Introduction to Industry 4.0 and Industrial Internet of Things

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Lecture - 20
Basics of Industrial IOT: Industrial Processes – Part 1

In this module, we will be talking about some of the basic concepts of Industrial IoT. To start with, we will talk about some of the issues concerning different industrial processes, what industrial processes are, and what are some of the important aspects of industrial processes that need to be understood in order to incorporate IoT into the industrial processes.

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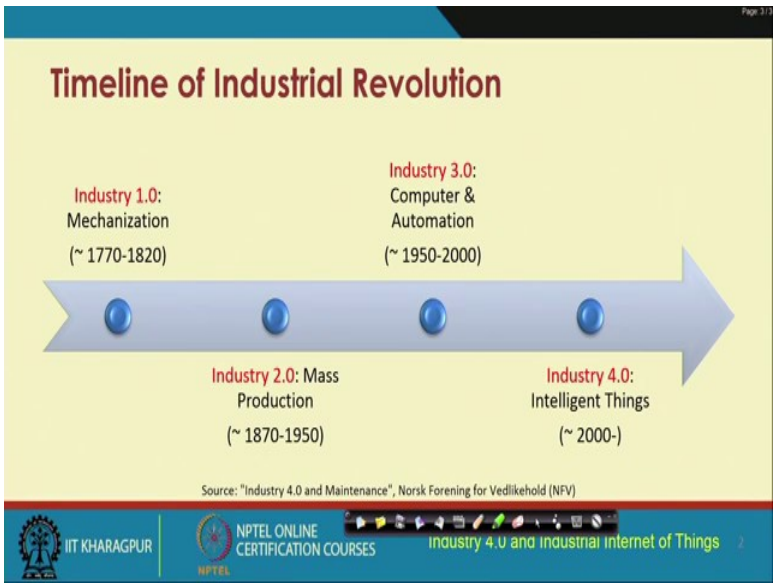

First of all, let us think about, how the industrial revolution has happened over the decades. It is started with Industry 1.0, which was all about mechanization in the 1770s to 1800s. So, it was Industry 1.0, which was particularly focused on mechanization.

Then came in the 1870s to 1950s came the Industry 2.0, which was about mass production. Then came in 1950s to 2000s, the Industry 3.0 revolution, which was about the incorporation of computers and automation in the industries. Industry 4.0 is a recent happening in the last few years, where we are talking about transformation of the industrial processes, with the help of advanced computers, automation, communication, sensors, cyber physical systems, and IoT.

Industry 4.0 is the recent happening; it is the current revolution in the industries that is happening globally. Unlike, in the case of Industry 3.0, where computers were also used, and automation was done. The focus was on automating separate, separate jobs, let us say the processes will be automated, separate from the supply chain. So, everything was done separately using computers.

In the current generation of Industry 4.0, we are talking about the same automation, but here we want to have complete autonomous systems in the industry, where this individual, separate, automated systems will also be talking to each other, they will be all interconnected. So, communication is very important in the context of Industry 4.0, because we want to have connected everything.

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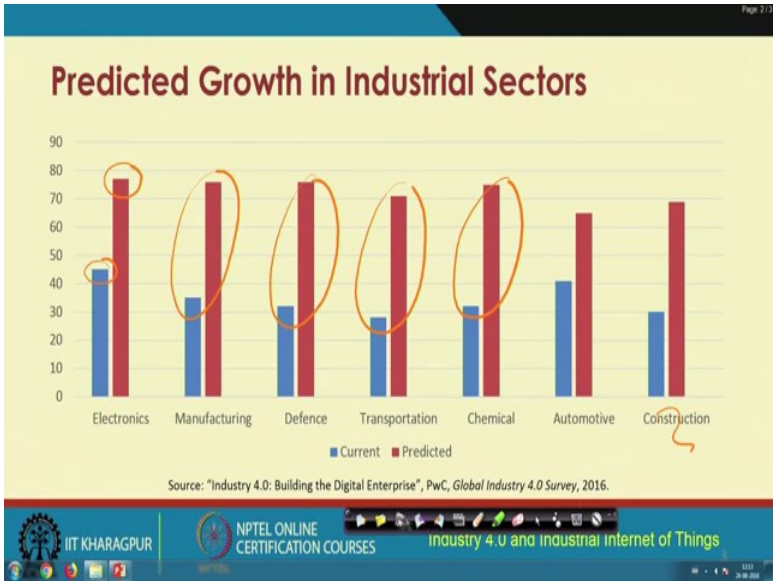

So, Industry 4.0 has become very popular. In this particular plot, as you can see, for different sectors electronics, manufacturing, defense, transportation, chemical, automotive, and construction. What is the current production, current growth, and with respect to that how much is the predicted growth?

For example, for electronics market, the current growth trend is about 40 to 50 percent. And it is predicted that with the incorporation of Industry 4.0, IIoT. The growth is going to be accelerated from about 70 to 80, it is a huge leap. Likewise, for manufacturing also we see, defense also we can see a similar kind of growth pattern. So, these are all huge

leaps in growth that are going to come in the industrial sectors, the different industrial sectors with the incorporation of Industry 4.0 and Industrial IoT, in general.

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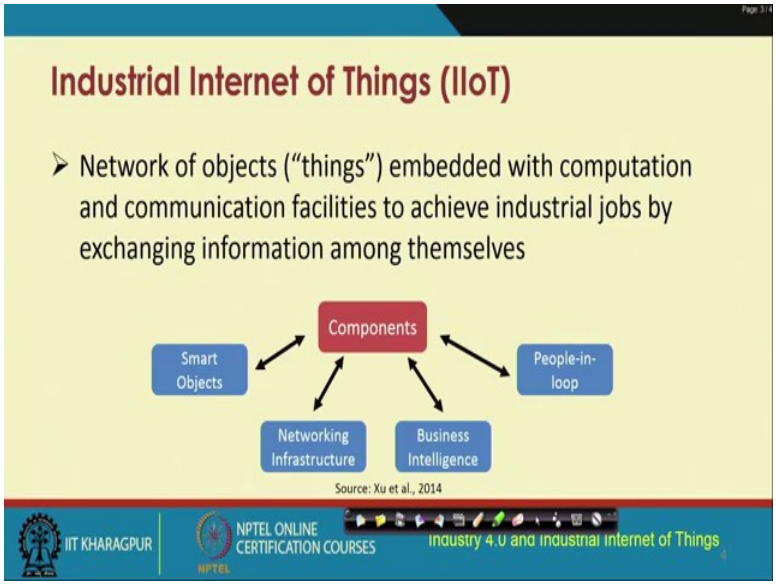

So, we need to understand some of the basics of Industrial IoT. Industrial IoT is essentially IoT for industries. So, here whatever we have learned about in IoT in the fundamentals in the first module, everything is applicable here as well. But, here additionally we are talking about consideration of industrial machinery, and industrial things, basically the industrial machinery, and industrial objects interconnecting them using sensors and actuators. And overall improving the industrial processes, their efficiency, productivity.

In Industrial IoT we are talking about networking of different industrial things or objects that have different embedded objects, which can perform different computation and communication facilities. They can together achieve industrial jobs by exchanging information among themselves. Basically sensing, actuation, computation, communication, everything put together in the industrial setting for improving their industrial processes, making the different machinery in the industries smarter.

So, we will have the different components of IIoT as the smart objects that means, the smart machinery, so basically all these industrial objects that we are talking about can be made smarter. Networking infrastructure has to be there, because the data will have to be

sent from these smart objects elsewhere for further processing that elsewhere could be cloud, it could be server, it could be server forms or anything.

Then business intelligence is another component. Business intelligence means like collecting all the data from these different smart objects, and trying to improve upon the business processes. Predicting the business outcomes, improving upon the business outcomes through the incorporation of different intelligence. So, different predictive techniques such as machine intelligence, statistical interference. All these techniques will be incorporated to improve upon the business intelligence.

The last one is people in the loop. People in the loop means, like decision makers, different other stakeholders, they will be also have to be kept in loop, so that overall not only these different objects, the connected objects, but everybody together will be achieving the improved ecosystem of industrial IoT.

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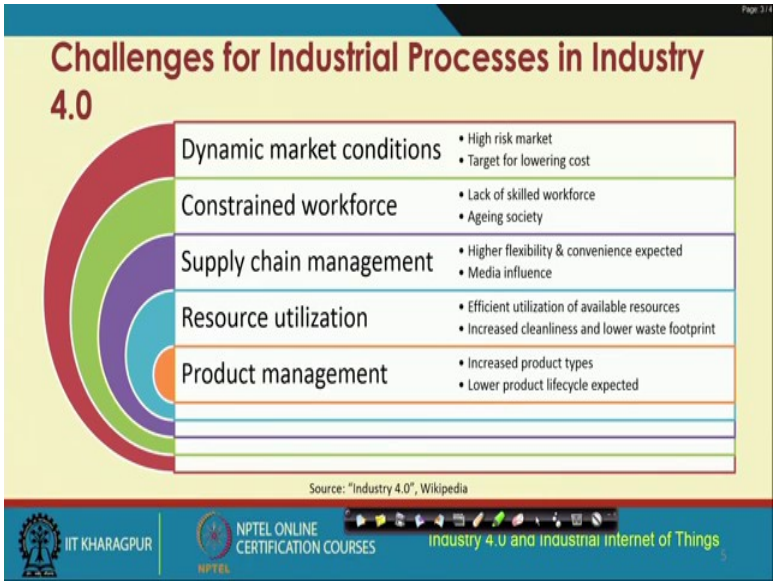

So, looking back Industry 4.0 if you are talking about incorporation of IIoT in the Industry 4.0 ecosystem, there are different challenges that are going to be faced for industrial processes. So, basically adoption of IIoT for improving industrial processes, different challenges are going to be faced. So, these are some of these different challenges categorized in different ways.

The first one is about dynamic market conditions. So, here we are talking about things such as high risk market, target for lowering cost, etc. So, these are the things that are going to happen, if you are gradually transforming towards Industry 4.0, with the incorporation of IIoT.

Constrained work force means, the work force that that is already existing is not already skilled to adopt industrial IoT. They do not already have the requisite skills that are required. So, they do not have, so they have to be skilled, that is work force will have to be skilled in order to be able to use IIoT for industry 4.0 compliance and improving upon these industrial processes consequently.

Supply chain management, the challenges over here are higher flexibility and convenience expected, due to the incorporation of IIoT in these industrial processes. So, higher flexibility is expected in the supply chain management. Media influence is also going to be there, so all these things will have to be handled. Resource utilization, efficient utilization of available resources that is what is expected, you want to improve upon the resource utilization. And there has to be increased cleanliness and waste disposal.

So, all these things are advantageous, but at the same time these are challenging. And we will have to be done adequately with properly skilled workforce. Product management is about increased product types. Here with the incorporation of different heterogeneous components, heterogeneous machinery, which were not connected before, what the challenge that we are inviting over here, is that we are having large number of different types of products, which will have to be interconnected.

And consequently what is going to happen is that the product life cycle is also going to be changed, it is going to be lower the number of that the duration of time, that a product will be developed over is going to be reduced. These are all advantageous, but at the same time this will also pose challenges for the industrial processes that would be required for complying with Industry 4.0.

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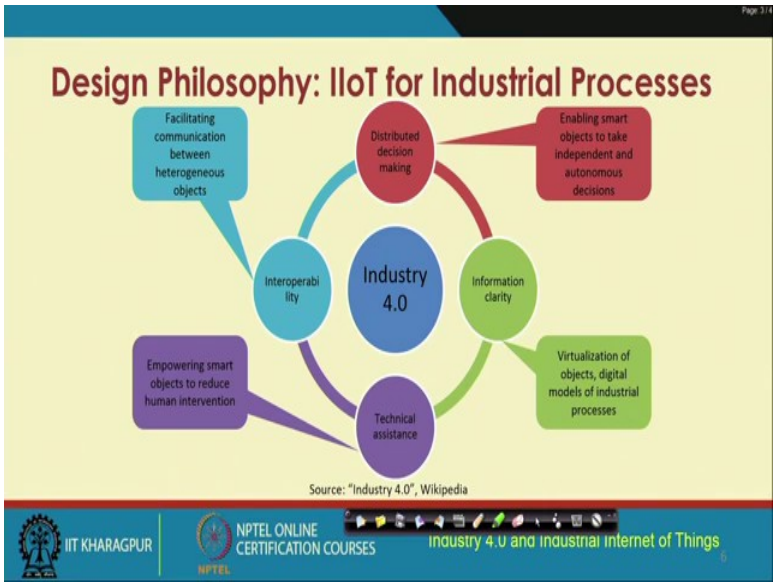

So, let us look at the design philosophy behind the inclusion of IIoT for improving the industrial processes. The first thing, so there are four different facets that we have considered. Number one is interoperability, second is distributed decision making, third is information clarity, and fourth is technical assistance. So, let us take up one by one.

Interoperability is about facilitating communication between heterogeneous objects facilitating communication between heterogeneous objects, heterogeneous machinery running different, different, because these are now smart objects. In the IIoT world we are talking about smart machinery and smart objects. These are all heterogeneous. And now you want to have communication between them, and that is what is the objective of Industry 4.0.

The second thing is distributed decision making, because these different machineries the physical objects and so on. They are now interconnected in the Industry 4.0; they are all interconnected. So, distributed decision making will have to be done. So, each of these different machines will locally perform certain decisions themselves, certain analytics will be performed in them individually plus together also they will have to do something, for the holistic good.

So, the third one is information clarity, where we are talking about the visualization of the objects. So, basically all these different objects, the digital models of these different objects, the data that are procured from these objects, these will have to be visualize, the

data visualization aspect of it for information clarity. This is what is the third component of the design philosophy. And the fourth one is the technical assistance. And here we are talking about empowering smart objects to reduce human intervention. And this kind of technical assistance will also have to be incorporated into the design philosophy of IIoT for industrial processes.

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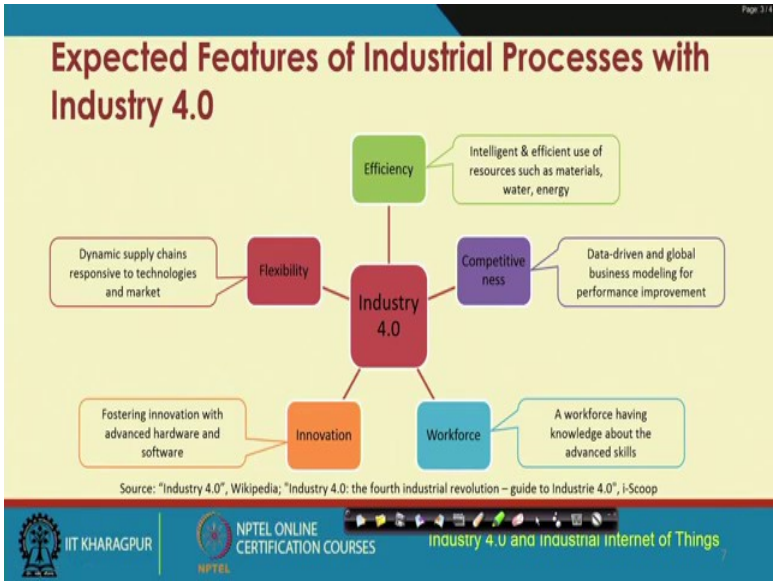

So, what are the expected features of the industrial processes with Industry 4.0, what are the expected features, what is going to achieve, what is going to be achieved. So, number-1 is efficiency. So, we are doing everything in order to improve upon the efficiency, of course that brings in challenges like the ones that I just mentioned a while back, but overall the efficiency in the industrial processes are going to be improved with the incorporation of Industrial IoT.

So, basically efficiency means like, we are talking about intelligent machinery, performing things efficiently. So, basically, even if you are talking about resources, efficient utilization of energy, efficient utilization of water, or other resources, and other materials that are used. These are all going to be efficient, and the reduce consumption of all these resources is also going to happen, with the incorporation of Industrial IoT. So, overall efficiency resource utilization, reduction in resource utilization, these are the things that are going to come with the incorporation of Industrial IoT.

Second thing is competitiveness. In the Industrial IoT era is that everything is going to be data driven, data are going to come from all these distributed machineries. And this is not going to be just local within a particular industry, but across different industry, and also you can scale it up to the global level. So, global business modelling for performance improvement is what is desired. So, everybody is going to compete with one another, but the data will serve as a basis for improving upon this competitiveness individually by each of these different industries.

Third is the work force. Here we are going to talk about is skilled workforce, which will have advanced skills in all these domains of IIoT, and that knowledge has to be built up. So, this is the third feature. The fourth feature is about innovation. So, in overall what is going to happen is through the incorporation of hardware, software, and the connected behavior between these different objects. You are going to foster innovation, and improve upon the efficiency. These are also interconnected. So, improve upon the efficiency through this innovation.

And finally, the flexibility this is also a prime feature of the incorporation of IIoT for improving upon industrial processes. This is flexibility about having dynamic supply chains, which are responsive to technologies, responsive to market changes, and so on. So, these are the different features of expected features of industrial processes for Industrial IoT or Industry 4.0.

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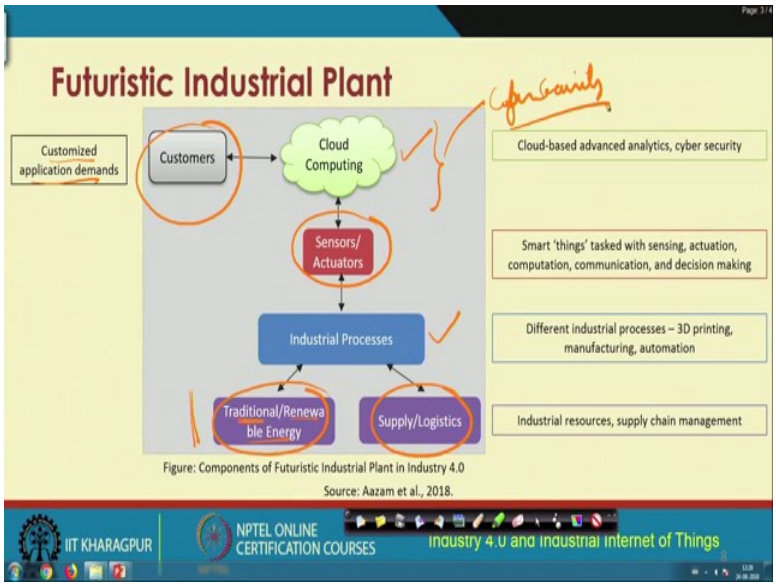

Figure: Components of Futuristic Industrial Plant in Industry 4.0
Source: Aazam et al., 2018.

So, let us look at in the IIoT world, how a futuristic industrial plant typically is going to look like. So, what we are going to have is something like this, we are going to have different energy sources, traditional energy sources, or the renewable energy sources. And renewable energy sources like solar, wind. And traditional means like whole-based energy, electricity, and traditional forms of electricity, plus you have all these different energy sources plus these supply and logistics. So, industrial resources, supply chain management, these are considered in this particular layer. So, these will help in improving these industrial processes. Different industrial processes in this layer will be considered like manufacturing processes, automation, 3D printing, and so on. So, these industrial processes with the help of these traditional or renewable forms of energy plus supply and logistics these are all going to show in this data, and with the help of the sensors and actuators, this data are going to be in fact collected.

These smart objects, the smart things, the smart machinery will be touched with sensing, actuation, computation, communication, decision making. And all these data will be sent to the cloud for further analytics. So, based on the analytics, the customers based on their customized application demand are going to get all these different services.

So, cyber security is also another consideration. And particularly in the context of cloud, people have lot of considerations about cyber security. And cyber security is something that we have already talked about in the context of Industry 4.0. So, cyber security is a fundamental consideration, because people do not want to, people are very much considered, very much concerned that the data that are coming from all these different machineries in different industries. They should not be compromised either through the network through, which the data are flowing or wherever the data are being processed, at the cloud end. So, cloud security is a very important consideration in the context of Industrial IoT.

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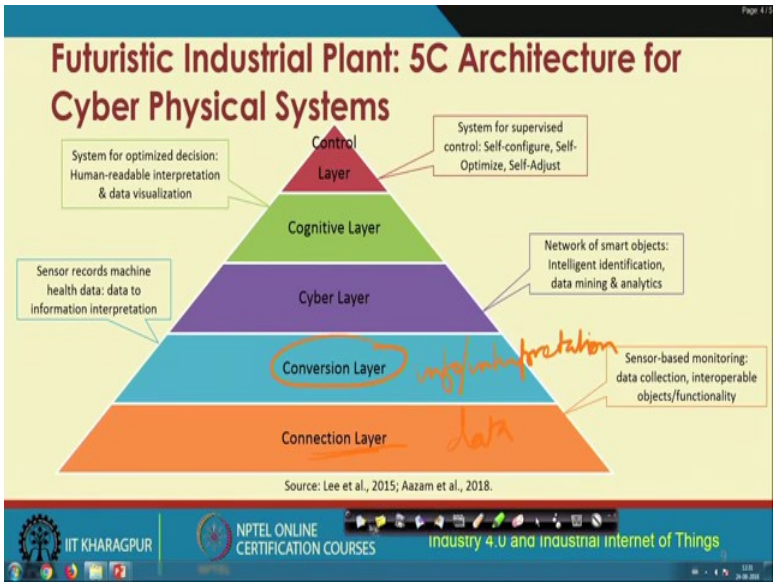

So, when we are talking about this kind of futuristic industrial plant, the 5C architecture. And this is actually an architecture, which has been proposed for cyber physical systems. And when we are talking about Industrial IoT, the connected machinery that we are talking about having all these smart interfaces through sensors and actuators.

So, what is going to happen, these machineries are all going to behave as cyber physical systems. And what is a cyber-physical system? That we have already seen in a previous lecture, what is a cyber-physical system, and the different properties of it, we have already seen in a previous lecture, we have understood what is cyber-physical system is, but now we need to understand that what are the different considerations from an architectural view point for these futuristic industrial plant, which use these cyber physical systems and IoT.

So, we will start from the connection layer. Connection layer is talking about the use of different sensors, the sensor-based data collection, interoperability, issues of objects, physical objects, smart objects, functionality of these different objects, all these are issues at the connection layer. Then comes the conversion layer, here we are talking about sensor records, machine health data monitoring, prediction, information interpretation, and so on. However, in this layer we are talking about the conversion of the data into information, and its interpretation. Then comes the cyber layer, and the cyber layer is talking about this networking aspect of it, network of smart objects,

intelligent objects, which will need some kind of an identifier, and from this objects the different data are going to be retrieved. And you need to run some kind of analytics to mind the data that is received to you need some kind of analytics, and basics of analytics also we have already understood in a previous lecture.

And then the cognitive layer, cognitive layer basically talks about having systems for optimized decision making. So, here we are talking about data visualization, human-readable interpretation, and so on. And finally, the control layer, this basically talks about actuation control, supervised control, then self-configuration, self-optimization, self-adjustment, which are different in different perspectives in the control layer. These are all important considerations in the 5C architecture for cyber physical systems.

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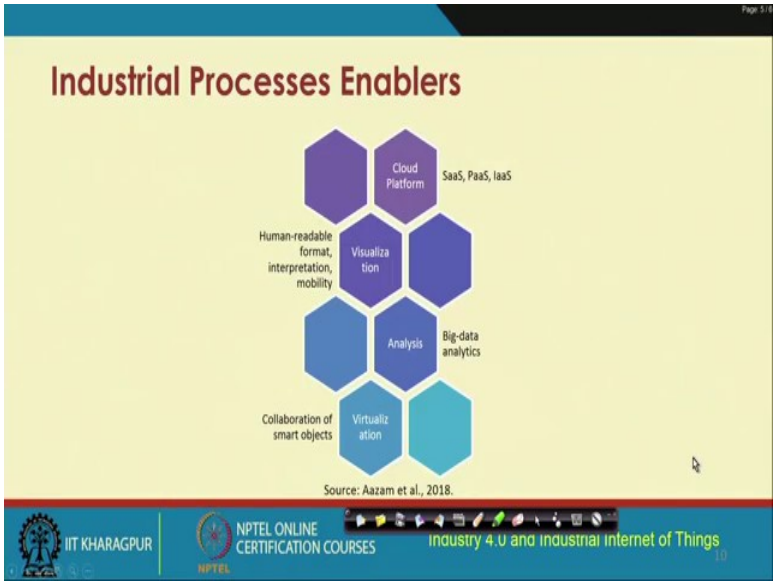

Now, what are the different enablers of the industrial processes in the Industry 4.0 concept different things, cloud platform offering different services like software-as-a-service, platform-as-a-service, in infrastructure-as-a-service.

Second is the visualization aspect, which is about receiving the data, reading the data, interpreting the data and so on. Then comes the analysis which is about use of different analytical method statistical wants big data, machine learning-based analytics. And finally the virtualization, which is about the collaboration of the smart objects, which are the different enablers of industrial processes.

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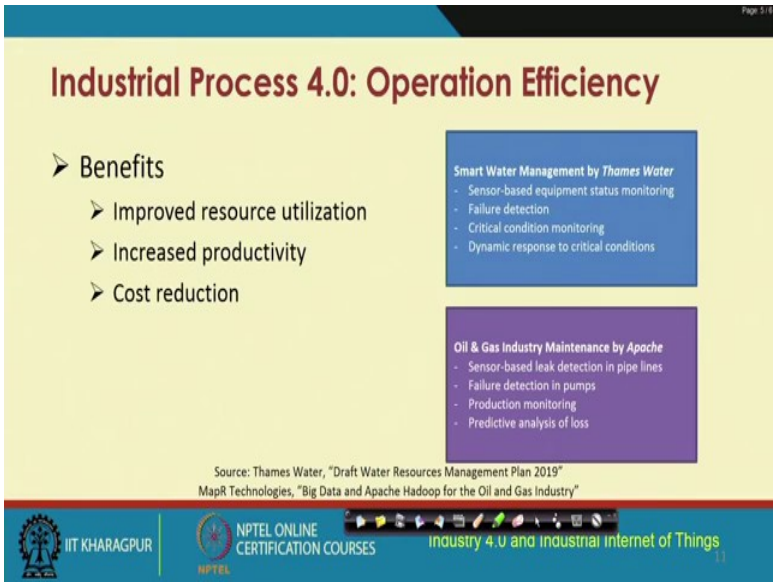

Now, let us look at one by one the different the different aspects of the industrial processes in the Industry 4.0. So, the first one will start with is operational efficiency. So, operational efficiency will have to be improved, it gets improved with the incorporation of Industrial IoT for Industry 4.0 in the industrial processes.

So, the benefits that are going to be resulting from this kind of transitioning is that we are going to have improved resource utilization. So, all these different resources, the machinery. The utilization of these resources are all going to be improved in the Industry 4.0 world. Second is that the overall productivity through the use of the industrial processes in the Industry 4.0 are going to be increased. There is going to be increased productivity in the industrial processes, and cost reduction.

Some of the examples of different industries, which I have used the solutions are Thames water for smart water management. Apache for oil and gas industry maintenance, and the different innovations that they have had in terms of the incorporation of IIoT, these are all mentioned in front of you.

So, these are basically they start with sensor-based equipment monitoring--the status monitoring, detection of failures, critical condition monitoring, and dynamic response to any kind of critical condition, that might be happening that happens for any kind of this kind of smart systems developed by all these different industries like Thames water by apache for oil and gas industry maintenance. So, it will start with the monitoring status

monitoring, failure detection, control critical condition monitoring, and the dynamic response to critical conditions.

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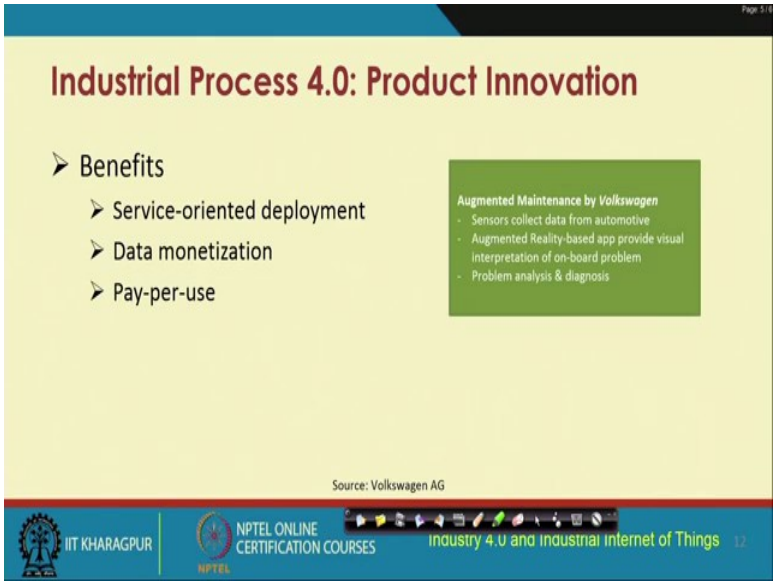

Product innovation; the benefits are service-oriented deployment, data monetization, all these data that are going to be retrieved huge volumes of data these are very much resource full. So, data can be used, it can be monetized. And companies like Volkswagen have already benefited out of it. So, they have started with the augmented maintenance, where they are talking about the use of technology is like augmented reality, and smart sensors, to improve upon the detection of different problems on board these machinery, and also the analysis and diagnosis of the different faults that are going to happen in these different machinery. So, product innovation is going to happened through this kind of transformations. And Volkswagen or augmented maintenance is an example of such kind of product innovation.

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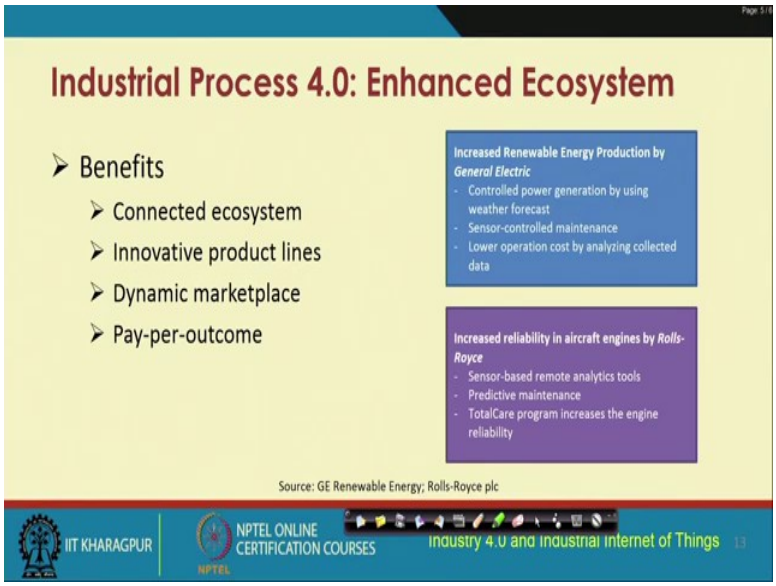

Third is enhanced ecosystem, the benefits are that we are going to have a connected ecosystem, where there are going to be innovative product lines, supporting dynamic marketplace, and there is going to be pay-per-outcome kind of ecosystem. So, pay per outcome means based on the outcome the users are going to be the users are going to be built, and they have to pay per the outcome that they are going to receive, company is like General Electric, they have come up with increased renewable energy production.

Then another company Rolls Royce increased reliability in aircraft engines, and this also they have achieved through a number of different mechanisms, and these are the different features that have been given for each of them. So, I am not going to mention them over here explicitly, but these are the different features for each of the systems that are produced by these companies like general electric and Rolls Royce, who basically supply the engines for the different aircrafts.

But, as you can see over here; here also you have sensor-based monitoring, predictive maintenance, then total care is basically there program, which increases this engine reliability in Rolls Royce. So, these are some of these things that they have achieved through the incorporation of IoT in their industrial processes.

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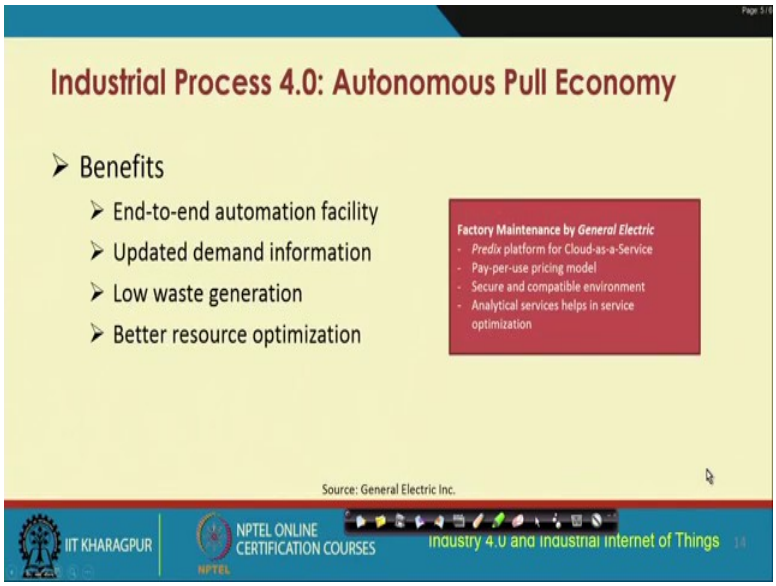

Next comes autonomous pull economy. Here the benefits are that we are going to have end-to-end automation facility, updated demand information, low waste generation, low waste footprint overall, this is very important, low waste footprint, and better resource optimization. So, the company general electric, they have come up with their factory maintenance system, which basically achieves these features through the incorporation of IIoT.

They have come up with a platform which is the Predix platform, they use this platform for offering cloud-based services. They have a pay-per-use pricing model in this particular platform. They have a secure and compatible environment for use of factory maintenance and analytical services, that helps in service optimization. These are the different features of the factory maintenance system by general electric, which is the Predix system.

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So, essentially we are transforming into the future, where we are going to have smart factories. And the different application areas for the smart factories are smart facility management, connected factory, inventory management, so basically smart inventory management, smart production line management, smart process safety and security, smart service quality control, smart supply chain optimization, and smart packaging and management. These are the different applications of the incorporation of IIoT and the industrial processes the different industrial processes for building IIoT based systems in the Industry 4.0 scenario.

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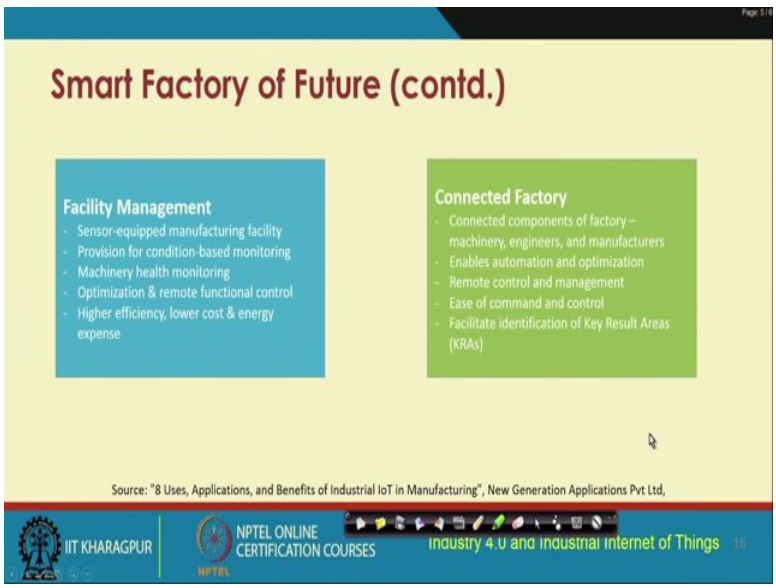

So, these are the ones like facility management, here we are talking about sensor equipped manufacturing facility. There would be provision for condition based monitoring, monitoring of machine health, optimization, and remote function control, and improving upon the efficiency, lowering the cost, and the energy expense.

Connected factory, here we are talking about connected components of the factory such as the machinery components, engineers will also be connected manufacturers will all be connected. So, it is not just machinery, but engineers, manufacturers, machinery, everything connected together in a smart factory. Enabling automation and optimization, remote control and management, ease of command and control, and facilitation of the identification of the KRAs, are the key result areas.

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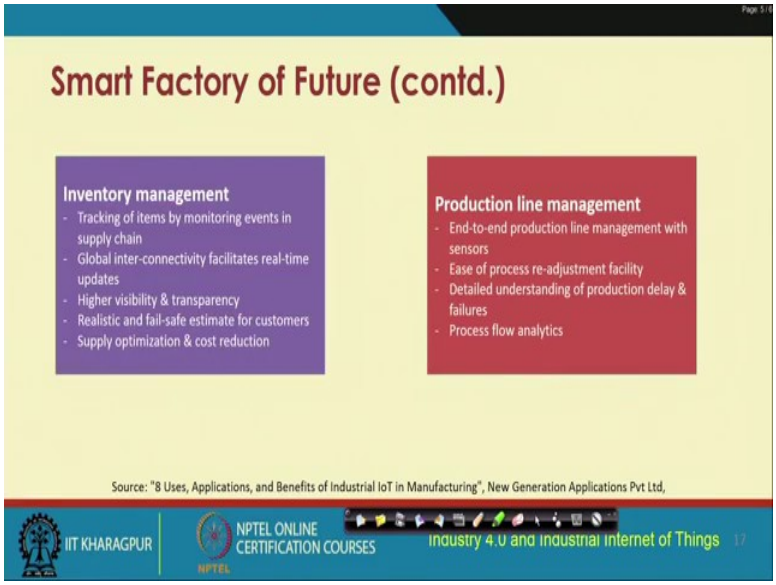

Inventory management, it talks about tracking of items by monitoring events in the supply chain. Global inter-connectivity facilities in real-time, and providing real-time updates. Higher visibility and transparency, a realistic, and fail-safe estimate for customers, and supply optimization, and cost reduction.

Production line management here we are talking about end-to-end production line management with different sensors, actuators. Automating the entire product line; then ease of process re-adjustment facility, detailed understanding of production delay and failures, and process flow analytics.

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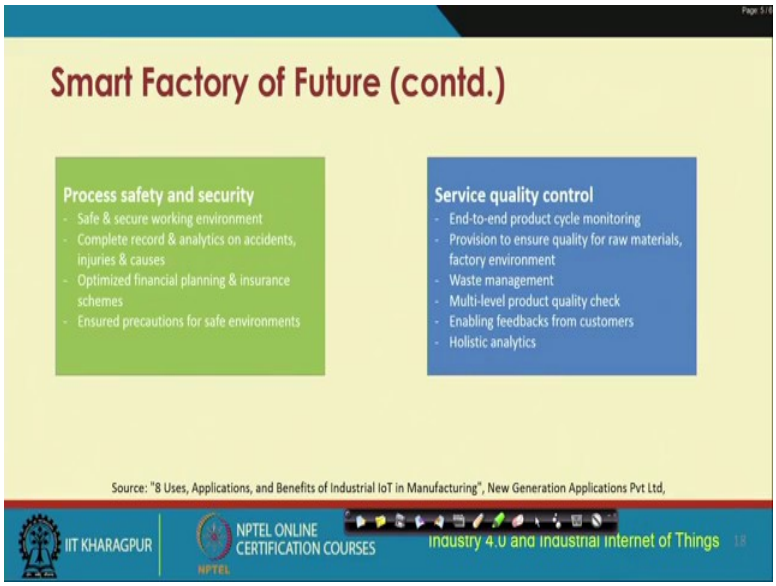

Process safety and security, here we are talking about safe and secure working environment. Safe and secure processes, safe and secure environment, these are all going to be performed with the help of these different IoT devices, these different sensors actuators. And we are going to get complete record based on the data that are received from these different IoT devices. And this will help in financial planning, optimized financial planning and insurance, planning about the insurance schemes that will have to be used.

Service quality control is another one, which is about end-to-end product quality life cycle monitoring, product life cycle quality monitoring, provisioning to ensure quality of raw materials that are procured, factory environment, monitoring and automation, waste management, reduced waste management, multi-level product quality check, holistic analytics, enabling feedback from customers. So, all of these things, the service quality aspects, and the control of them are all going to be performed with the help of smart factories.

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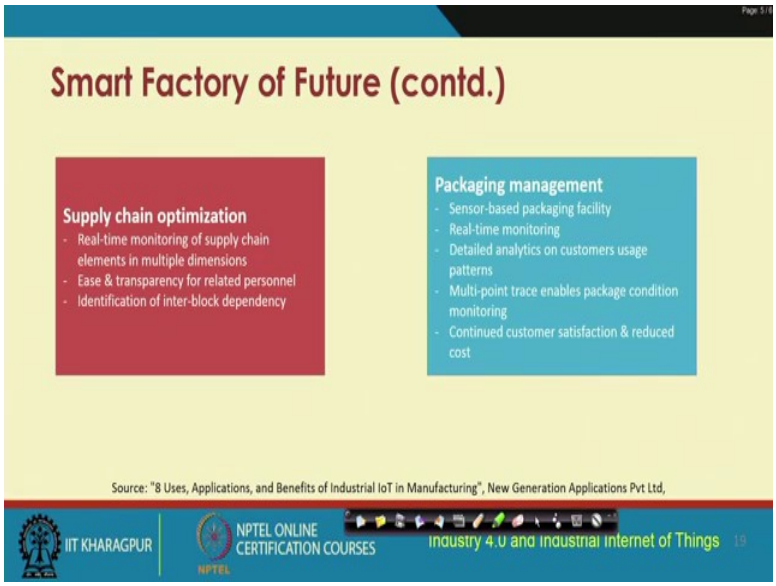

Next comes supply chain management and optimization. Here we are talking about real time monitoring of supply chain, elements in multiple dimensions, ease and transparency for related personal, and identification of inter-block dependency. Packaging management talks about sensor based packaging facility, real-time monitoring, detailed analytics on customer's usage patterns, multi-point trace enabling package condition monitoring, continued customer satisfaction, and reduced cost.

So, multi-point trace means what? Like tracing basically if a particular package is lost, where it is lost, not only lost if it is misplaced. All these tracking and from multiple points tracking of these different packages would be possible in a smart factory. And this is a common problem actually, tracing and tracking is a common problem in factories, and through the use of smart factory IIoT, the industrial processes will help in this kind of tracking affairs.

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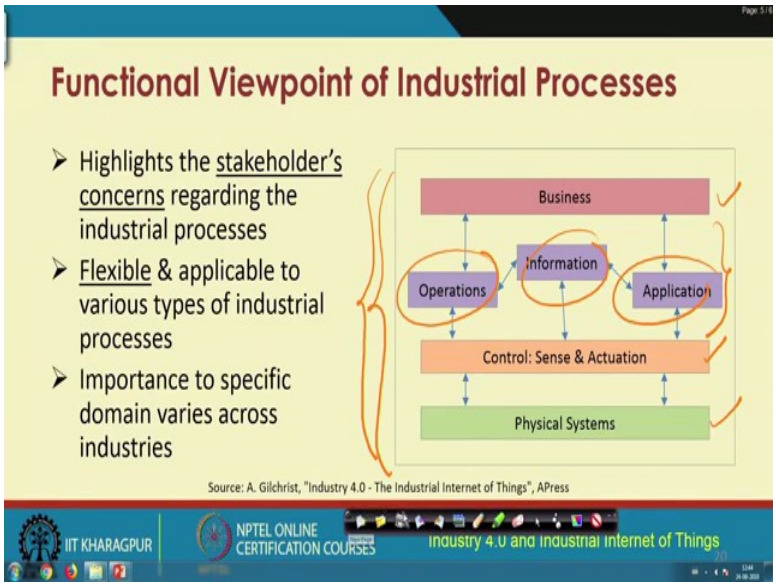

So, now let us look at the functional viewpoint of industrial processes. So, physical system, then we have the control, which is basically talking about sensing and actuation, and on top we have business layer. So, in between we have the operations, information, and application, which will basically help in growing up this entire model.

So, basically we are talking about highlighting the stakeholder's concerns regarding the industrial processes, and flexible and applicable system for use of various types in the industrial processes. So, all these things are going to be performed with the help of this kind of functional viewpoint architecture of these different processes industrial processes in the Industry 4.0 world.

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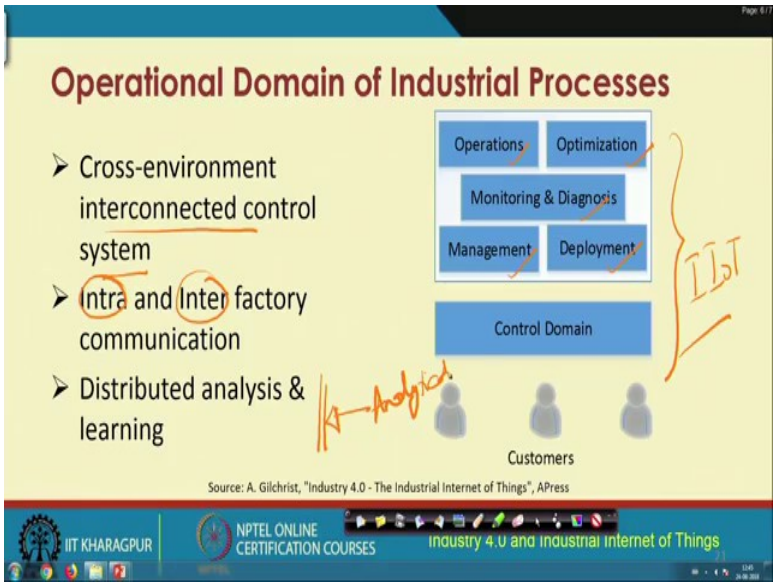

The operational domain of the industrial processes includes the control domain, the management, deployment, monitoring and diagnostics, operations, and optimization. These are self-explanatory, so I do not need to explain them further, but what we are going to have is a cross environment interconnected system in the IIoT world. And that is where this interconnected control system is also very important interconnected control system.

And so we here because it is interconnected, if we are talking about not only intra-factory communication, but also inter-factory communication. And all these data from inter-, intra-factory communication. Those will have to be analyzed, and different kinds of analytics will have to be executed with the help of statistical methods and different other machine learning and AI techniques.

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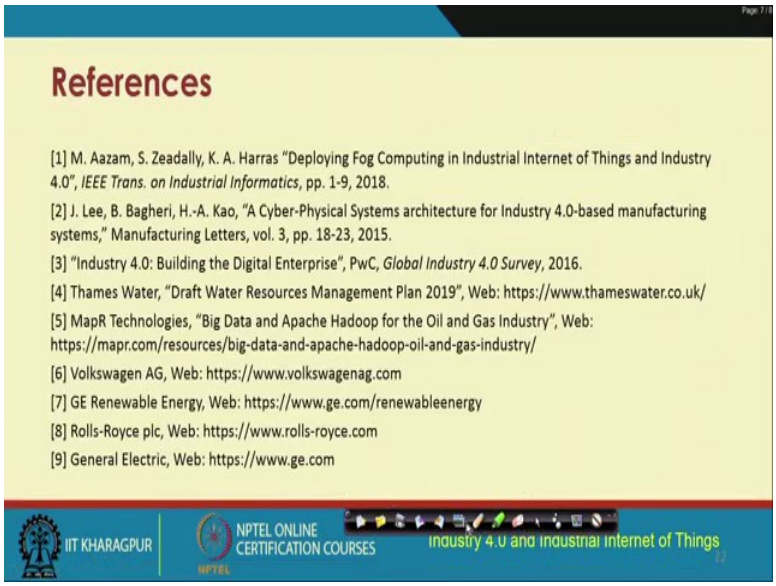

So, before we go to the references, I wanted to show you something at the end to highlight the importance of (the importance of) the incorporation of IIOT in the industrial processes.

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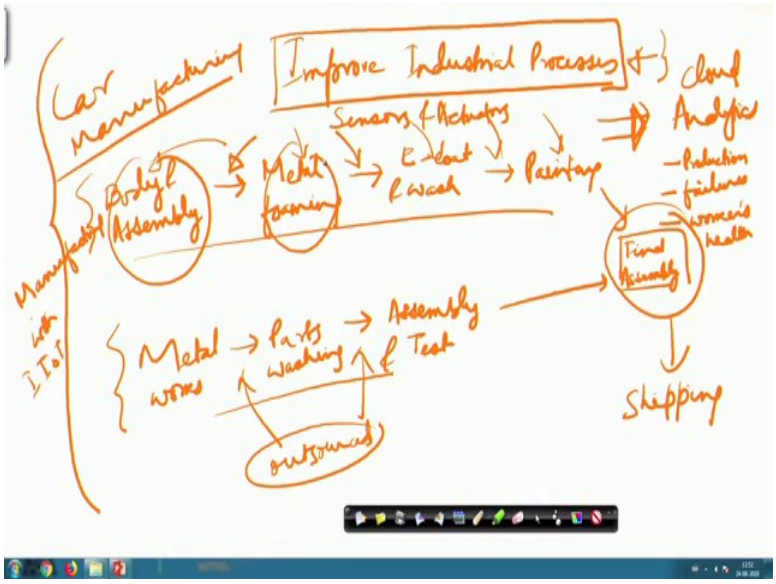

So, we want to do what, we want to improve industrial processes this is the overall objective. So, industrial processes are varied depending on different industrial requirements, different industries have their own set of processes. So, industrial

processes are different. So, let us take the example of a car manufacturing process; car manufacturing process.

So, here we are talking about, let us say just an example body and assembly, body and assembly. Then thereafter, we will have something like metal foaming, these are this is a typical traditional process in a car manufacturing plant. Then something like a layer of coating e-coat and wash, then painting, full painting, of these different machinery that the different parts and so on.

In parallel, there would be metal works, their needs to be parts washing, there needs to be assembly and test, and after all of these things together, so this row, as well as this row together, finally will give you the final assembly. So, what we mean is these processes, they are going to be performed in parallel and together will get into the final assembly. And after final assembly, it will be shipping. So, this is a very broad high level view of the industrial process, a traditional industrial process, in a traditional kind of car manufacturing industry.

Now, let us look at we want to make it smarter, we want to make it smarter with the incorporation of IIoT. So, we want to use these different IIoT components, sorry, in this IoT components in it in order to have improved industrial processes, which will have better efficiency, and manageability, product production is going to be improved and all these different features that we have talked about in this lecture earlier, so going to have that.

So, now if you want to do this, these are the things that you can do. You could use table sensors over here sensors and actuators, you could use different sensors and actuators here and not only in these different transitions, but also in each of these different phases. So, throughout you can use the suitable sensors and actuators.

So, this will continuously monitor, and do any kind of actuation that might be required. So, sensors and actuators will do the continuous monitoring of these different units and the different phases. Likewise, here also you are going to have all of these. So, this will be like let us say that these are outsourced, they maybe outsource or they may not be outsourcing.

So, even if they are outsource component, but with the help of these different sensors and actuators, and different other monitoring units, you could be end-to-end this continuous monitoring could be performed. Now, what is going to happen, these sensors and actuators are going to throw in lot of data. From this data you can run different analytics.

And these analytics could be run at different server, server forms or whatever or in the modern day we can used cloud-based services for these analytics. So, we can use cloud-based analytics. So, we could use cloud, and we can come up with different predictions about let us say production predictions about the future production rate, production rate, we can have predictions about failures. We can have predictions about workers' health, and we can do monitoring of the different the health condition of these different machinery.

So, essentially what we are doing is that this is the example of use of IIoT in a typical car manufacturing with IIoT. So, the previous one was without any sensors, actuators, without any kind of computational facility, no cloud, no analytics, nothing. Some maybe if you are talking about Industry 3.0, some individual components might be using separate computers separately, but in the Industry 4.0, we are talking about this holistic connectivity.

And holistic monitoring lots of predictions autonomous behavior of the systems, autonomous monitoring, maintenance, prediction everything together of these different industrial processes. So, this is the example of how IIoT can transform, and improve upon the existing industrial processes for improving the productivity, efficiency and safety.

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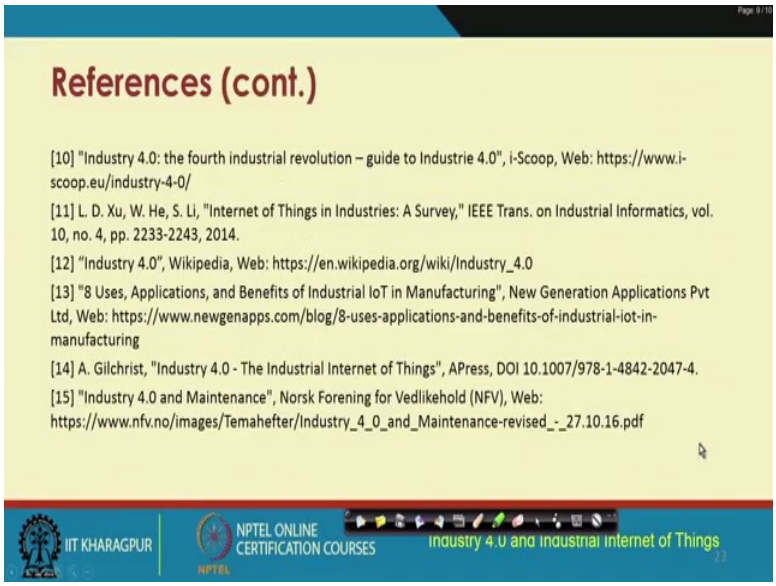

Now, let us go back and look at the differences that we were talking about, these are the list of different references. And if you are interested, and I would encourage you in fact to go through some of these references to have further understanding about the industrial processes, the different aspects of it, what are the I know in this particular lecture, we have talked about the car manufacturing.

But, I would also encourage you to look at other industrial processes, particularly if you are taking a course, and you come from a particular industry sector like car manufacturing could be coming from different are the industrial sectors. Like let us say steel plants or, food processing industry or, pharmaceuticals industry. You can also think about how you can transform your existing processes in your industries to be more modern efficient with the incorporation of IIoT, and trying to be compliant with the expectations and objectives of Industry 4.0.

Thank you.