The Future of Manufacturing Business:
Role of Additive Manufacturing
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Lecture-04
Mass production to Mass Customization

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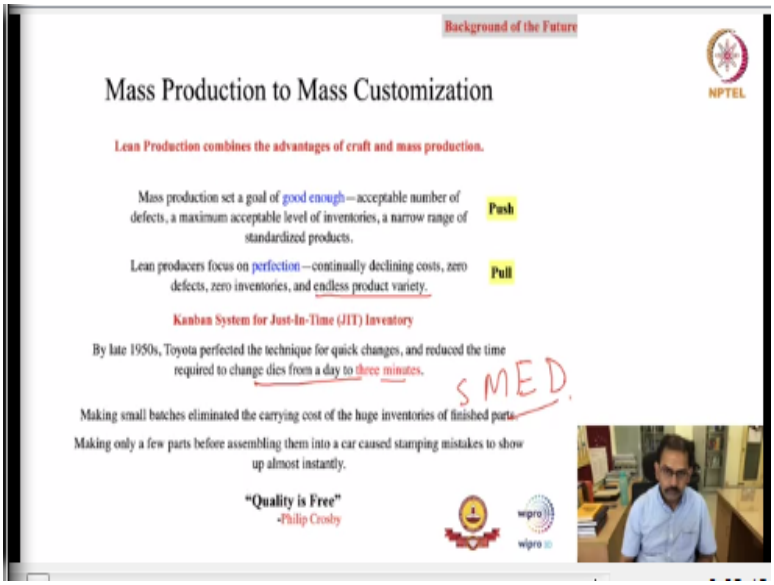

Welcome back to session number 4. In the previous session we closed with some ideas about lean production. Lean production combines the advantages of craft and mass production. Mass production we define that the set a goal of just good enough acceptable number of defects and maximum acceptable level of inventories, and narrow range of standardized products.

Compared to in the lean production we are looking for more perfection, zero defects, zero inventories and endless product variety. When we talk about endless product variety that is where we are looking for mass customization. One of the main ideas is to reduce the setup time. We reduce it from say a day to 3 minutes. I will relate when we talk about the Little's law that what are the advantages of reducing the set of time. One advantage which explicitly comes in is you can actually want to produce more variety but now the batches are much smaller. In fact if you recall we talked about that single minute exchange of dye. It means that you are still not to a continuous production but you actually are closer to it.

You keep on changing the dyes and you keep on bringing more and more variety. When we talk about small batches, in fact I will show you as I mentioned that it will reduce the amount of inventory. With this I will go to the next one.

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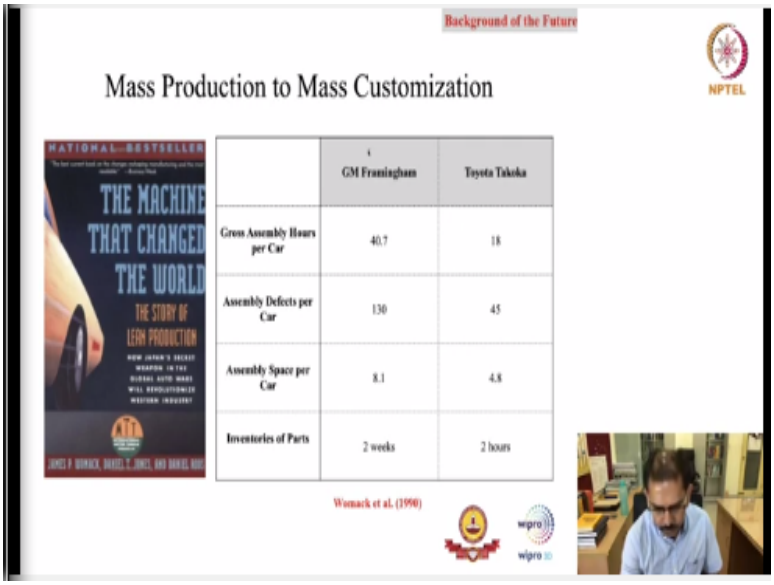
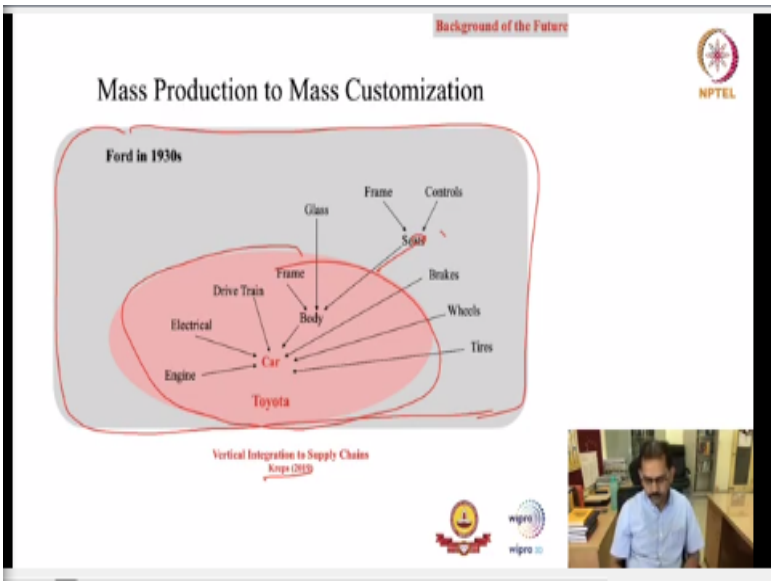


If you look at these numbers, so these numbers are for 2 different plants. I have taken it from this book Womack, the title is "The machine that changed the world". It is an extremely good description of or maybe a comparison of the lean or the mass customization to mass production systems. We sometimes call it the food production system or a Toyota production system.

It compares both of them and you can see the number. You look at these inventory numbers. It says 2 weeks; it is just 2 hours, so these numbers were significantly lower in the Toyota's case. If you look at it the plant the numbers are much smaller compared to what you see at the GM plant. This gives you some idea about what are the benefits of reducing the inventory.

It is not about zero inventory, I think the idea should be I need the right amount of inventory in my system and my process should be synchronized in such a manner that inventory should always be available. **(Refer Slide Time: 03:25)**



When we go from mass production to mass customization, something also changed is the organization architecture or the structure. If you see this, so this outer boundary the grey boundary is actually for a Ford setting in 1930s. It means that the organization was heavily vertically integrated. So, it means that they were virtually producing each and everything.

You can see the tires would the produced by Ford itself, the seats everything and if you take it to a typical Toyota plant, some of these things they still do make but some of these things are getting outsourced. I have taken it this from book by David Kreps. It talks about vertical integration to supply chains. So, you start seeing the emergence of supply chains in the automotive industry when some of these things are getting outsourced.

The main idea here is that when we talk about the vertical integration, in fact this problem is not new. This may start in 1930s.

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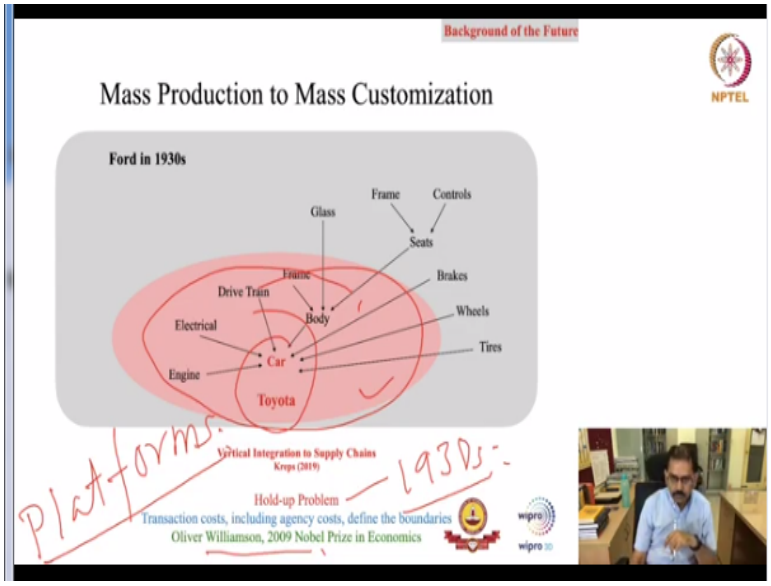

The academic research is started in 1930s. That is why some of these companies are vertically integrated. The concept which comes out is the transaction cost and which includes the agency cost. When I say agency cost it is the cost of maintaining a supplier. I should ensure that the supplier is doing, what is actually in my benefit.

This becomes a problem of incentive alignment. All these costs are agency cost. Let me emphasize that maybe in 1930s the technology was not available to put a proper monitoring at the supplier end. Therefore, supplier may do what is in their benefit compared to the benefits of the supply chain or the OEMs. As the technology improves, you can see that these transaction cost

(I can call it the cost of monitoring someone) comes down. So, with the more advent of communication networks, communication systems observability and verifiability. I will define what they mean. Oliver Williamson shared the Nobel prize for defining or distinguishing different architectures of organizations.

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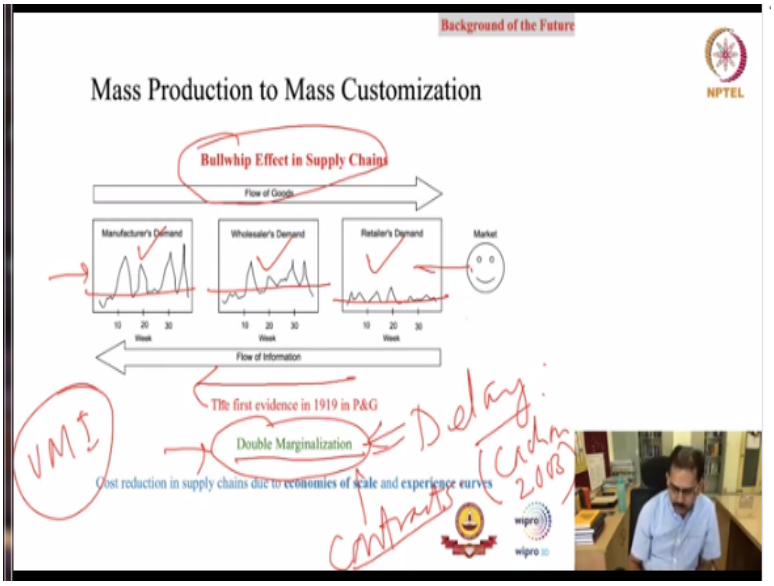


One of the classical examples of incentive misalignment comes in the form of a law of nature which in supply chains we call is the bullwhip effect. The word comes because if you might have seen the bullwhip, so a small variation, a small fluctuation in my hand the other end of the whip the fluctuation may be very high. You can see that in this case there are 3 agents in a supply chain there is a manufacturer, there is a wholesaler, there is a retailer and the retailer is closer to the market you can see that.

Now what happens is, the retailer gets better information about the demand from the market because being closer to the market then that information flows in the upstream direction. The retailer gets that information that information goes to the wholesaler and then wholesaler gives that information to the manufacturer.

Now, something evident from this figure is that here the fluctuations maybe ok but the fluctuations are getting inflated as you go upstream in the supply chain. So, this is something which has been observed in multiple supply chain settings. The fluctuation or the variability as you go upstream in the supply chain that keeps on increasing.

The first evidence maybe the first documented evidence came from Procter & Gamble in 1919. It is maybe more than 100 year old problem and the reasons could be multiple. In fact one reason could be the delay of pass of that information. The retailer may get that information but by the

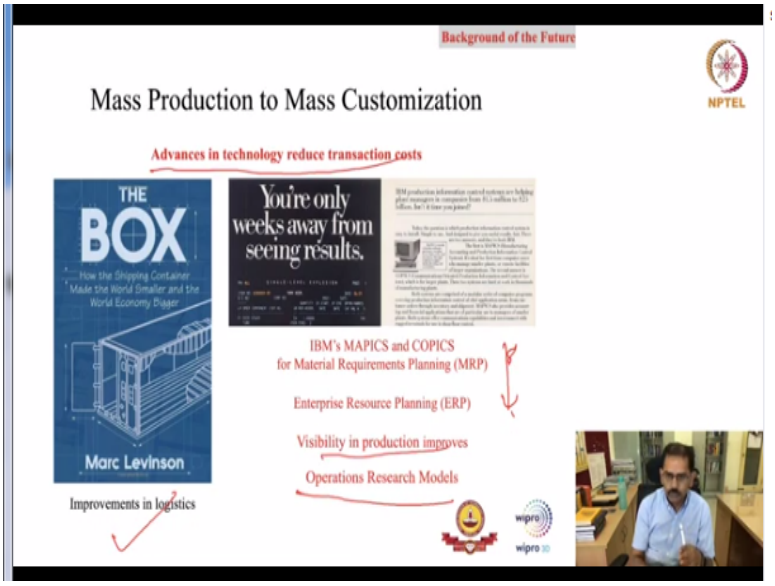
time the information actually reaches upstream, the production planning everything has been done at the wholesaler demand.

It means that there is some kind of asynchronous production and the demand. So, that will create some kind of fluctuations but that is not enough, I think one of the critical things which could be is in the form of because these are all firms and they look for their benefit or profit. They optimize for their benefit. If it is in the favor of the retailer to inflate the demand, they will do that.

It will be rational for them to do that. This brings an idea in supply chains what we call as double marginalization which means that two forms when they look for their benefit, individually they gain but collectively they lose. So, this brings the problem of what we call as a supply chain miscoordination or uncoordination. It means that the retailer will be looking for his or her benefit.

Wholesaler will also be doing the same thing but collectively they lose. So, lot of the literature on supply chain contracting would be how you mitigate this problem of double marginalization. There would be a substantial literature on how you overcome this. Technology could be one enabler which actually can reduce the impact of the bullwhip.

I will talk about it but just to give you an idea that there is a possibility of say vendor managed inventory. In this case the wholesaler will have better information about what is happening in the market. **(Refer Slide Time: 10:24)**



If you see some of the ERP systems, they will actually be doing the same thing. So, for time being I think I will not spend too much time on this but the point here is that this how to mitigate this in double marginalization. In fact most of the supply chain contracting literature would talk about that. If you want a reference for it, you can actually see a paper by Cachon (10:52) published in 2003 on supply chain contracts.

Now, what is the advantage of outsourcing something? The first thing is when we look at a setting like this the Ford system you can easily see that they need expertise in virtually everything whatever goes into an automobile. They should be experts in seats, they should be experts in brakes, they should be experts in wheels, and they should be expert in tires. All these things should be available all that knowledge should be available within the form.

Now as the complexity of a product keeps on increasing, getting that expertise will not be that easy. What it means is that when you outsource something, there should be some benefits which comes in. That could be in the form of expertise availability. Other point which may be more explicit is the cost reduction in supply chains due to economies of scale and experience curves.

It means that when I am outsourcing something, I may not be the only person who is outsourcing. There would be maybe other firms also doing the same thing. Like there is a possibility that the same supplier will actually be providing the things to Ford as well as to

Toyota. So, you can actually see large volumes coming at the supplier and you already have seen the benefits of the increase in scales.

So, economies of scale come into the picture and what it will do, it will actually improve the cost. It will in fact reduce the cost and when I will say it will improve it will reduce the cost. The other thing which comes more again explicitly is the experience curve because the supplier would be doing the same thing again and again; the cost keeps on decreasing rates. The cost benefit comes when we outsource something.

The point here is we have to actually compare whether the transaction cost of outsourcing is higher than the cost reduction which comes because of this. If I can monitor my supplier well, in that case the cost reduction which comes because of economies of scale and experience curve, those things will actually dominate the transaction cost.

You would see more and more things getting outsourced. I think you are getting the sense of it and the sense comes in the form of that advances in technology reduce the transaction cost. There would be a lot of things which may have happened post 1950s. You can see the emergence of MRP and ERP systems.

If you see a typical operations management or supply chain course you would find these concepts. But the point here is they allow us to reduce the transaction cost of getting it from the supplier. One other thing which comes is the significant reduction in the logistic cost. This book by Mark Levinson talks about how the shipping container actually, so the some people claim that shipping container itself was a big innovation in the past 50 years.

The shipping container improved the trade and reduces the transaction cost and made the world say smaller and the world economy bigger. The transaction cost comes down, you can trade maybe far distances. Supply chains start becoming more and more globally distributed. So, even when these systems like MRP or ERP is there the visibility in the production improve. We will talk about that.

Lot of operations research model comes in which is start allowing us to optimize just not maybe an organizational level maybe at the supply chain level. Lot of these things has significantly reduced the transaction cost and you start seeing the emergence of organizations maybe in this form. But the key question is what next? Can we improve this further?

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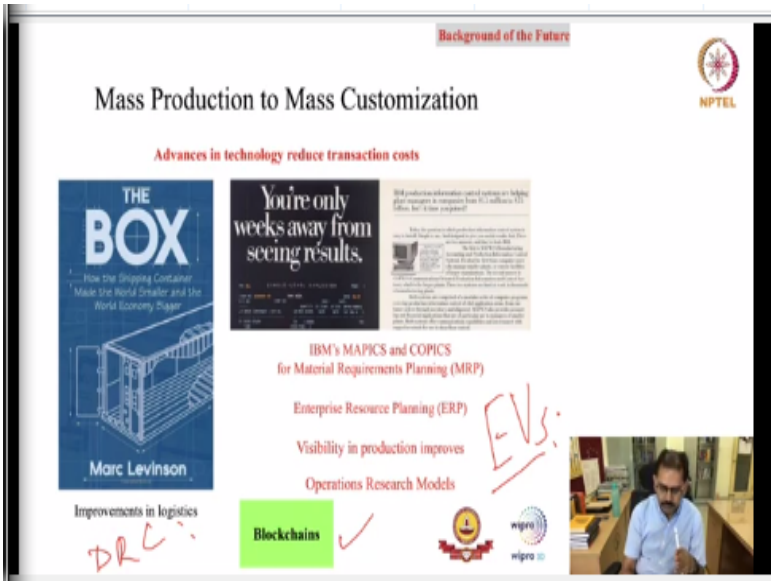

One thing which could come is when I talked about the visibility; you can think of a typical supply chain. I give you an example. There is a lot of emphasis on the electric vehicles these days. Significant amount of cobalt is used in the production of lithium ion batteries. So, battery maybe the lithium ion that is something which is the dominant chemistry for these electric vehicles and a significant amount of cobalt goes into them.

Most of the cobalt comes from the Democratic republic of Congo and the supply chains are highly opaque. So, there is a lot of debate, how we ensure that these supply chains are using the ethical sources. We want to ensure that there is no child labor involved in these cobalt mining. Now to ensure that thing, so as of now I think the visibility is not much, the supply chains are highly opaque.

Can we use technology to actually improve the visibility? At that point I think we are pointing towards something like the technology of block chains. I will talk about that. I think we will have ample discussion on block chains. But the point here is, can block chain improve the visibility

and reduce this transaction cost? So, when I say visibility, I am looking at can I observe what is actually happening at the supplier end. I extend this argument further.

These days we talk a lot of things about the internet of things. We are going to talk about significantly again in this course. When we talk about internet of things, many things will be based on the sensor. You would have an embedded sensor. Now, whether that will improve the visibility? The point here is, can this technology or maybe the emerging technology or maybe disruptive technology will it improve the transaction cost.

So, in which direction we are heading? My emphasis would still be on that I am moving towards from mass production to mass customization. The organization architecture is changing and you can see that we are moving from say fast, cheap, and better. So, I think there is lot of emphasis on quality also comes in but at the same time we are also looking at diversity.

We are moving in the right direction. If you recall I mentioned about the quality part. We have faster, we have cheaper, we have better and we have diverse also. But the question is always they are can we improve, can we do better. Will there be a possibility of going for mass personalization? I can produce something specific to that customer. So, instead of saying that I produce say Toyota car and 3 or 4 variants, I can customize it to the customer requirement. Is it possible to go to that extent?

Moreover, I may be looking for an organization which is not even integrated vertical integrated to this extent. I maybe looking just this. So, whatever I need should come maybe from outside but can we extend that argument that whenever I demand something, it becomes available. We are going to talk about the platforms.

I think that is where when we talk about, can we redesign our supply chains. So, instead of talking about supply chain, in fact I am now using maybe a word called platforms. I think there is an HBR (20:25) paper will briefly talk about as we go further into the course; the title itself is pipelines to platforms. From supply chains to platforms. The whole organization architecture or significantly maybe for manufacturing should completely move from the pipeline structure to

platforms and what enables that is the technology like block chain, the technology like the additive manufacturing, the technology like machine intelligence, and the technology like IoT. What the point here is that we are looking for more and more visibility, more and more tracing. If I can ensure what is actually happening upstream or downstream, the things will be much more transparent and you will actually see an emergence of a different manufacturing architecture altogether.

I am not talking about the product architecture, I am talking about the organization architecture. So, I think this is fine.

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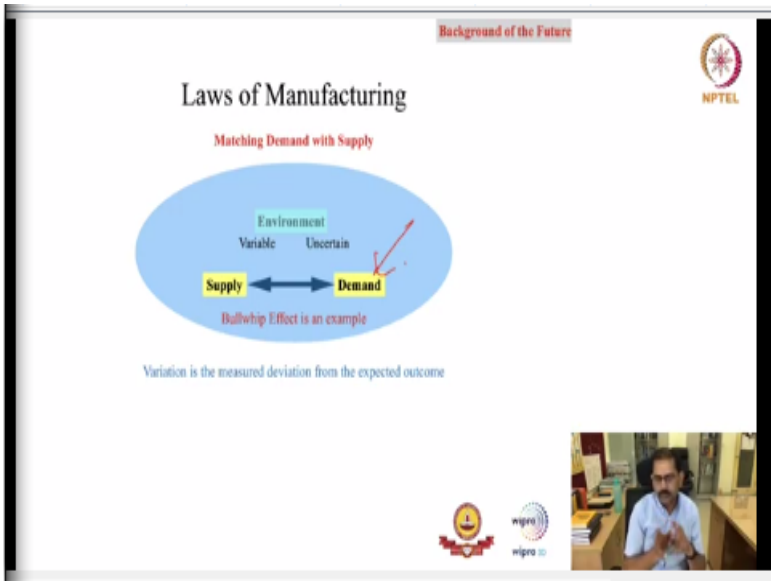

Let me now start talking about the different laws of manufacturing. The fundamental thing, when we talk about any manufacturing organization, there would, so at the core, we always want to match the supply with demand. Independent of whether it is a typical survey or in manufacturing, there will always be some kind of what we call uncertainty or variability on the supply side. There will always be uncertainty or variability on the demand side, and we will want to match that supply with demand, and you want to do it in an environment. In this case, the environment could be the business environment, it could be the national environment or it could be anything. We think of the COVID scenario, something which comes abruptly. Now what I want is I want to match that available supply with demand.

You can think of the demand for ventilators. Suddenly that thing has come and there would be ample supply constraints. You cannot get it from outside India; you have to do some local sourcing. But whatever available, you want to match it with the demand for the ventilators. In this kind of environment, you will always see a lot of variability and uncertainty.

So, when I say variability, it means that the environment will not remain constant. It varies with time and that variation is unpredictable. I cannot put a function to it. Even if I put a function, it will come with a lot of errors. So, there will always be some uncertainty and variability; within that kind of an environment setting, I want to match the supply with demand.

The bullwhip effect what we have seen earlier could be an example for it. You can see that, there is so much of variability there and that variability is increasing as we go upstream. Let me make it more precise that I want to match demand with supply in an uncertain and variable environment and let us say that variability and uncertainty is more of a rule rather than exception.

Now this becomes in fact in operations management this is the objective. I want to match demand with supply. How we define variation? Variation is the major deviation from the expected outcome. You expect some outcome and so that could be true even for demand. I expect my demand to be high but it turns out to be low and that which I can measure. Variation is the major deviation from the expected outcome.

Now the interplays always that I cannot remove this variation, I cannot remove this uncertainty. Maybe I can reduce it, I will talk about that. But the point is, given this variability and uncertainty in the environment, how should I change my supply strategy? How should I look at the demand? How I do this matching? Demand is more or less exogenous. You cannot control much on the demand side but there is a possibility that you can always reduce the variability of the demand. We will talk about that. But you believe me that these things will not be static at all. They will always be so much of variability and uncertainty.

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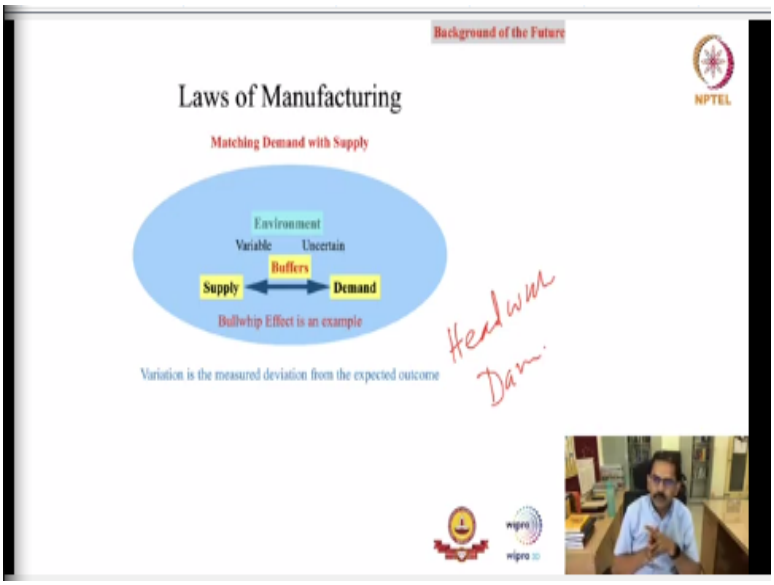

Now what actually matches this, is this notion of what we call as buffers. I give you an analogy from a typical civil engineering setting. We sometimes called maybe a headwork or a barrage or a dam. If you talk about maybe a runoff which comes during the rainy season the monsoon. It comes for a very short period but the demand of say water downstream will always be. There would be variation there also.

That will be more or less constant in a year but the supply is highly variable and it comes only for a very short period of time. So, what we do, we normally need some kind of a buffer which actually becomes like a control structure in the form of headwork or a dam which stores the water and which can be released maybe continuously to meet the demand maybe for round the year.

Now what we are doing in this case, we are talking about maybe a highly uncertain variable environment. But the objective is still how you actually match the supply with demand and what is needed is some kind of a buffer.

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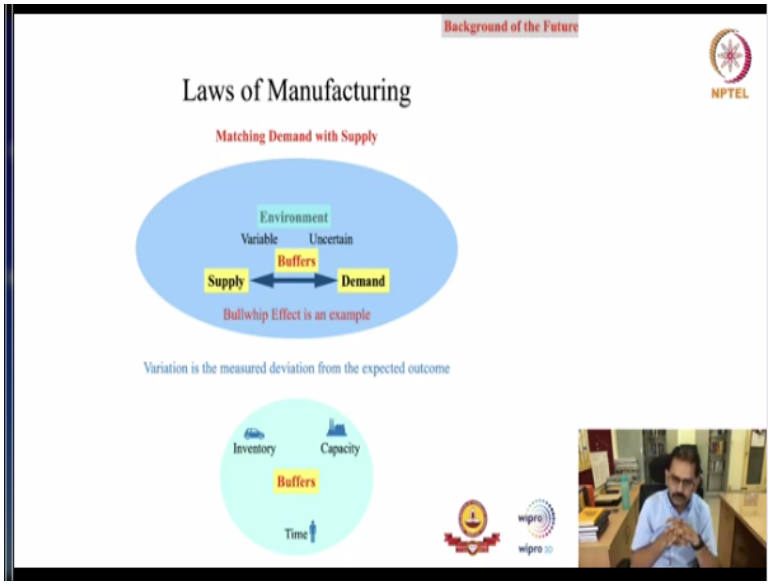

When we look at a typical manufacturing setting, we see three kinds of buffer. One is the inventory buffer; the second one is the capacity buffer and the third is the time buffer. The point is, these buffers are not cheap. They are expensive. The inventory is costly, the capacity is costly and even the time is costly. In the next session, I will continue with this idea of buffers.

I will conclude these laws of manufacturing and the role these buffers play in matching these demand and supply in a typical manufacturing setting. Thank you.