering cost is gonna be real high. But as I began to order larger amounts, the number of orders I make is less and my total ordering costs, gets less. But this graph is not linear, all right?

It's curved, and then if I take total cost, which by the way, total cost = holding cost + ordering costs. I get this other curve right here, total cost, right? And remember what I said in inventory management, we're trying to minimise costs. So an inventory man is trying to minimise total costs.

Well, where's the total cost graph a minimum? It turns out it's right there. That's where total cost is a minimum. And it turns out if I, kind of, drop that down it turns out it, kind of, ends up being, where holding costs = ordering costs. So now if I set ordering costs right here, equal to holding costs and I'll spare you the math but if I rearrange this so that I get Q on the left side, right?

So if I can get Q only under on the side by myself and I get everything else to the right, I will get this equation right here. Q = the square root of 2SD / H, okay? And I'm gonna call that Q\*. And the reason I'm gonna call it Q\* is because that's the quantity where ordering cost equals holding cost.

Was for from the prior graph that I just showed you, that’s the quantity that gives you the minimum total cost. And so we’re gonna call this EOQ, economic order quantity, right? That by the way is basically saying when you are going to order more, here’s how much it should be.

Here’s the quantity a replenishment order should be that is gonna balance the cost of ordering, cost that you incur, with the cost you have to hold inventory. This is gonna give you the how much, okay? That's the first part of our inventory policy. The second part of our inventory policy is, when we should order more right?

And because we're talking supply chain here, right? Supply chain folks love to talk in terms of quantity not time right? Most people say kind of denotes time to me. Here, when is going to meet at what quantity level do we wanna get more? And so if we go back to before we're drawing hey, we call this Q here before we said demand is known and constant and it's going down.

The ideas optimally when we run out of material we would like to order more to bring us back up, okay? In reality, we know when we order from a supplier, there is a lead time, it could be three days, could be five days, whatever is. But the idea is optimally we would like to place the order in time, we would like to place the order here, knowing that if that's two days and when we hit two days we'll be down here, right?

So what we're doing here is translating lead time into trying to figure out what would be a quantity level. Which by the way we're gonna end up calling it reorder point, right? Reorder point is a quantity level. If we know what this lead time is here we're gonna define lead time as L, and we're gonna also define lead time in terms of number of days, and if we know, what the average daily demand is for our product.

That daily demand, by the way becomes the slope, it turns out, it's the slope here, right? If you multiply the slope times as lead time, it will give us this reorder point right here, right? So reorder point is average daily demand times lead time. This is when we should order more.

So if we put these two together, right? Really what we have is an inventory policy now, this EOQ tells us how much to order. If our goal is to minimize total cost, this tells us how much to order and reorder point tells us when to order more, right?

And so the idea would be with something like this, let's say again, you're a retailer and you're stocking I don't know what it is as hammers, okay? And you wanna know and you wanna try to balance the cost of having inventory of hammers in your store versus the cost order more of them, right?

The idea here is you're gonna monitor how many you have in the store and when the inventory drops down to the real point you place an order for how much for Q\*, EOQ more. Now also what I'd like you to do is, I would like you to pause here for a second and take out a blank sheet of paper cuz the best way to learn things is to practice them, right?

And in the next lesson we will practice, right? In order to practice you're gonna need these two equations. So what I want you to do is pause for a second, get a blank sheet of paper and write these two formulas down on the paper, and then go ahead and continue All right, so now, while we have some equations to determine how much to order and when to order, and give us an inventory policy, I wanna make sure you don't lose sight of how we got there, right?

We made some pretty big assumptions, right? For starters, we said that demand was known and constant. So I'm gonna challenge you to find a product where demand is known and constant, right? We said replenishment was immediate or at least known and constant, that's not always the case, right?

The only two relevant costs were ordering cost and holding costs, right? Again, those are necessarily the only relevant costs. And so now you may be going okay, why do we talk about this then, if these assumptions aren't real? And the answer is because this makes a good starting point for a more rational inventory policy.

In the next lesson we'll apply these equations.

## Inventory Management Example Problem

>> So for our final look here in inventory management, I wanna give us a sample problem to kind of put this into context, and then see how it could be used. How our inventory policy, how much, and when could be used. So our learning objective will simply be to use those two metrics to determine how much to order, and when to place an order for more.

So at Georgia Tech, our mascot is named Buzz, right? And one of the things most people don't know about Buzz is that he actually owns a used car lot called Buzzlot. Yeah, I am making this up, but here it is. And here's some information about Buzzlot, all right, that's gonna be used in coming up with an inventory policy for Buzz, all right?

Buzzlot, right, sold 5,000 cars last year, right? And when they go to Auto Auctions, cuz used cars, turns out the way that they get most of the used cars is from Auto Auctions. When they go to an Auto Auction, it'll take them 10 days to get new cars from the auction to the car lot.

It costs Buzz $15,000 per shipment of cars that go from the auction site to his car lot. And Buzz over time has determined that the cost to hold one car per year on his lot is $500. So what I'd like you to do is to take out that sheet of paper from the last lesson that you wrote, where I asked you to write the formulas on it, all right, and prepare to pause this lesson, okay?

And so it may help to go back to the prior slide if you need to, to get the information that was written there, that was presented about Buzzlot, in terms of how many cars, etc. And I want you to use that information to create an inventory policy for Buzz.

And then when you have an answer to when it goes to auction, how many cars you buy? Right, sorry, when should he go to the auction and buy more cars? And then the second question when he goes, how many used cars should he purchase each time he goes to the auction?

When you have an answer for that, then you can proceed, right? Again, to me, practice is a great teacher, so don't cheat on this. Don't just continue on, pause it, go back, try to make a valid attempt to solve this problem first, and then continue on, okay? So go ahead and pause now.

All right, so I hope you were able to generate an inventory policy for Buzz, right? So to go over the solution, I'm gonna go ahead and start with the determining of when to go to the auction to buy more cars, right, to determine the reorder point. And so for that, I need average daily demand, and I need the lead time.

And in the problem statement, right, or the information, it says that it takes 10 days to get cars from the auto auction to Buzz's used car lot. So our lead time here is 10 days. Now what's not given that you have to determine is what is the average daily demand?

In this problem, we were given that the annual demand is 5,000 cars per year. And also, if you all know noticed, on the bottom of the products lot, I said assume 365 days per year. So if we take 5,000 cars per year, and divide it by 365 days in the year, we will get on average 13.69, which will round up to 14.

There's no 0.69 of cars, so we'll round that up to 14 cars per day. Average daily demand is 14, lead time is 10 days. If we multiply those together, we get a reorder point of 140 cars. So again, what this is saying is when we get down to having 140 cars left on the car lot, it was a lot.

We need to go that day to the Auto Auction, and we need to order more. So let's determine the more, right? And the more is gonna come from a determinant from calculating EOQ, or what we're calling Q star. And here, again, going back to the information we were given, right, in the problem statement, our setup cost, or cost to ship cars is $15,000 per shipment.

That's our cost to place an order, right? Annual demand, 5,000 per year, and we were told it cost $500 per car per year to hold it on the lot. Literally, put those three values into the equation for Q star, EOQ, you will get 547.72, which will round up to 58 cars.

All right, so now with these two, we have a recommended inventory management policy to give to Buzz for his used car lot, Buzzlot, all right? And that policy says hey, this is real simple, if you wanna minimize total inventory costs, right, keep track of how many cars you have on your lot.

When you get down to 140 left, go out that day to the Auto Auction and buy 548 cars more. And then come back to the car lot and keep selling, and when you get down to 140, go back and buy 548 more, okay? If you do that Buzz, you are going to balance the cost of ordering more cars, right?

And that $15,000 charge with the cost to hold these cars on the lot at a cost of $500 per year, right? This will give you the lowest total cost solution. So this concludes our brief lessons on inventory management. And again, keep in mind, we made a lot of assumption, okay, many of which can be relaxed by adding some complexity to the equations.

So for example, it is possible to look at what do you do when, right, when lead time varies? Or what do you do, more specifically, what do you do? How can you handle when demand varies, okay? And those will be for another time in a more detailed course.