The Future of Manufacturing Business: Role of Additive Manufacturing
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Lecture – 13
AM Implementation and SC Configuration - 1

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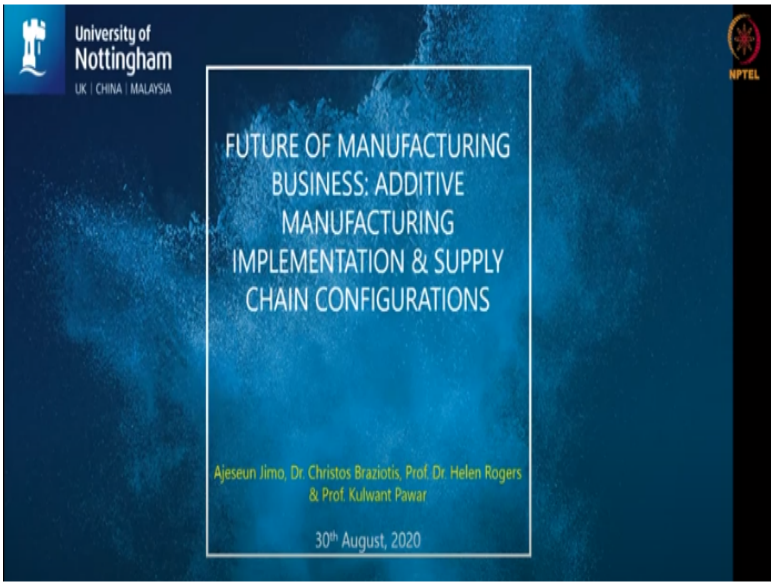

Good morning, afternoon or evening everyone, depending on where you are in the world today. Thank you very much for attending this presentation. My name is Jimo Ajeseun and I am a doctoral researcher at Nottingham University Business School, the United Kingdom and we are affiliated with IIT Madras in Chennai through the SPARC UKIERI Program, which has been fostering educational linkages between India and the UK since 2006.

So, as part of this series on the future of manufacturing business, I will be talking to you today about additive manufacturing and supply chain configurations. This lecture series is divided into two parts, the first part is going to last for about 30 minutes and I will be laying the theoretical foundation for additive manufacturing and supply chain configuration based on research that has been carried out over the past couple of years.

The second part is also going to last for 30 minutes and then I will take a more empirical perspective for caution on implementation issues associated with additive manufacturing and supply chain configurations.

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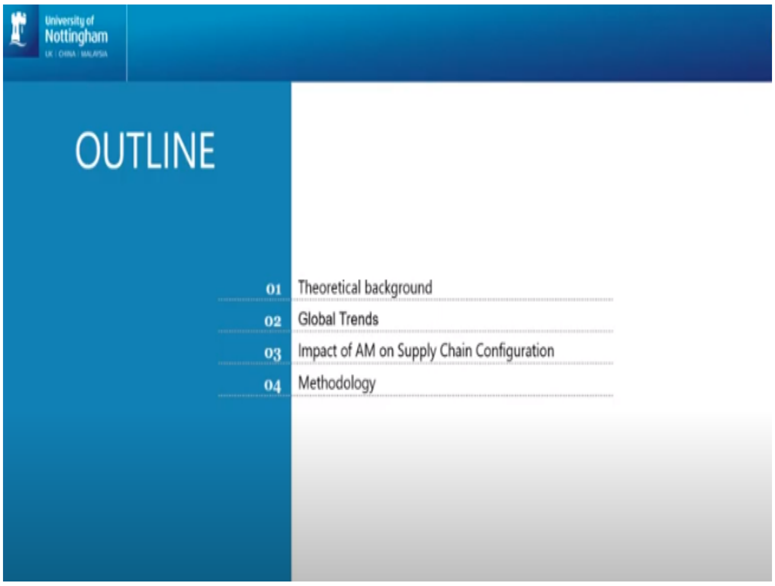

So, let me start by running through the outline of the first part of this presentation. First of I will start by laying a theoretical foundation looking at some global trends that are driving the adoption of additive manufacturing across different industries around the world and then I will take a theoretical perspective looking at the impact of supply on supply chain configuration of additive manufacturing.

I would lastly conclude with a brief summary of the methodology that was employed during the course of this research.

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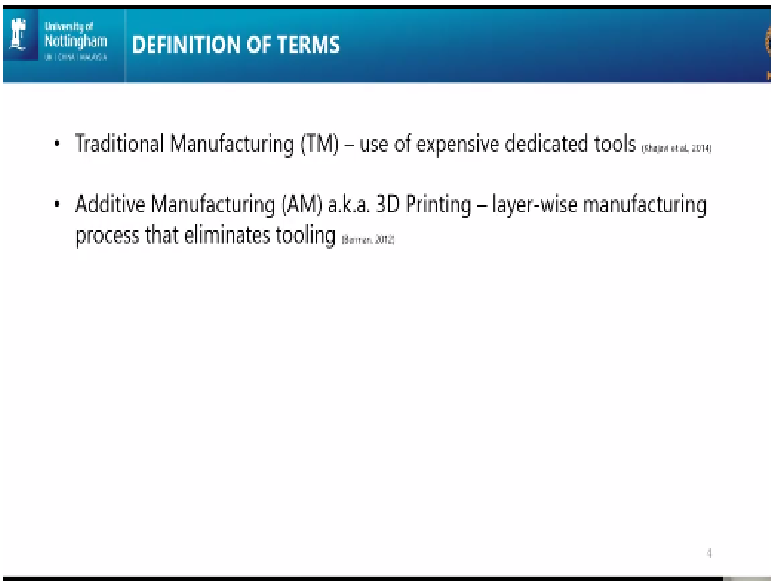

So, just before I proceed, I would like to introduce some terminologies that I will be using throughout the course of this presentation. Traditional manufacturing here refers to old established manufacturing technologies that are characterized by the use of expensive dedicated tools and very good examples are CNC machining, casting and forging. On the other hand, we have additive manufacturing, also popularly known as 3D printing as you may be aware of.

This is a more modern form of manufacturing that is characterized by the elimination of those expensive and dedicated tools and its layer wise manufacturing process that has become popular in recent times for making end-use parts.

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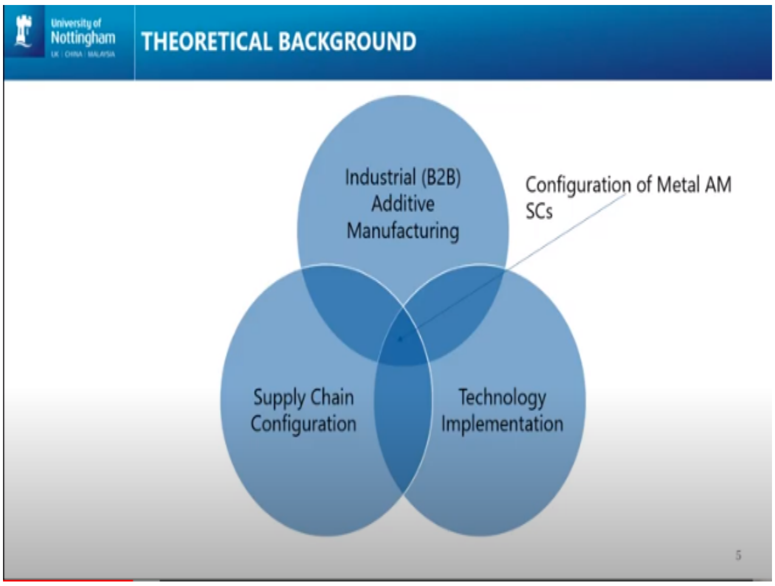

So, essentially the idea, the agenda of my research over the past couple of years has been at the intersection of supply chain configuration and technology implementation in the context of industrial additive manufacturing. By industrial additive manufacturing, I mean the adoption or the implementation of additive manufacturing for end-use parts.

The interesting thing is that AM or 3D printing has been around for about three decades since the 1980s when it was introduced, but was predominantly used for prototyping up until the time of the 19th century where there was exploration and lot of patents and improvement in the process technology that made it more suitable for implementation when it comes to manufacturing actual end-use parts.

So, the trend is that we have seen a number of applications across a number of industries and of course at different maturity levels.

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Why is this subject important one may ask? Well, the truth is that the capabilities of traditional extended global supply chains have been called into question in recent times by events that we have been seeing in the global space. Events such as the trade war between the United States and China, Brexit here in the United Kingdom.

Also, the steady increase in labor costs and so called developed or developing economies has called into question the low-cost outsourcing strategies that have dominated global manufacturing since the 1980s and indeed, very recently the

COVID-19 pandemic has revealed very gaping weaknesses and local supply chain capabilities of different economies across the world.

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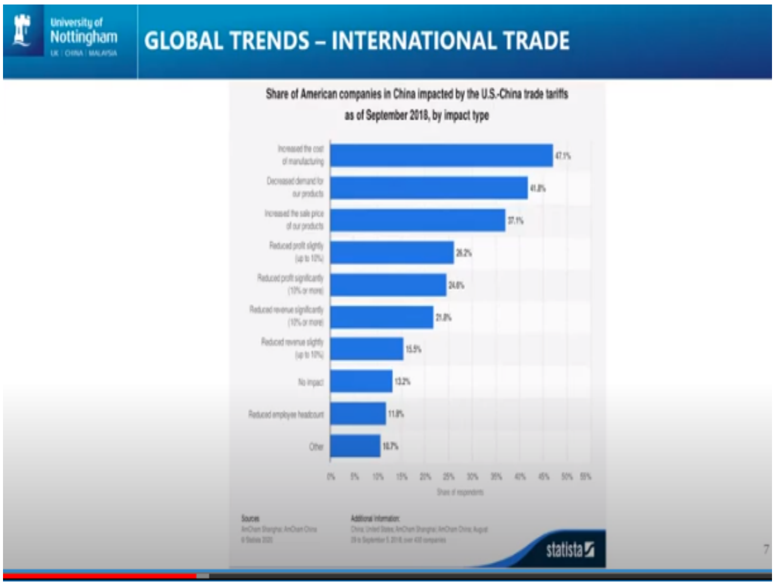

There is evidence to support this argument. In this report, released by Statista, we see American manufacturers domiciled in China bearing the brunt of the trade wars between both countries. As a result of increased tariffs in both directions, manufacturers have seen an increase in production costs and this has had a ripple effect on the level of demand, plummeting revenues and in turn plummeting profits for manufacturers in the supply chain.

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Interestingly, there is a trade, a massive trade deficit between China and India as evidenced by this report from Statista. So, it would be interesting to understand where the low cost of trade would shift, depending on events, current events at the Himalayan border. It will be interesting to see how those trade relationships are managed in the current climate, if you will.

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A very interesting trend to note as well is the steady rise in labor costs in the so called under developed economies according to this report by Statista. We see a steady rise in labor costs in China for example, from 2016 to 2020 to a lesser degree, was seeing the same trend in Mexico and in Vietnam. So, the question remains is the low cost of sourcing strategy of the 1980s prevalent in developed economies such as the UK and the United States, are these supply chain strategies still viable?

Are those assumptions to through concerning you know, the low labor cost philosophy? So, it will be interesting to examine, want to revisit some of these assumptions you know, in the midst of the growing trends.

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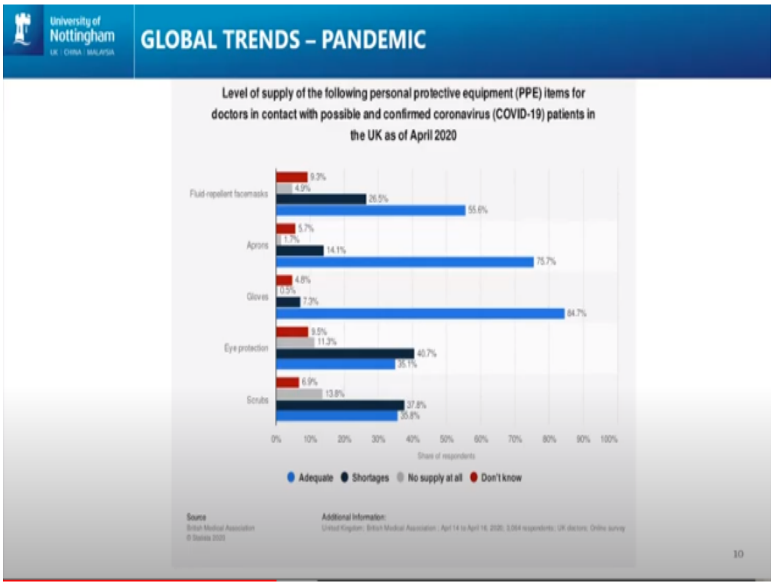

As I mentioned earlier, the COVID-19 pandemic has revealed very gaping weaknesses in local supply chain capabilities. As we can see in this report again presented by Statista we see shortages in desperately needed personal protective equipment at the inception of the Coronavirus in the UK. Shortages of PPE such as scrubs, eye protection equipment, and gloves.

The local supply chain in the UK was unable to respond to the sudden surge in demand and this has you know sparked conversations about the importance of local manufacturing.

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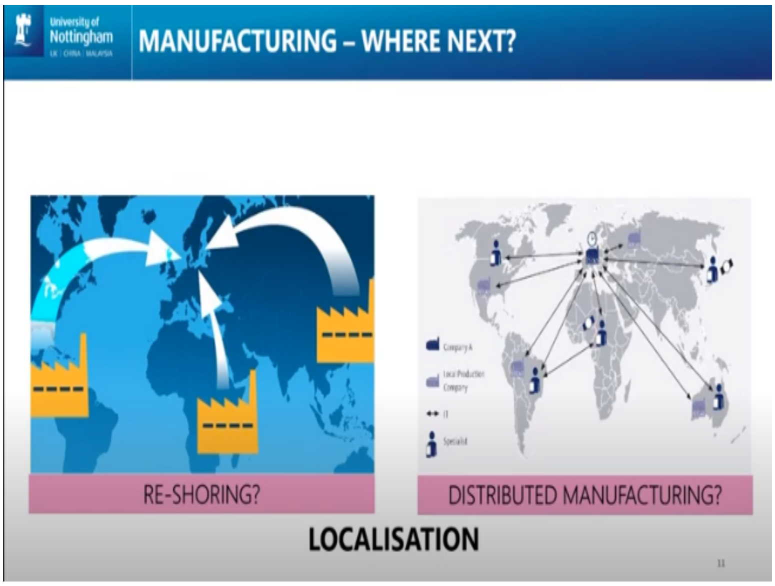

So, these trends, as I mentioned earlier have sparked conversations particularly in developed economies about re-shoring of manufacturing from low cost destinations.

In a parallel manner it has also reinforced a conversation about distributed manufacturing. So, this is essentially manufacturing close to the point of consumption. Now that point of consumption might be an assembly line.

It might be a maintenance and repair operation or indeed it might be an actual market location responding to demand, for customer demand for parts. So, whether it is distributed manufacturing or re-shoring that one is talking about, the underlying principle still remains one of localization. How can we make locally? How can we compress the length of global supply chains or reduce the risk associated with international trade and long lead times?

How can we eliminate the red tapes at the borders? How can we reduce our stock holding requirements and inventory costs? How can we do this in the current climate to respond to on demand of various markets?

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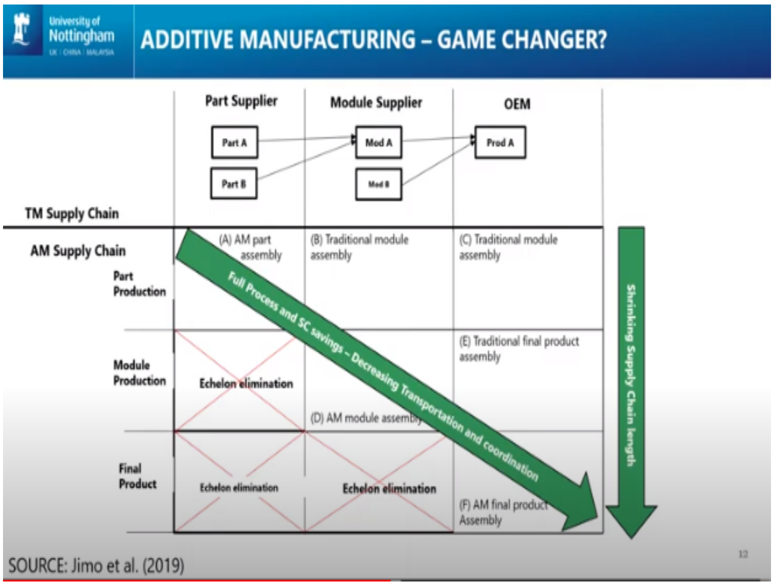

The challenge for traditional manufacturing is that it is a tall order to respond to automaker locally because of economies of scale, attend mostly towards centralization. So, what we did was that we examined the or we investigated the scope for additive manufacturing to enable localization when deployed at different tiers in the supply chain.

So, when deployed at the tier one, the tier two or indeed an original equipment manufacturer deploying additive manufacturing and what we found was interesting.

We noticed that the scope to compress your supply chain or the scope for you to localize your manufacturing actually depends on the scope or the level in the product hierarchy that additive manufacturing is deployed.

So, whether that is deployed at the part level, the module level, or the final product level that will determine the scope, that you are able to compress your supply chain and enable localization. As I said earlier, additive manufacturing is still an emergent technology and the vast majority of applications that we have seen in industry had been applied at the part and at the module level.

So, this gives impetus to actually investigate this phenomenon of the impact on supply chain configurations at the part and the module level as evidenced by different industrial applications.

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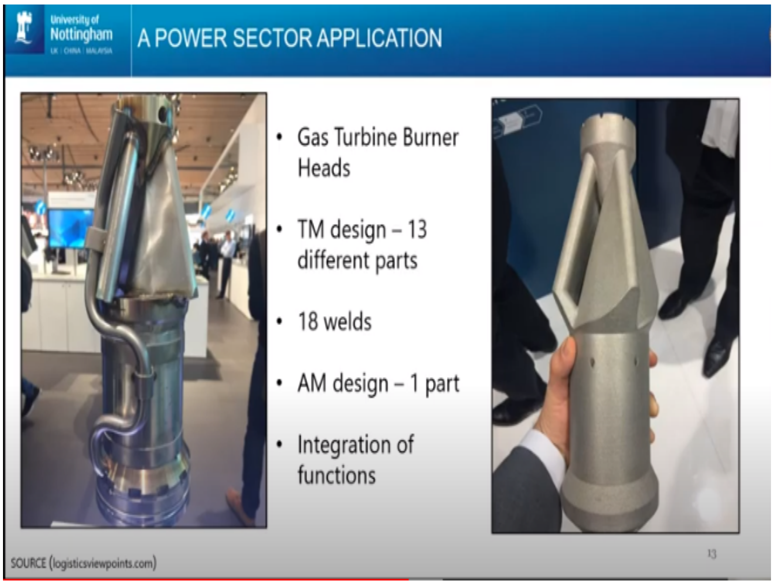

And indeed, there are n number of applications to substantiate these arguments. A very good one is the gas turbine burner head, made by Siemens. As you can see in the diagram, the original traditional manufacturing design consisted of that in different parts, and 18 welds. These 13 parts have now been consolidated into one monolithic design, with the capabilities of additive manufacturing.

In this case, with selective laser melting, a powder bed fusion technology. So, think about the impact on the supply chain. Think about the reduction in coordination requirements from traditional supply chains where you have to deal with 10 different parts and the intermediate steps involved in producing that traditional manufactured component.

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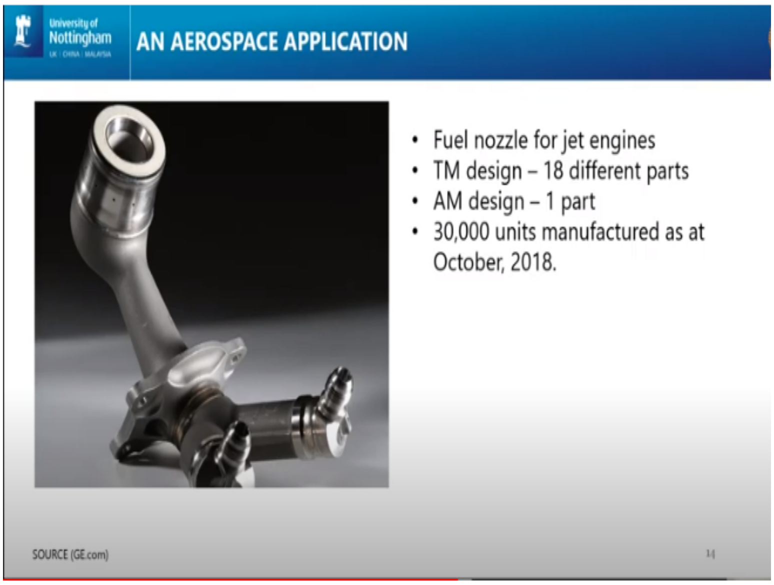

Another very good example from the aerospace is the fuel nozzle made by General Electric. This is a well cited application and in the same manner, the traditional manufacturer design consisted of 18 different parts. Those parts have now being consolidated into one with the capabilities of additive manufacturing. This has been a very successful application of 3D printing in the industry.

As a matter of fact, in 2018 October, General Electric celebrated the production of 30,000 units in its series production line. So again, just reflect a little bit about the impact on the supply chain. Think about those 18 different parts. Think about where they come, where those parts come from the suppliers, their locations, the intermediate manufacturing processes, the Assembly requirements involved.

Think about the logistic burdens and the production costs that could potentially be eliminated by consolidating that design into one monolithic structure in the build chamber of an additive manufacturing system. It is truly revolutionary.

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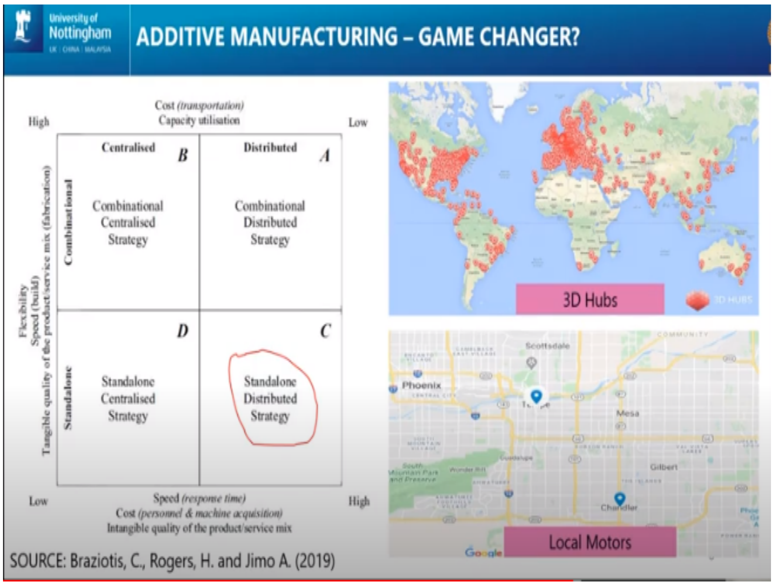

But you thing the additive manufacturing as well as that there is a lot of hype behind the technology. So, to get away from the hype, we decided to investigate the practicalities of additive manufacturing for industrial applications. Because the literature presented a sort of ground utopia about manufacturing something in a box. But the reality in industry is far from the case.

So, what we did was we mapped the configuration of additive manufacturing operations on the process and the supply chain level. At the time additive manufacturing was introduced for end-use parts, there was a big conversation in operation management circles about whether 3D printing will replace traditional manufacturing.

But the consensus at that time and indeed now is that additive manufacturing will not replace traditional manufacturing, but will coexist in different combinations with to complement the existing capabilities of traditional manufacturing. By effect, we did notice that there were some situations as well where traditional manufacturing could stand on its own to make end-use parts.

So, we came up with this process configurations. The first one being the combination of configuration, where additive manufacturing and traditional manufacturing coexist alongside to make end-use parts. And on the other hand, we came up with the concept of the standalone process configuration, where you have a 3D printer operating on its own to make an end-use parts.

Then what we did was we looked on the supply chain level to understand the potential configurations that could be practically achieved at that level and what we noticed was that there was a conversation between the centralized paradigm and the distributed manufacturing paradigm. The centralized paradigm is not new. That is the philosophy of traditional manufacturing too because of economies of scale to enhance capacity utilization of equipment.

But the distributor strategy is a new paradigm referring to more localized production capabilities close to market locations and what we discovered our conclusion was that it will be more feasible for you to distribute your manufacturing capacity if additive manufacturing is operating in a standalone in a standalone configuration at the process level. So, with less dependence on traditional manufacturing.

With less dependence on economies of scale and their examples in industry to evidence this capability with companies such as 3D Hubs, a Local Motors deploying the capabilities of polymer additive manufacturing, to make and do spot for the assembly lines and customer locations at different parts of the world. So, it is not a farfetched vision, if you will.

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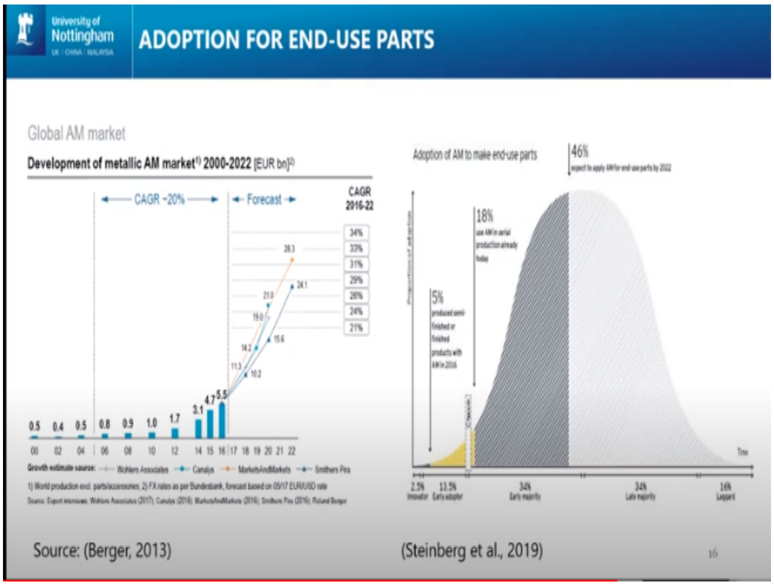

But the situation is much different on the metal side of things. A lot is not known about the configuration of metal additive manufacturing supply chains and this is particularly important because analysts have forecasted an increased growth in market size. According to this report released by Roland Berger, it predicts a fourfold increase in market size between 2016 and 2022 of the metal additive manufacturing market.

In a similar vein, analysts have also or rather manufacturers have indicated an increased appetite to adopt additive manufacturing for end-use parts. According to this report released by Ernst and Young it forecasts a 28% increase in adoption of additive manufacturing for induced spots between 2016 and 2022 again. However, it should be stated that these forecasts are pre COVID-19.

So, it will be interesting to see where the locus of demand shifts as a result of current event.

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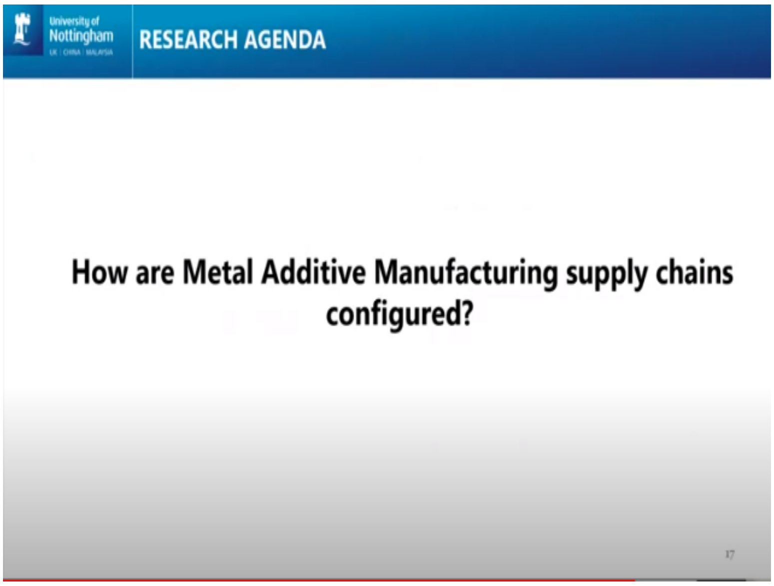

So, over the past couple of years, we have been interested in understanding the configuration of additive manufacturing supply chains, what is actually going on? This is the research question that has driven our inquiry and in this particular case, focusing on metal additive manufacturing supply chains. So how are metal additive manufacturing supply chains configured?

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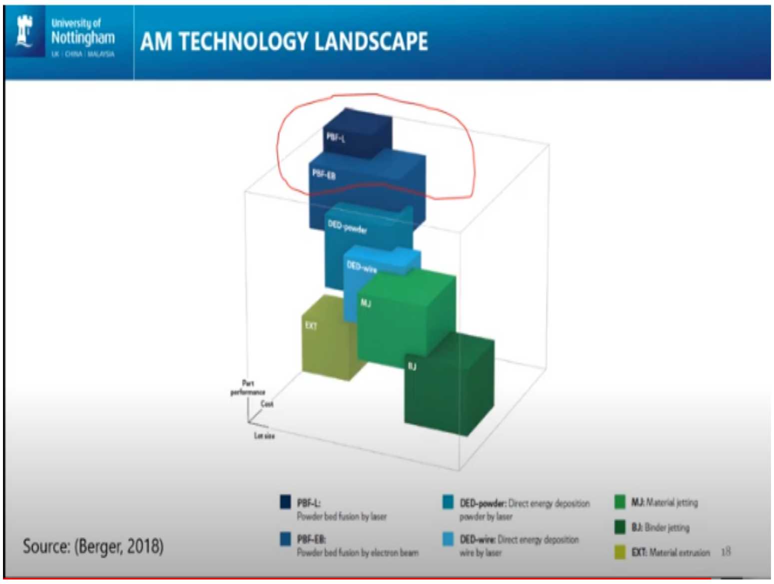

To answer this question, it is very important to understand the process landscape of additive manufacturing. Currently, additive manufacturing is currently in its formative phase and that is the phase between concept and growth of an innovation. This particular phase is characterized by lots of technological uncertainty and this is evidenced by the proliferation of different AM process systems in the marketplace.

According to this Roland Berger reports, you can see different metal additive manufacturing processes. The popular ones known as the powder bed fusion processes, direct energy deposition, binder jetting, material jetting. It feels like a murky landscape at the moment and a lot of processes are trying to find their niche in the additive manufacturing space.

So, niche in terms of production costs, production volume, and also the performance of end-use parts. But the two dominant processes in the metal space currently, from the powder bed fusion family, namely the laser powder bed fusion processes and the electron beam melting processes. This process or these processes rather have dominated applications in the industry, in different industries.

So, aerospace, automotive, energy and medical sectors. These are the technologies that are dominating that space. As a result, we decided to focus on these technologies in our study to understand the impact on supply chain configurations.

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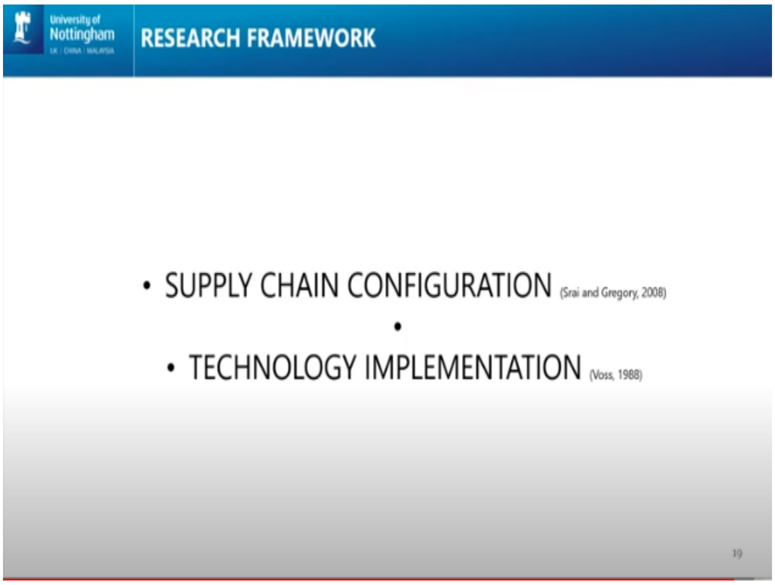

So, we adopted a very exploratory orientation for our research, because there is a lot of theory that needs to be developed in this field, were employed to established management theories known as supply chain configuration and technology implementation to explore different low volume applications in different industries.

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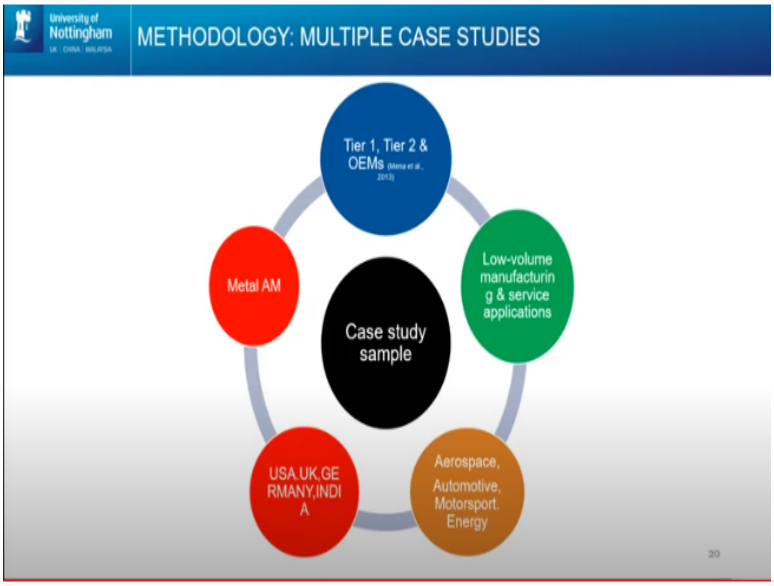

We looked at low volume applications because additive manufacturing is considered to be very slow at the moment and not very economical for high volume cost sensitive applications in industries such as high volume automotive. So, we looked at low volume sectors such as aerospace, motorsports, their niche segments within the automotive industry, high end value cars, that can absorb the cost of premiums associated with additive manufacturing and also we looked at applications in the energy sector.

Our sample was also very wide ranging. We looked at different countries, companies domiciled in the US. US is at the forefront of additive manufacturing developments, the United Kingdom, Germany, a very key market, when it comes to 3D printing and we looked at India as well to understand the developments in additive manufacturing in a developing economy context.

We looked across the supply chains, so tier one, tier two and original equipment manufacturers. We also talked to various research and development organizations at the forefront of innovations with additive manufacturing. So, this research framework generated a lot of data for analysis for us to understand the dynamics and the operation of the metal additive manufacturing supply chain.

In the next section of this lecture, I will be elaborating more on some of the findings that we picked up from the industry from the different applications that we have studied over the course of three years in this research. So once again, I would like to thank you for spending time listening to this presentation.

If you have any queries or inquiries about any elements that you do not understand, please feel free to send me an email, which I would share at the tail end of the second part of this presentation and I look forward to seeing you in the second half. Thank you very much, and goodbye.