The Future of Manufacturing Business:
Role of Additive Manufacturing
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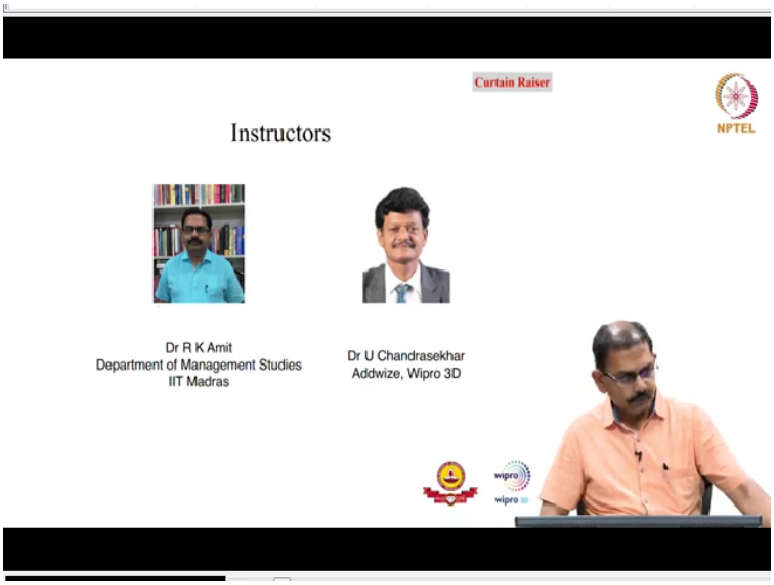
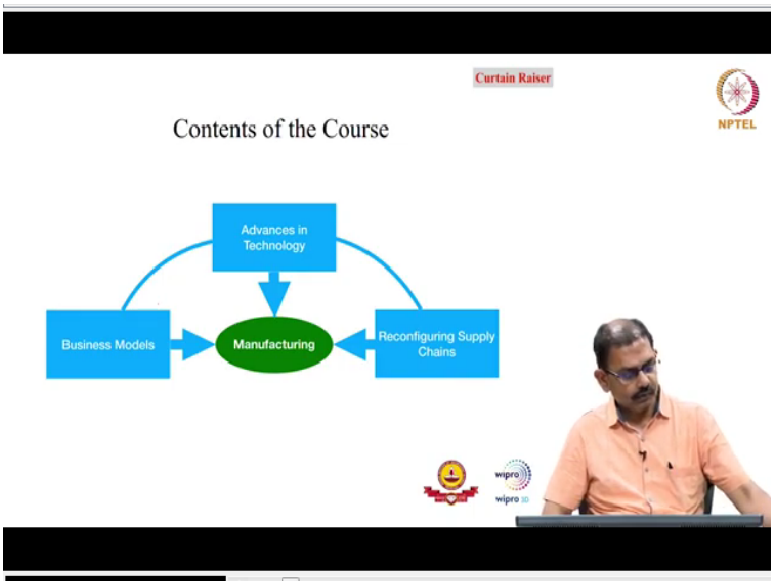
Lecture-01
What is Manufacturing?

Hello everyone. The course title is the future of the manufacturing business role of additive manufacturing. I will give you a brief overview of the course; you might have already seen that in the introduction, what had uploaded earlier. **(Refer Slide Time: 00:32)**



This course will be taught by me and Dr. Chandrasekhar from Wipro 3D. I would cover mainly the business part of the manufacturing and he will cover more on the technology side of additive manufacturing. **(Refer Slide Time: 00:53)**



If you look at the course content broadly, we will talk about business models, technology and how you can actually reconfigure supply chains.

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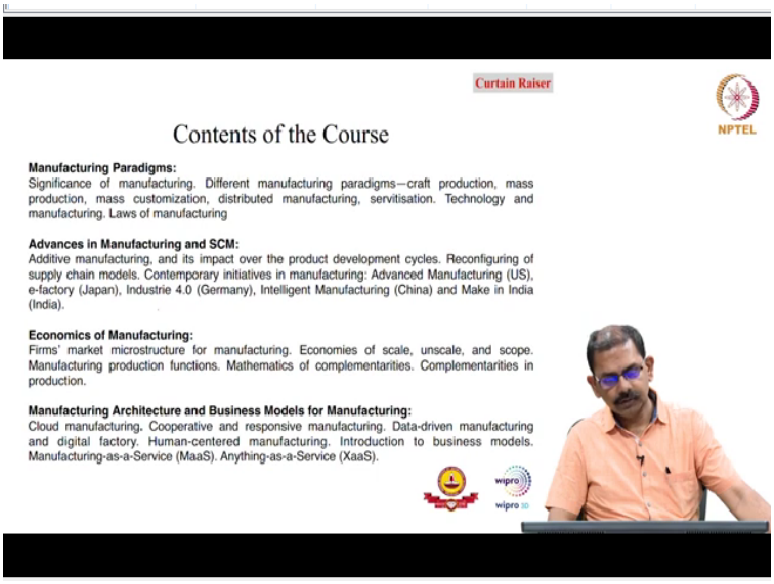
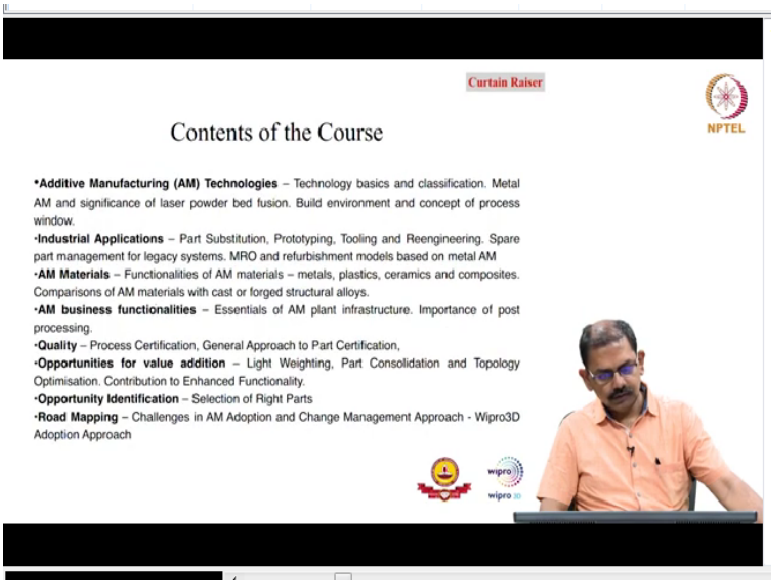


My part would be on some of these topics like the manufacturing paradigms, advances in manufacturing and supply chain management, the economics of manufacturing and manufacturing architecture, and business models for manufacturing. As we go along, you will actually realize that I have classified all these topics into 3 broad themes. One is the background of the future, second is the technology of the future, and then at the end we will have the future and all these things are mainly for manufacturing. So, when we talk about the background I will give you different manufacturing paradigms. I am going to talk about the economics of

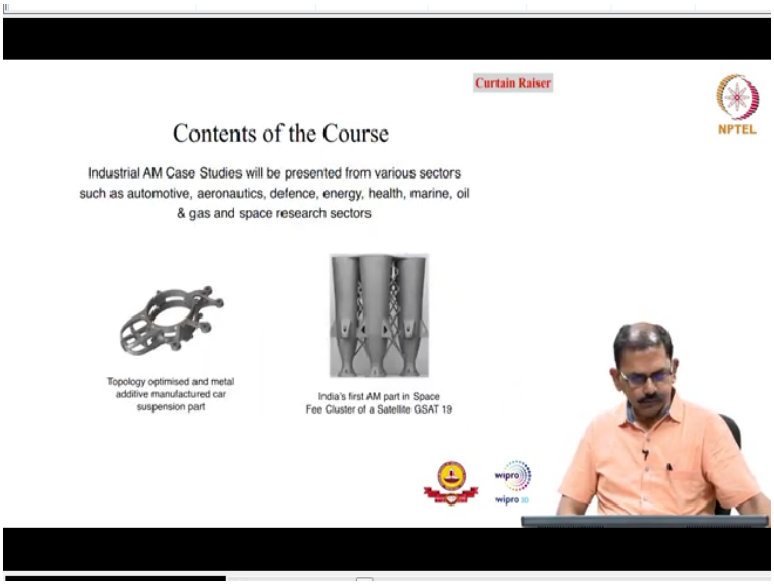
manufacturing, introduction to business models. When I talk about technology, I will actually self-selected some technologies, which may be relevant to the future of manufacturing.

I may have a brief introduction to artificial intelligence, how it is coming in manufacturing, a brief introduction to blockchains, how they are actually helping us to reconfigure supply chains and manufacturing and some introduction to additive manufacturing, because the bulk of the introduction or technical backgrounds will be covered by Dr. Chandrasekhar. So, these are 3 broad technologies.

Maybe I will also have some discussion on the IoT part. So, that will be very brief, but mainly these three and when I talk about the future I will actually look mainly at the cases. Maybe the successful cases of how manufacturing is changing with the introduction of these technologies. So, this is the portion that is going to be covered by me. **(Refer Slide Time: 03:05)**



This is the portion that is going to be covered by Dr. Chandrasekhar and he would be talking more on the materials and the technology side of additive manufacturing. At the end of the course, we actually have invited one industry speaker, who is going to talk about the future of manufacturing radar. So, he will actually show you how these technologies actually integrate. **(Refer Slide Time: 03:36)**



So these are some of the cases, which will be discussed by Dr. Chandrasekhar, so we can actually see that in fact, one thing which here if you see this. He is talking about India's first additive manufactured part in space. It is actually used for the satellite GSAT-19. He will cover some of these cases and some of these cases are actually part of Wipro 3D and I may also touch some portion, how additive manufacturing is actually allowing us to match supply constraints with critical demand during COVID-19. I will try to bring some use cases from COVID-19.

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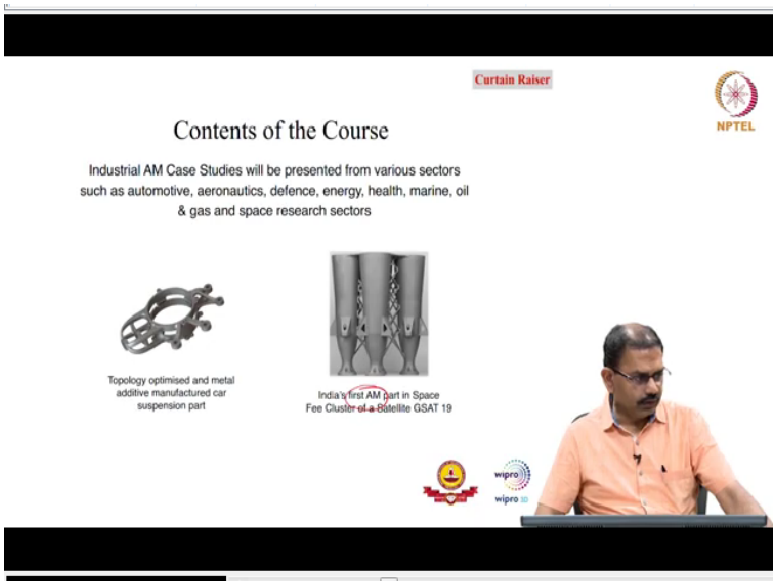
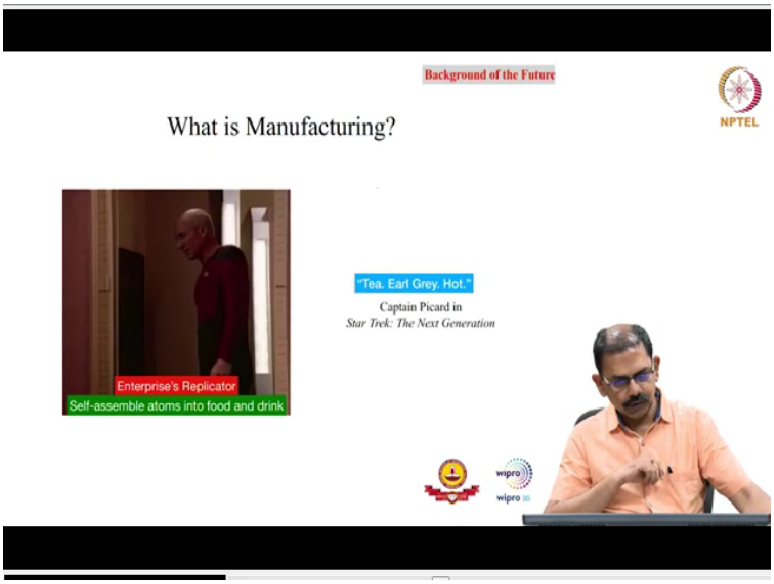


So, continue with this, I will now venture into the technical side. We will start with the simple question what is manufacturing; how you define manufacturing? I have just taken the definition which is given by CIRP that defines manufacturing is a series of interrelated activities and

operations involving the design, materials, selection, planning, manufacturing, production, quality assurance, management, and marketing.

So, if you see this definition, it is highly encompassing. It covers more or less all functional areas of management; from the procurement to the marketing, and supply chain everything is integrated into this definition. So, looking at this definition it means that we are actually talking about a very large spectrum of activities and just to give you a flavour of how this word come.

The origin is a Latin word. Manus is hand and Facio is to do. When we are talking about manufacturing we are talking about the Latin origins. It is about doing something and maybe doing by hand but I think that is where the technology differs because more and more automation and digitization is coming and we will discuss as we go along. **(Refer Slide Time: 06:06)**



So, with this simple definition, the definition part is over. Then the question here is, what is ideal manufacturing or put it that way is what actually you what you should get out of manufacturing, what are the goals of manufacturing? If you look at this particular slide, the slide is from a very famous science fiction serial Star Trek The Next Generation.

Some of you might have seen it. When I was a kid, I think it used to be telecasted in DD. This is Captain Picard, one of the actors in that serial, and very often he used to use this particular thing, Tea, Earl Grey Hot and as soon as he says this within some seconds, the tea will actually come in

it will be Earl Grey, it will be hot. The spaceship, in which they are actually have shorted the whole thing was the centre praise and this machine is the replicator.

The back end part of the replicator at least what is revealed in this whole science fiction thing is that it actually can self assemble items into food and drink. So, if I am looking for an ideal manufacturing scenario, the machine actually can convert anything to everything. So, as soon as I start thinking about something the machine has the capability to convert any raw material to whatever I am looking for.

So, if you think of maybe Aladdin's lamp whatever you wish for will be immediately provided. So, can we actually have a manufacturing system of the term? Is it possible to think of that?

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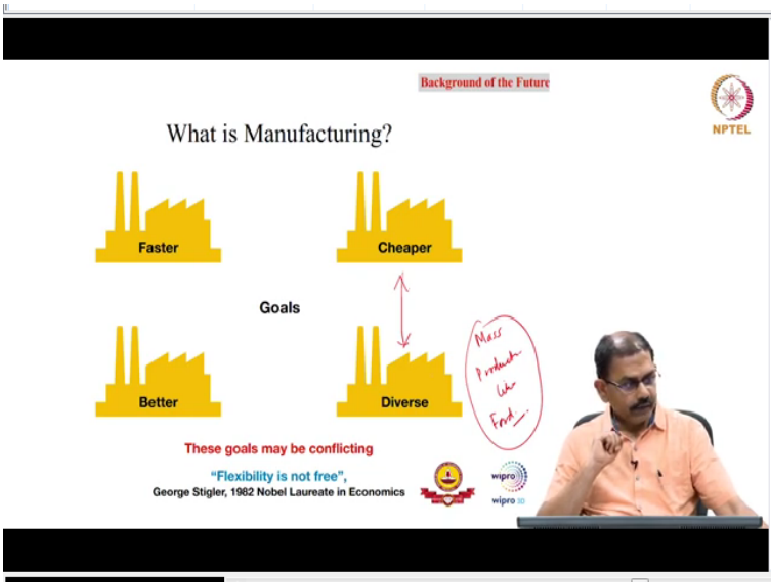
So, coming out of science fiction is it possible to actually have those things in reality. The science historian James book has a very interesting condition that something is going to happen in the next 40 years, that will change things probably more than anything else since we left the caves and I think his context was talking about manufacturing when we look at it. This is some kind of a blog, The title is how a machine that can make anything would change everything.

The machine which may resemble the enterprise replicator may be going to come in the future and that is nanofabricators. So, you may actually see advances in technology to such an extent that the atoms can be reconfigured into different kinds of products. So, that is actually too far

into the future, we may not be covering that dimension of manufacturing in this course, but let us see how far we actually can go closer to this.

So, suddenly as of now, we do not have the technology of nanofabrication. We do not have the technology that maybe there in the replicator. But let us see how far we actually can go close to it. So, whether we actually can be too far from that. So, let us see, that how far we actually can go closer to this. **(Refer Slide Time: 10:00)**



I asked you , what should be there in manufacturing, what are the goals of manufacturing, what is the ideal manufacturing system. If you just look at the previous examples the 4 things, which came out very explicitly. It should be fast, cheap or economical and it should be better. In fact, we should look for best for time being let us confined to better.

It means that we are looking for good quality and it should be diverse. So, if instead of Captain Picard someone else comes and say that I want some other type of tea, or why tea it could be anything else. So, replicators should have the capability or the technology to replicate to make something which is very diverse. But unfortunately, these goals are not in tandem with each other.

These goals may be conflicting. So it is possible that you actually could have something which is fast, economical may be high quality, but may not be diverse. In fact, when we talk about a

typical mass production system, like Ford motors will discuss that in detail. It may be fast, it may be economical. It may have reasonable quality it may not be the best, but it may not be diverse at all.

The Ford motors used to produce only one type of model the Model T at the peak of their mass production system. So, these objectives, these goals may be conflicting and then again the important question is, is it possible for technology to bring these goals into sync with each other. There is a very famous quotation given by the economist, George Stigler he got the Nobel Prize in 1982 for a different field altogether.

But he has a very interesting paper which he published in 1939 and one of the very famous quotation came out of it is that flexibility is not free. So, it shows that these two goals may conflict with each other. So, if I want high flexibility the things may not be economical and I think that is the idea, which comes in mass production systems where Henry Ford decided to forego flexibility in favour of the cost.

So, will keep on talking about these things, at least in the first part of the course. Our objective is to see how we actually can bring these goals into sync with each other. **(Refer Slide Time: 13:21)**

Based on this simple background I will go into some data, we try to look into the macro picture of where the manufacturing is contributing. So, this particular slide if you see it talks about the world GDP. In the last 2000 years, and everything has been adjusted to some people who have seen how the GDP is normalized, so everything has been into international dollars in 2011 prices.

So, if you see that for the initial maybe till 1600 years or 1500 years there is some kind of the wolrd GDP was more or less constant. So, there is not much difference, but post 1500 and after maybe 1600 there is a gradual increase and then there is a really big increase, maybe in the 20th century. Now, if you look at these numbers, one thing which comes significantly, that the advances in technology during the Industrial Revolution has significantly impacted the productivity.

Most of these advances were actually in the context of manufacturing. So, if I put indirectly, that manufacturing has changed the way we live. I am just adding something from my side from economics. So, we call it the great divergence and great convergence. So, when I say, great divergence, it means that the impact of industrial revolution was not constant across the globe.

Some countries have advanced significantly compared to those other countries. If you talk about some of the European countries like UK, France, like America (U.S.). These countries have significantly gained because of the impact of industrial revolution. We see great divergence, but of post second world war**,** you can see Japan , start matching the American productivity even overtaken the term.

In the 80s we are talking about emerging economies like China, India, Brazil, and then we are talking about the great convergence. So, is it possible for some of these countries the emerging economies to leverage manufacturing and start matching what has been observed in the advanced economies? So, these may be more macro side. I will show you some more data on macro. So, this sources, our word in data. org.

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This is taken from our trading economics.com and this is actually from the data, originally from minister of statistics and program implementation government of India and these are in Indian rupees in billions. We are talking about 6000 Indian rupees in billions. So, that is the kind of output, which we see as the contribution of manufacturing in the Indian GDP.

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Now I look at similar data for the US economy and the contribution of manufacturing is more than 2 trillion dollars. This data is maybe the first quarter of 2020. So, if you look at the Indian size of the Indian economy which is about 2.7 or 2.8 trillion dollars. So, US manufacturing itself is touching that number. So, when he talked about the great divergence that is something I was looking at.

So, whether it is possible for Indian manufacturing by using whatever technology to start hitting the numbers like 2.2 or 2.3 and then we actually can achieve the dream target of 5 trillion dollars. So, if I just start multiplying all these numbers that is something which we can easily achieve. When we can do that, I think that is a different question altogether.

Now, another thing which has been observed in the association of manufacturing technology. They have estimated in U.S. 1 million if you sell dollar 1 million sales of manufacturing goods in the U.S., it normally supports 8 jobs in manufacturing and 6 jobs in the supported domains. So, it means that 1 million dollar sales will support about 14 jobs, and what they have estimated that none of the other sectors even come closer to it.

So, this becomes really relevant, that the countries, actually should emphasize on growth through manufacturing and one more thing which I think you can easily look at these numbers when I talk about the great divergence that a large number of these countries who are using manufacturing as the engine of growth, they actually were producing the machines which also make machines. So their differentiation was very high. Therefore, you cannot easily replicate what they were actually doing.

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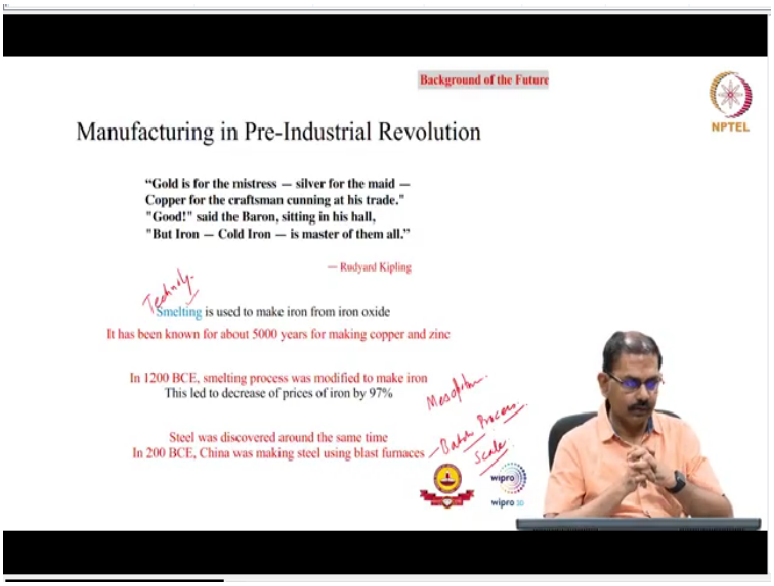
These questions are actually significant. When we talk about manufacturing and this data is 2018 data. It actually tells you how each country is actually contributing to the global manufacturing.

China may be about a quarter or more than a quarter of the global manufacturing and for historical reason, let me just put that at the beginning of the industrial revolution China was contributing about 33% of the global manufacturing and India was contributing about 25%.

China still is closer to that number, but India has come down drastically. So, from 25% they are now at about 3% and you look at the countries which I was talking about in great divergence look at U.S., Japan, Germany, Italy, France, and the UK. Most of the countries that actually have leveraged the industrial revolution well; they are actually part of the top 10 list.

China in fact has significantly gained a lot of outsourcing. When we talk about supply chains, a lot of cost arbitrage is involved. The U.S. traditionally is a high manufacturing country, but its global contribution is about 16%. Therefore, this data I think will give you an idea that, whether it is possible for India to start hitting these numbers and whether the technology will allow us to do that. This gives you the macro picture. Now I will continue my discussion by talking about the background of the future. **(Refer Slide Time: 22:07)**



I will start building the manufacturing paradigms; Manufacturing in the pre-industrial revolution. My story will start with a very interesting poem by Kipling, in fact, Kipling is known more for The Jungle Book. You might have seen that character of Mowgli. So, if you just look at this particular poem by Kipling it says gold is the mistress, silver for the made, copper for the craftsmen but the last line is significant, that cold iron is the master of them all and in fact, iron

comes as at the centre of all this, manufacturing revolution, maybe iron and steel. I think now we start building the case, how these advances and maybe iron refining industrial manufacturing has actually brought those thoughts of, which actually takes us to the goals of manufacturing.

So, now I will start building the case. A lot of you would have heard about a simple process of smelting. I think in our high school books we talk about smelting. It is a reduction process to make iron from iron oxide, but traditionally this process maybe I go to 5000 years back. This process even existed at that time, but it was not used to make iron, it was actually used to make copper and zinc.

So this process continued for copper and zinc and then there was some modification which was actually done in about 1200 BC, where this process was actually modified in fact the modification came so in terms of keeping the furnace sufficiently hot so that you actually can use a smelting to make iron and then what actually happened. So, the cost of iron refining is substantially reduced.

Because of this, I can now call the contribution of technology. So, let my technology be smelting and that actually is significantly reduced the cost of iron refining during that time. This is all the statistical data. I have taken it from a source where all these numbers have been normalized. This led to a decrease in prices of Iron by 97%. Steel was also discovered around the same time.

So, this process was in Mesopotamia which will be closer to modern Iraq. Steel was also discovered around the same time. You can get different kinds of steel but you when we talk about steel we are talking about as an alloy. So, the Chinese were a pioneer in that and they were in fact using the blast furnaces.

If you go to a modern steel plant we still talk about blast furnaces to make steel. They are still the pioneers. China is the largest producer of steel about 800 million tons. India is the second-highest, but India is about 10% of that number and the Chinese were using these blast furnaces to make a steel way back about more than 2000 years ago.

So, what it actually signifies because when I talk about blast furnace. I am talking about a batch process. We will discuss those things as we go deeper into that. These blast furnaces are normally large in scale; it means that the Chinese got some idea that if you scale the production up the cost would actually come down. So, we are actually not talking about the economies of scale, which we formally will see as we go more into the goals.

But for time being just believe me that the Chinese were using the blast furnaces. They actually have some idea about how the scale and the costs are actually related and I think they are making the best steel till the advent of the industrial revolution. So, for time being we stop here. So, we will continue our discussion on manufacturing in the pre-industrial revolution and we are going to see different manufacturing paradigms, as well as different kinds of manufacturing processes and how these processes, these manufacturing paradigms are actually linked to those four initial goals. So, I will continue this in the next session. Thank you.