The Future of Manufacturing Business: Role of Additive Manufacturing

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Lecture – 12
Technology and Manufacturing

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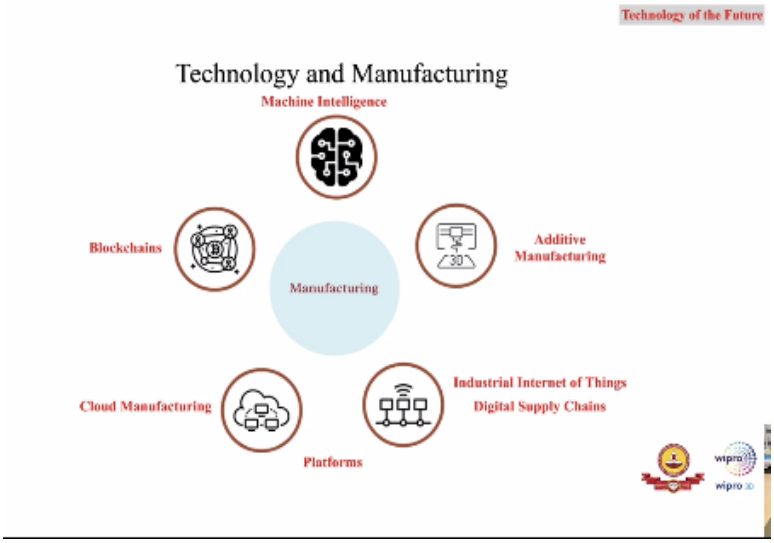

Welcome back. You would have attended lectures by Mr. Murali on the manufacturing radar as well as agile manufacturing. So, with this background I will start the discussion on the technology of the future and we are looking at technology and manufacturing and the slide, you might have seen earlier also where we are putting five core technologies, which is IoT, additive manufacturing, machine intelligence, blockchains and cloud manufacturing.

These technologies, so when we talk about the future these technologies may integrate at the platform level. So, with this background, I will continue my discussion on technology and manufacturing.

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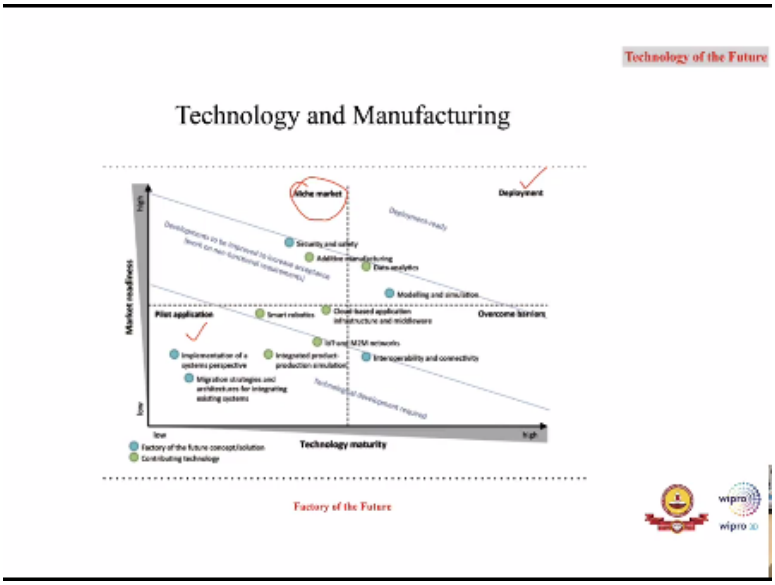

This particular slide I have taken from a report called factory of the future, which actually if you look at the y axis that is the market readiness and if you look at the x axis is the technology maturity. Then, if you look at the blue dots, they are called a factory of the future concept and the green ones are contributing technology. So, if it is market ready as well as the technology is mature, we can actually put for deployment.

If you look at the technology maturity is low as well as the market readiness is low, we are calling it they are still at the pilot level. Now if you just look at so this is something which is relevant for the factory of the future, how these technologies actually integrate. Now if you look at an example of additive manufacturing, technology is still not very mature as per this particular figure.

But it falls into the market readiness part. So, it actually comes under something called as the niche market. Data analytics is ready for deployment. So, modeling and simulation because these technologies have sufficiently matured and they are ready for their market readiness is also high. They are ready for deployment. So, deployment ready.

The whole idea here is that additive manufacturing still needs more maturity at the technology level to go for the deployment. But let me just revisit this point that what we are seeing now you might have seen in the business model example also that these

technologies are now getting converged. So, there is some convergence in these technologies.

What we observe is maybe the exponential adoption, if they bring positive externality to each other, and that can happen at the platforms level. So, this background gives you an idea what is happening in this area.

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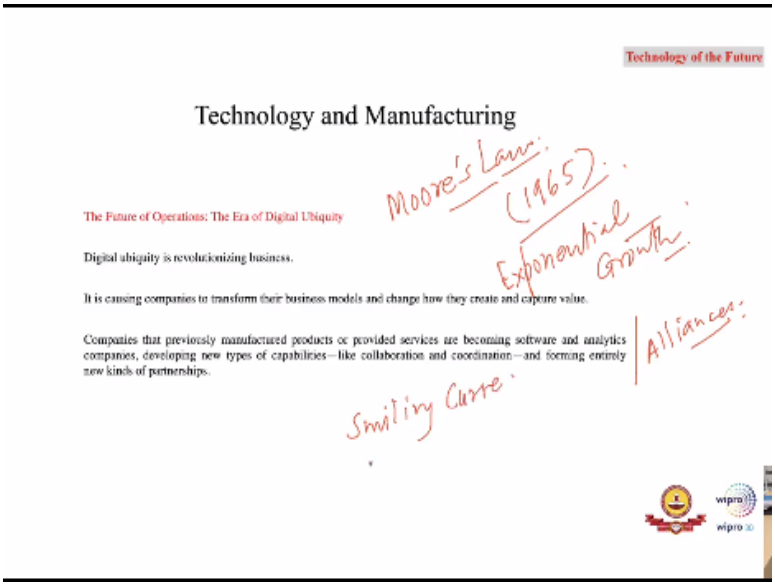

But the future of operations is something which will be more digital and I think if you are aware of the Moore's Law, I hope it would have come earlier. So, when we talk about the Moore's law, the Moore's law says that so it was given in 1965. When we look at platforms, we may revisit this law again. So, Moore's law is mainly about the computing power.

If I recall correctly, it says that every 18 months, the size of the integrated circuit would keep on shrinking and the computing power may keep on doubling and more or less this law has been followed from that time till today. There may always be some, I think, it has reached to this limit, but for till this point, it was followed.

So, what it actually says is that if you put your processes on the digital curve, the curve will so your process start following the Moore's law. So, what it means that you can see exponential growth and I think that is the advantage which comes with the digitization, because if you just think of digitization, like you can think of a typical example like a print copy of a book.

So, even now the print copies are available, but to replicate a print copy, you need lot of infrastructure. It may be expensive also. It is not free. But when we talk about the digital thing, you can easily replicate that. So, you can actually create value at a lower cost, and I think that is where the business models around the whole digitization is actually changing.

So, this is the second line, it is causing companies to transform their business models and change how they create and capture the value. The companies that previously manufacture products or provided services are becoming software analytics companies developing new capabilities like collaboration, coordination and forming entirely new kinds of partnership. So, I can call it alliances and that may be true for manufacturing also.

So, you may be aware of that, if you recall, we discussed about the smiling curve. So, when we talk about the smiling curve, the main idea that the main value is generated in the sales and maybe the after sales. Manufacturing is not generating much value, right at least for commodity kind of goods. In that case we are moving to an area where you actually can create the value maybe by the usage and you monetize that value.

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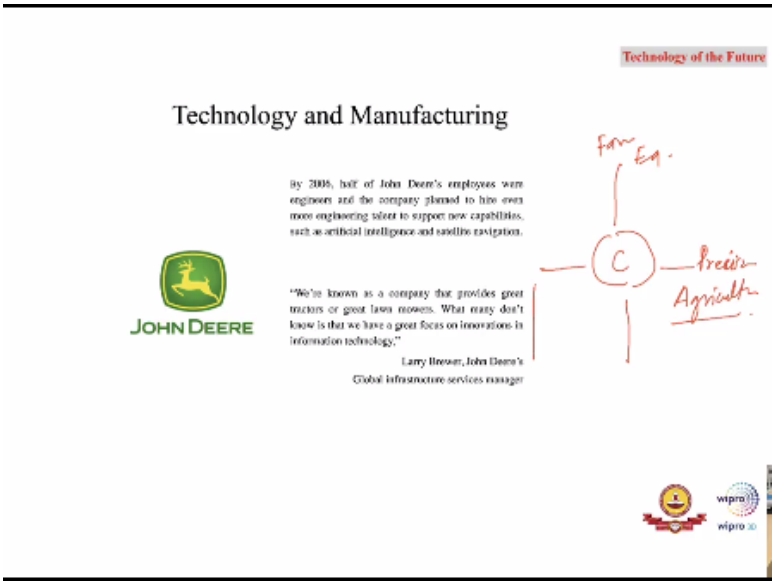

I will give you an example maybe a company like John Deere. So, this point is very critical. That a traditional maybe agricultural equipment company, like they were

manufacturing tractors, they are actually moving in a different direction altogether. It means that you keep maybe the company at the center. Now you are actually saying that we have farm equipment.

We also provide support for precision agriculture and there would be lot of other things. It means that the farm equipment which was the core area of value generation, that is now maybe at the periphery.They are hiring engineering talent for AI and satellite navigation. So, I can give you an example like when we talk about say precision agriculture, if you are not aware.

This concept is not new means even when I was doing my undergraduate, these things were discussed. So, precision agriculture, if I just look at the core thing you can actually sense what is the moisture content in the soil. So, whether it is actually done maybe through the remote sensing satellites, whether it is done through some handheld sensors, whether it is actually inbuilt into a farm equipment, whether it is actually inbuilt into a tractor.

But you actually get a sense of what is the soil condition, whether in terms of water, whether in terms of the minerals, and then you actually provide those things. So maybe in the real time. Even that process can be automated. So, this is something where they see more value generation for even it actually can integrate with the weather forecasting like not a short-term forecasting, it could a long duration forecasting.

It would actually tell like, what should be the moisture or water irrigation requirement. The point here is that you are actually generating more value by providing the services rather than actually selling the product. So, you can actually see that a company which was traditionally making tractors is now becoming a more of a service-oriented company.

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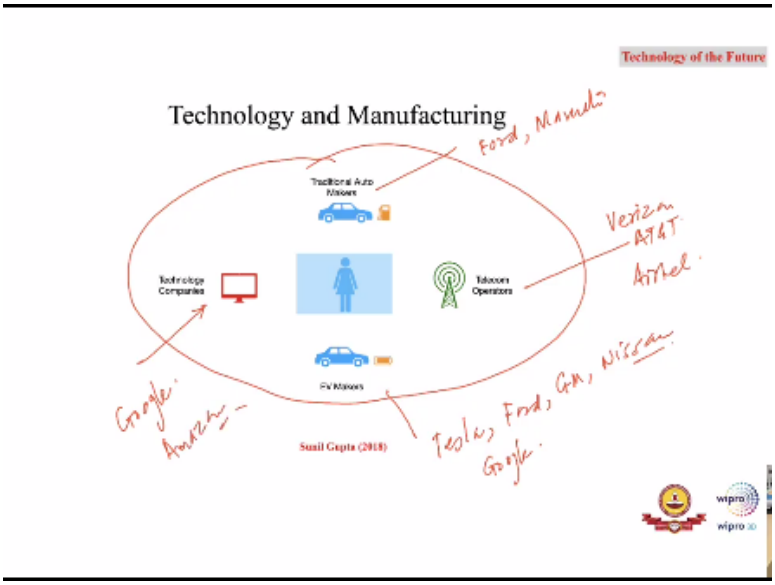

There is a recent book by a Stanford professor Sunil Gupta. The title is, Driving Digital Strategy. I have taken this particular so this is adapted from there. You can actually see if you recall, we talked about the marketing myopia where the we talked about that the consumers worry about the usages rather than the products, how we actually use it.

The same thing is happening here. You can actually see customer comes at the center and now there is a whole automotive ecosystem. So, there could be traditional automakers like Ford, maybe Maruti. You have telecom operators like Verizon or AT&T or even Airtel. So, they come into the picture as so you can actually see connected vehicles.

That is where this telecom operators comes into the picture. You have lot of EV manufacturers also. Tesla could be one. In fact, some of these companies could be the traditional OEMs. Automotive OEMs could be EV makers also. May be you can think of GM or Nissan Leaf. There will be so many products like this and then you have technology companies.

I can put Google there. So even Google could be an example for this, not EV manufacture, maybe for autonomous vehicles. The whole ecosystem of the automotive automobile is actually drastically changing. The customer is at the center and you are not just talking about car now. You are actually talking about lot of peripheral things also.

Traditionally in fact, I was attending one seminar by from Mercedes person and I think he mentioned that they perceive that the main competition does not come actually from, the competition will still be there, but the competition will actually be from companies like Amazon and Google. Even I think I can put Amazon here. So, I hope you are getting the sense of in which direction the manufacturing is heading to.

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I give you a very related examples of I can actually put everything in a bracket of servitization. Two more examples, which may be related. Phillips is we know for the lighting equipment the lighting solutions. So, if you go to the Schiphol Airport at in Amsterdam, they are actually putting a model called light as a service. You actually pay for the usage not customer, the airport authorities have to pay for the usage rather.

This is actually so everything is taken care by Philips. The same example or not the same maybe a similar example is for compressed air on demand. You can actually see this and they have come up with a product called airLET, a now pay as you go compressed air scheme, where LET embraces the latest energy efficient air compressors and predictive maintenance technology backed up by full after sale service support to provide end users with a guaranteed and reliable compressed air supply with a flexible agreement. It is designed specifically for customers who may experience periodic extra usage demands or have limited capital reserves and I think I can even put the typical cloud services in this example.

You can think of software as service or infrastructure as service, all these examples. So, maybe examples of servitization. So, I can actually get something on demand.

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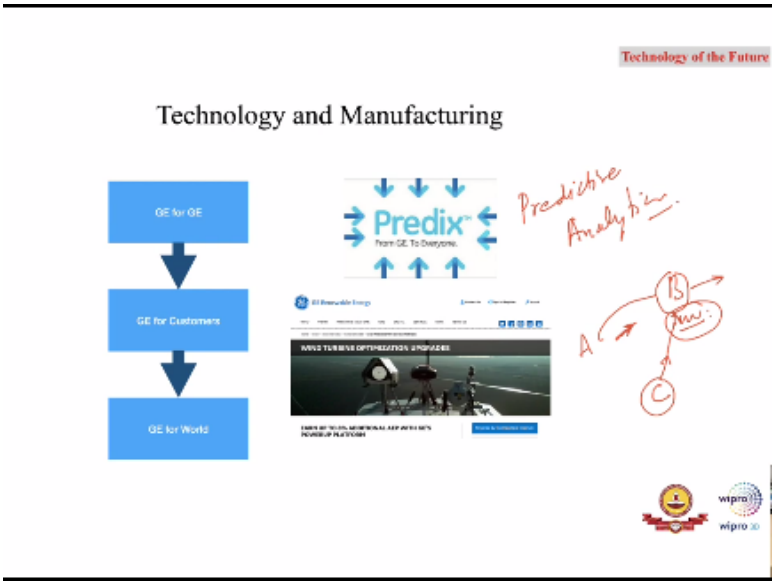

So, continuing on the same line, I think some of you may be aware that there is a GE platform called Predix. This is maybe part of the predictive analytics and this whole concept was launched, I think mid of around 2005 or 2006. The main thing was that they were perceiving more competition from the companies, which were monetizing the data.

Like companies like Amazon or Google. So, GE were not looking at their main competitors from the traditional companies who may be making aircraft engines or turbines. They were, so they want to come up with the how you actually can use the data for value generation. If you see the progression is like GE for GE, GE for customers, GE for world.

They want to come up maybe with a general purpose platform, where you actually can do lot of prognosis and it actually can, so maybe you can think of a digital twin, which is put on this platform, and which can actually tell you in real time, what is the status of the equipment and you can actually integrate the whole supply chain along with it

So, if you are flying from A to B, and if there is anything, so the plane which is flying from A to B, and if there is any problem coming here, and if there is assume that there

is no inventory for the spare part at B, and it is available at C, so before the plane actually reaches B, you can actually so you are not doing maintenance once the plane actually lands there.

Then you have to wait for it. So, your uptime of the plane would be higher, if you already shipped the spare parts from C to B and so the plane would actually be again, ready to take the next flight at B itself. Your outage time would actually be lower. So, some of these models, some of these platforms are already there in the form of we already have seen the Phillips example, maybe the Predix example and all.

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I think there would be lot of discussion around it. I just give you an example, which is ManuCloud. This is something which I think is an initiative of the European Union to put manufacturing on the cloud. We call it cloud manufacturing in fact We are working on a project with the University of Nottingham on cloud manufacturing.

This is taken from the Dassault systems. If you see it is somewhere here. I have just taken the screenshot from there. It says, manufacturing as a service and if you read this, so it is personalized, customized, one of many customers are gravitating to products, they can personalize when purchasing cars. So, we already have talked about the flexibility part in the initial slides, if you recall that.

Where we say that flexibility is not free and we talked about the cycle, where we have mass customization and now, we are coming to mass personalization. At that point, we mentioned that whether the technology allows us to do that.

This discussion is mainly centered around that part, where you actually say that your operations, your manufacturing systems, or sorry, manufacturing operations are so flexible, that you actually can provide personalized products. So, your diversity becomes very high. At the same time, you want, so we still have that faster, cheaper, better and diverse.

You want things to be fast. You want things to be cheap. You want things to be diverse. You want things to be of high quality. Now whether we actually can achieve at the platform level and I think that is where the integration of these four or five core technologies. So, it is not necessary that all have to come together. Maybe a subset of that can also be there.

So, it may happen that you have additive manufacturing and machine intelligence. So maybe put on the platform, and blockchain may come gradually. When I talk about blockchains, I think we will have ample discussion down the line. But when we talk about blockchain our emphasis is on actually to make supply chains as transparent as possible.

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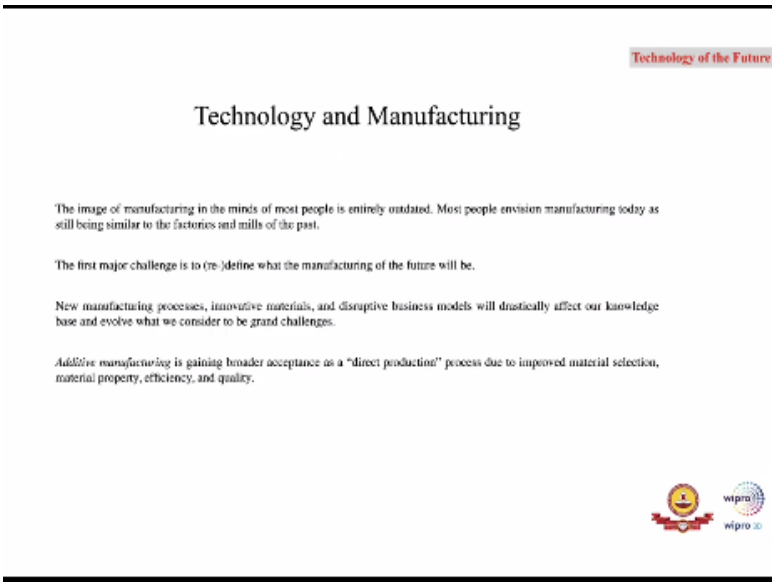

So, I continue my discussion. Image of manufacturing in the minds of most people is entirely outdated. I assume that most of you agree with this. Most people envision manufacturing today as still being similar to the factories and mills of the past. The first major challenge is when we define the technology of the future, what the manufacturing of the future will be.

You can see new manufacturing processes. I think as a part of technology, you can think of additive manufacturing, you can think of innovative materials. So we, in fact lot of so we are not emphasizing much on the material side of it. Dr. Chandrasekar will cover the material part for additive manufacturing. But this space itself is very huge.

So, we are not looking at how innovations in materials are changing the manufacturing. Disruptive business models, I think we already have talked about platforms will drastically affect our knowledge and base and evolve what we consider to be the grand challenges. Additive manufacturing is gaining broader acceptance as direct production process due to improved material selection, material property, efficiency and quality.

So, additive manufacturing if you may be aware came as part of rapid prototyping, but now we are actually calling it more as a direct production process. It is not just for the prototypes, it is actually used for the as part of the production process.

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So, in addition to changing our products, it is also changing the supply chain, even how the products are designed. I remember in the initial meetings when we venturing into this area, one point so the skill set part is important. I think, maybe Dr. Chandrasekar will emphasize more on that side.

But one point which was very critical, when we initially started discussing on say additive manufacturing, the point was whether so the people's mindset, the so assume we talk about a designer. They are still designing the products based on the traditional manufacturing. So, I put that way subtractive or additive, so let us say subtractive manufacturing.

You may not actually design it in the best optimal way, which is actually suitable for additive manufacturing. You actually need not just design thinking you actually need design rethinking for additive manufacturing. I think I am pretty sure Dr. Chandrasekar will cover lot of ground on that side.

But when we give you an example one example, which is the most common one is about this GE 90 jet engine fuel nozzle, which is actually manufactured by additive manufacturing and I am pretty sure that you may be aware that lot of discussion is around like some of the companies may be producing or using the durable goods. Like you can talk about the refineries or where the life of a of the machine is pretty long like 50 years or something.

So, for their used spare parts, some of the spare parts are unavailable. They are actually keeping the digital inventory. They are printing whenever they want on demand. So, at least in that direction, the additive manufacturing is pretty much used. But we are actually talking about can we used it as a direct production process.

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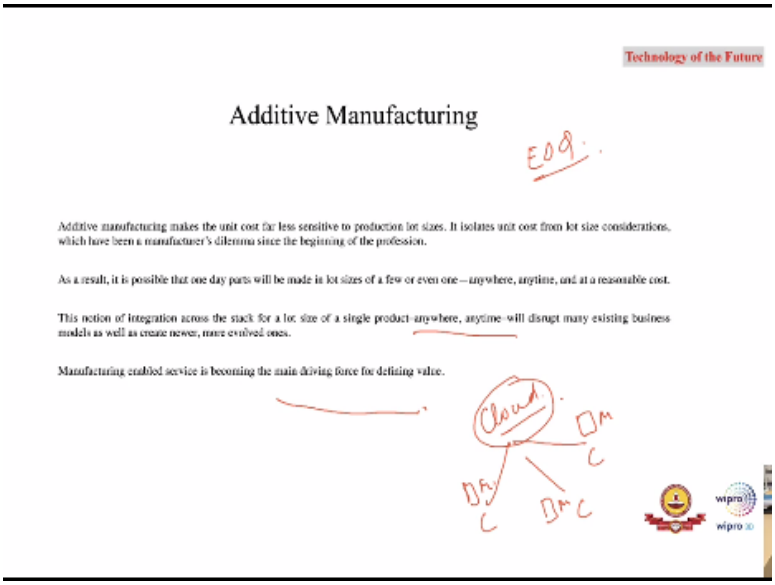

So, we already talked about the SMED, which is single-minute exchange of dye. If you improve the cycle time, the inventory will also get reduced. I think we have seen the Little's law. Now the same if you look at the same contribution of additive manufacturing from the production and the operations management side, additive manufacturing makes the unit cost far less sensitive to production lot sizes.

So, the batch size is not important because you can actually customize each product for each unit separately. It isolates unit cost from lot size. So, economies of if you recall the lot sizing was so optimal lot size, if you recall the EOQ formula, I think all of these things we have discussed earlier. It is actually a function of what is the lot size.

So, you remove that dilemma altogether. It is possible that one day parts will be made in lot sizes of few or even one and you are actually producing the thing, so closer to the customer. So, if I put our lens example, we said that this lens are actually manufactured closer to the customer. The same logic should be applicable in this case. So, I may have a digital inventory.

Let the customer make the choice, and you actually produce that thing closer to the customer. It says anywhere, anything, and what we actually can think of is maybe you actually can put these things on the cloud and let the cloud do the, the cloud will do the optimization. So I show the architecture of it. For time being just believe me.

So, there could be a customer, distributed customers and then there would be a cloud hovered to the optimization. This could be the manufacturing thing, which may be closer to the customer. So, the whole optimization is actually done on the cloud.

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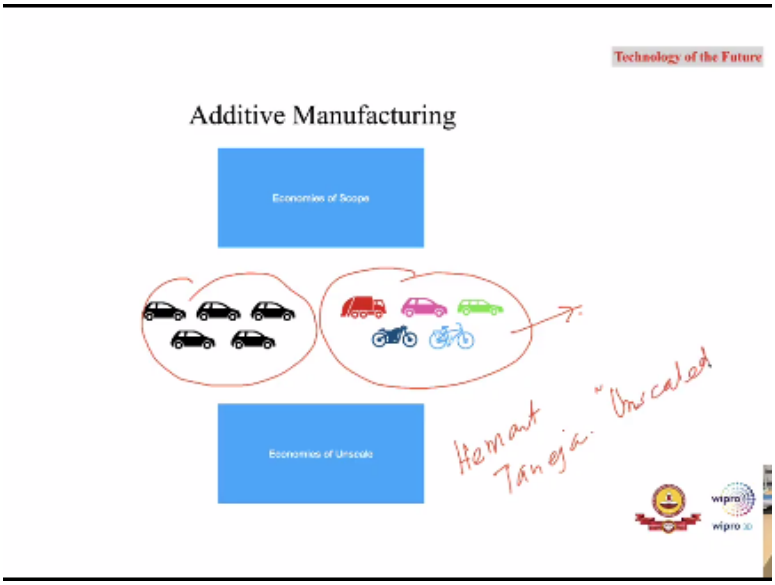

So, what advantages does it bring. So, economies of scope. We already have talked about economies of scale. If you scale up, the cost keeps on and that is the thinking, the traditional thinking in manufacturing. But we are actually going next level when we talk about the economies of scope. Because additive manufacturing means that so this, if you recall, the Ford classic example, that you produce only black cars.

But now you actually can produce variety of, it is not just the cars, you may actually produce the different other kind of products and so this is where the economies of scope come in. The cost of doing that will also because you can actually match the demand in a better way. The inventory cost would come down. That will lead to the economies of scope.

Now there is a very recent book by Hemant Taneja, which is titled Unscaled. I have taken this concept from Hemant Taneja's book, which is called economies of unscaled. We have talked about economies of complementarities, we have talked about economies of scope, but what Hemant Taneja proposed is economies of unscaled.

What that means is, if you so instead of becoming larger, if you are a smaller, the cost would actually be lower and this idea actually goes back to that servitization. If I actually can get the services on the go, in that case my capital investment would actually be lower and I can actually, so if assume that I want to manufacture something, it is not necessary actually I need to put the whole thing.

Even now I think if you look at a typical automotive manufacturing, it may be not exactly economies of unscaled but it may be closer to it. I can give you an example of in fact it really gels well with this concept of the Ford and Toyota.

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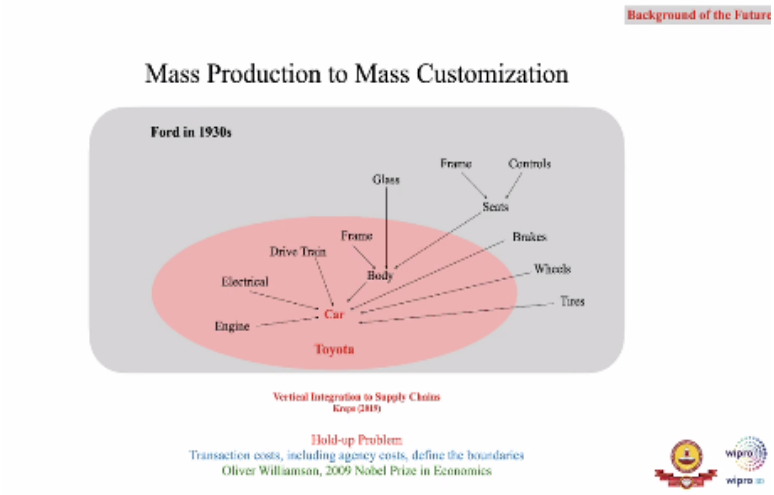

So, we talked about vertical integration to supply chains. I think from Ford, you can actually see that there was an unscaling of organization. So, when you go to Toyota it was unscaled organization and that was better than actually having the fully vertically integrated. company like Ford. So, these concepts were already there, I think long back.

But now they are actually going even next scale that even this Toyota thing will go and you would actually see a very unscaled organization and that is where the economies of unscaled come into the picture.

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So let us take the main advantages which comes along with it. The first is, its ability to produce complex products. So, material wastage, because we are actually producing closer to the customer. The logistic cost in fact, when you look at the transportation cost or reduced cost of inventory, this point will come again. So, material wastage will come down. The carbon emissions will come down.

It is very easy to customize the product. When we talk about masked work personalization, this point will become relevant. This is something which comes from this company called Mattel and they name it Thing-maker. So you can actually produce something at your home. Toy makers, in fact, we can think of an example like Lego right, which you can customize at home.

On demand production, so decentralized manufacturing. So, manufacturing will become more and more decentralized democratic. This example you can actually see make in space. This is for International Space Station. So, instead of actually carrying the spare parts there, you actually can put a printer there and you can print it on demand. Reduced cost of inventory.

You need not to, so transportation cost comes down and many a times you need not to have things in stock and along with it, you can actually even think of design platforms. One example is Shapeways where the customers actually can co-design with the manufacturer and you can actually see how their design is actually

developing. This is some advantages, which comes along with the additive manufacturing.

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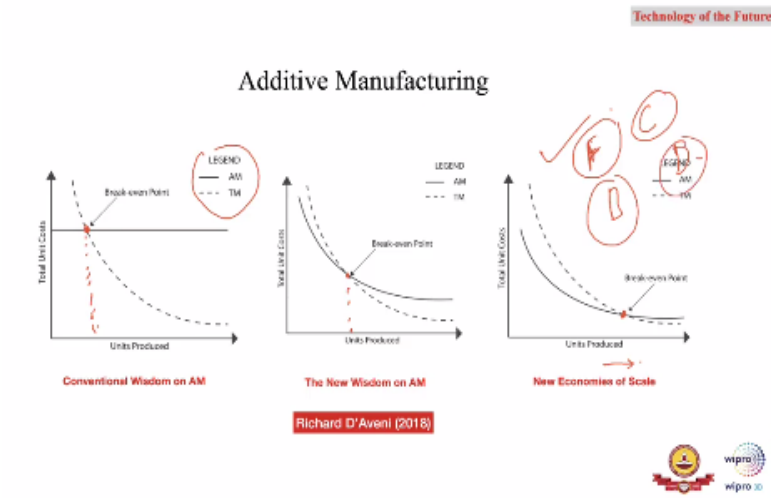

So, there is always a debate that whether additive manufacturing will be cost effective compared to the traditional manufacturing. I have taken this particular set of figures from a very recent book, The Pan-Industrial Revolution by Richard D'Aveni. This book, I think, came in 2018 and there are three different what you call settings.

One is conventional wisdom on AM, the new wisdom on AM, and the new economies of scale. This is something which so you can relate to that economies of scale example earlier. AM is the additive manufacturing and TM is the traditional manufacturing and what it actually says the conventional wisdom is that for small units, additive, so you can actually see that the cost for additive manufacturing is assumed to be not changing, it is more or less horizontal.

You can think this may be in terms of average cost. You can say that for a small number of units, the traditional manufacturing may be more expensive than the additive manufacturing. So, when you scale up, the traditional manufacturing cost will come down, compared to the additive manufacturing, that is the conventional wisdom. The new wisdom says that even in additive manufacturing, there is a possibility of economies of scale.

And moreover, the breakeven point would move towards the right. Then he goes further. He says that that point will go further because you would actually have maybe economies of scope, economies of unscale, economies of complementarities. All these things come together and, in that case, the additive manufacturing cost would actually be lower than the traditional manufacturing even for larger scales.

So that is something which comes as part of the new economies of scale and I think that is the best scenario where you actually can realize the dream of flexible, sorry yeah flexible means diverse or faster, cheaper, better. So, you can actually realize all these things together. So cheaper part will also come along with additive manufacturing. So, still it is away but I think that is something which we can realize.

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So, I think in that direction, there are some examples. NextGenAM is one example. You can actually see how they have built. Machines are arranged in banks for each stage of production, 3D printing, annealing, heat treatment. They have the whole process defined how to actually integrate the other processes with the 3D printing part.

So, there are some examples in that direction. This will give you a very basic view of what are the possibilities which comes along with additive manufacturing. So, the technical discussion certainly will I delegate it to the part two of the course, which is to Dr. Chandrasekar. But the business side, which we want to cover in this particular you can see part one of the course.

Now I will explain what we are going to cover in the next mainly the four sessions. I have an invited talk. In fact, a set of invited talk. One is by Mr. Jimo. He is a senior PhD student at University of Nottingham and he is working in the area of how supply chains are getting reconfigured with additive manufacturing. He will give you some insights about the used cases in different countries.

So, how additive manufacturing and supply chains integrate? What is the convergence point and how they influence each other? That would be an interesting thing to see, because we talked about the reconfiguring supply chains. I think that is something which we will, which will be covered by Mr. Jimo and so that will conclude the additive manufacturing part in the business part of the course.

The next, so Jimo will take two set of lectures and then Mr. Murali whom you have met in manufacturing, radar and agile manufacturing. Mr. Murali will talk about the industrial IoT. Once Mr. Murali gets finish his part, I will come back and I will talk about the briefly about AI platforms and blockchain. This is the path which we have to trace for this course. Thank you.