The Future of Manufacturing Business: Role of Additive Manufacturing

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Lecture – 20
Blockchains and Use Cases

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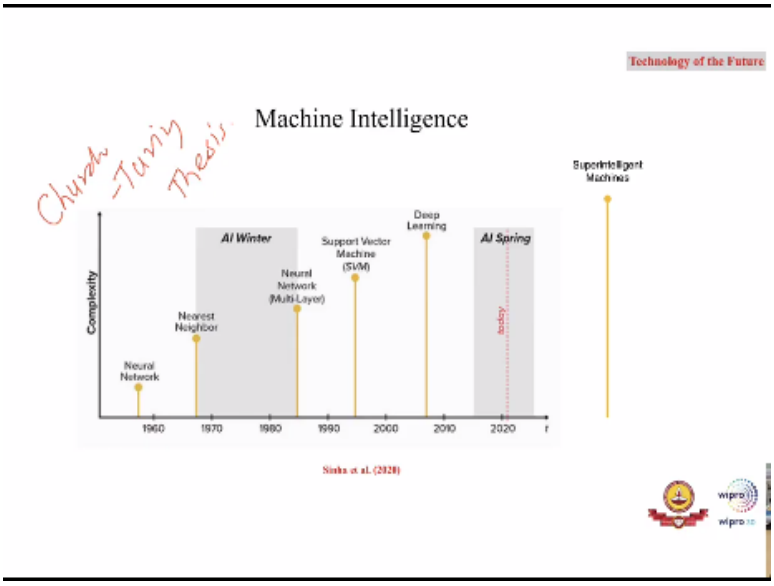

Alright, so welcome back. So, if you recall, we talked about the Nash equilibrium and what actually constitutes machine learning. I will just spend maybe two minutes on. I have taken it from a recent book by Sinha et al. (2020). You can actually see the complexity and the time progression of machine intelligence and maybe what is the most dominant algorithm.

As I mentioned in the previous session, the things started, maybe 1956. You can see neural network. There would an AI winter then we are talking about AI spring these days. So, you have deep learning algorithms. But the future would be we are looking for super intelligent machines.

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Machines, which can allow us to meet, their action should be such that they achieve our optimal objectives. So, they just do not achieve their objectives. They should not just achieve our objectives, but they should achieve our optimal objectives. They actually sense the environment and decide what is the best action for us. So, we need computability of that order.

In fact, this could be highly philosophical. I do not want to spend too much time on that looking the course objective is, the focus is more on manufacturing. But if you are keen maybe look at Church - Turing Thesis. So, I close the machine intelligence part. Certainly, I think each of these algorithms like deep learning, you can actually see courses on that. So, that is not something which I really want to emphasize as part of this course.

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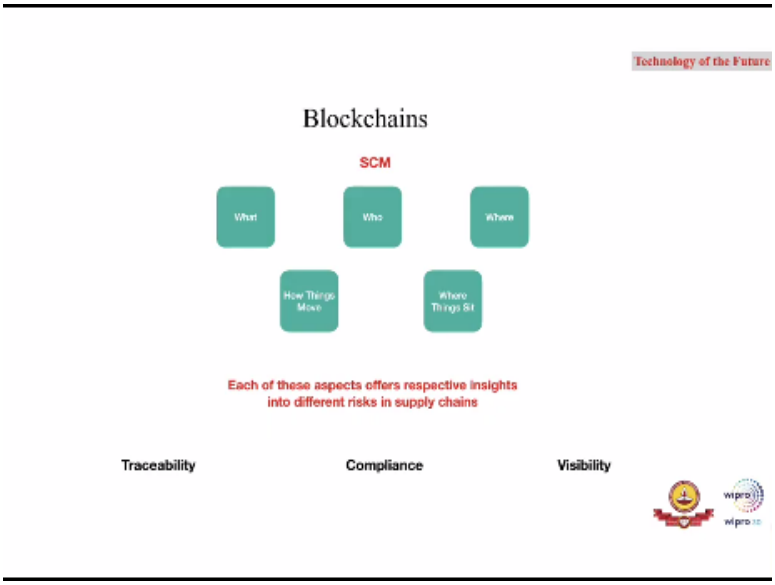

But what would be relevant for me to actually see how the blockchain as a technology can help the manufacturing context. If you recall, we talked about the manufacturing objectives, which was again the flexible, cheap, diverse, better, and sustainable also. So, five objectives there and for supply chain also I think these are the five important primitives.

What goods are moving? Who is the buyer or who is the seller? Where it has to go? Where to locate? Then two things where things move or sorry, how things move. So, you talk about logistics and where things sit. You talk about inventory. These five primitives become the part of supply chain and each of these aspects offer respective insights into different risk and supply chains.

So, I think I mentioned in the previous sessions that the supply chain of a company like Intel, they could not trace the supply chain beyond two or three tiers when the Japanese earthquake came in 2011. So, what it actually brings is, you are looking for traceability, compliance, and visibility. So, I can trace from where that material is coming.

I can trace, so I want that all the compliance part should be taken care. So, lot of regulatory requirements may be there. You can think of even Tesla recently announced that they want to come up with a zero cobalt battery and the main objective is because the cobalt supply chains are still not fully traceable. So, if there is a compliance requirement that it should come from ethical sources.

Let me also add that large number of cobalt supply chain, the origin goes to Congo and you would actually see lot of child labor is involved there. We want at all those things should be avoided in the supply chain. So, you want traceability, you want compliance and you want where the goods are sitting? How much is the delay? What are the quality issues? All those things should be visible.

So, these three things become a part of the story of the modern supply chain management and I think we extend this argument to digital supply networks also.

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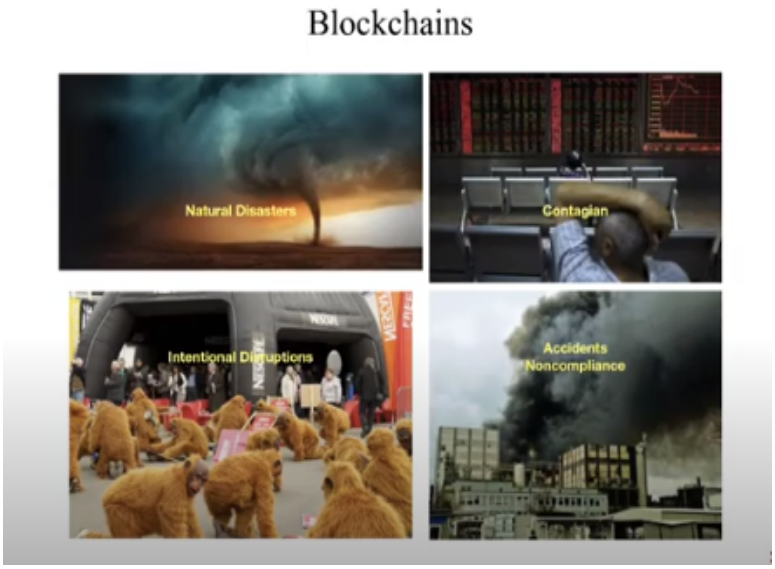

These are some of the risk. COVID times, you would see lot of discussion on resilient supply chains. Can blockchains allow us to make that? Can blockchains allow us to achieve that? So natural disasters, you can think of national disruption, accidents. So, I am pretty sure if you start mining, you would relate to lot of examples like this.

So where you see lot of risk, which comes in achieving these supply chain objectives.

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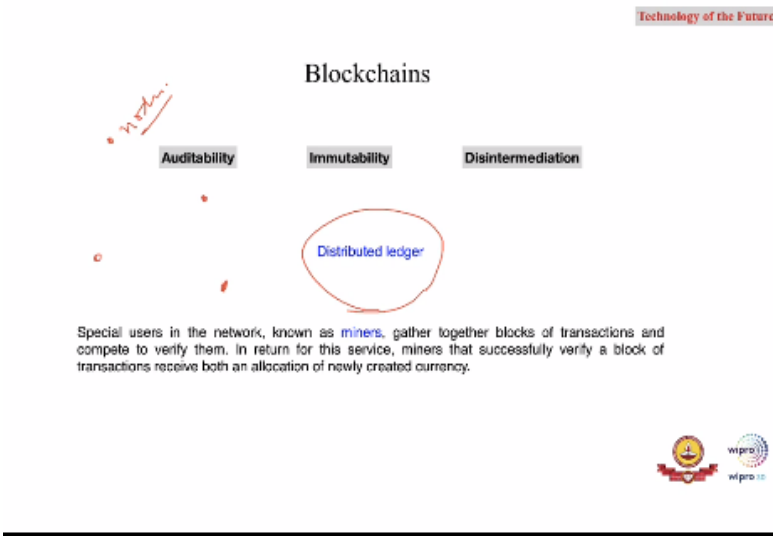

Now, I will go slightly deeper into that. When we talk about supply chains, when we talk about blockchains and supply chains, distributed ledger is something which most of people associate when we talk about blockchains. We have spatial, so we are talking about now network. There could be a network where so you can think of a network something like this.

Some of these could be nodes and some of these nodes could be miners also. So, what they do is, so they actually gather blocks of transactions, and they actually compete to verify them. I think I will explain all these things and in return for their service. Miners that successfully verify a block of transaction achieve both an allocation of newly created currency.

So, for a distributed ledger, I will give you an example. Like if you have to transfer a money to some other bank account, a request you send to your bank. The bank will give it to a centralized ledger, maybe sitting in the RBI and then it is verified that you actually have that money and it will be transferred to the other bank's account. So, it is done through a centralized ledger.

But now we are actually saying there is a distributed ledger. So, all these nodes could be part of the distributed ledger. In this case, the verification is not centralized, it is in the distributed manner. Only thing you have to ensure that no single node is powerful enough to change the ledger and that is where all this part auditability, immutability and disintermediation comes in.

It means that you can easily verify. It should not be immutable, means no one else, one person can be powerful enough to change that thing and it should not be centralized. You want no intermediation there. So, you just want that everything should be distributed and this actually, so you have to come up with some kind of a mechanism where you achieve all these things at the same time and that is where the whole notion of blockchains comes into the picture.

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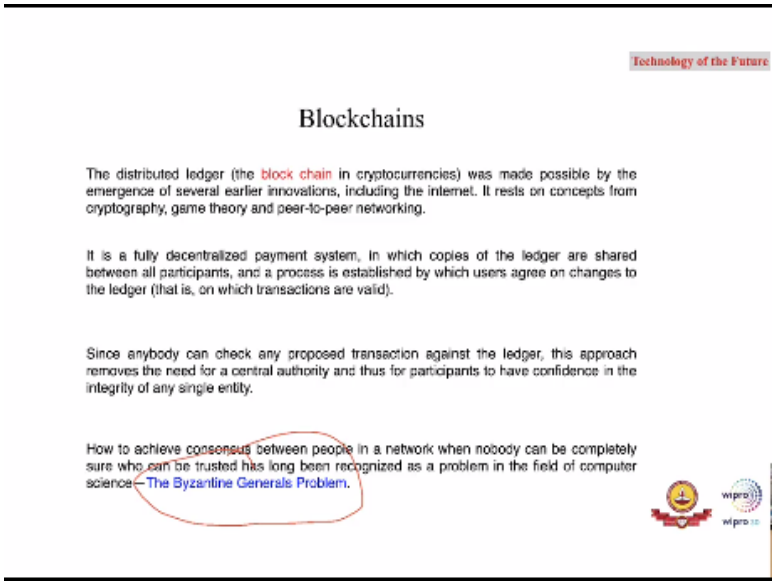

As I mentioned that we use some ideas of game theory. In fact, the main idea of game theory is to avoid that peer this cheap talk. Distributed ledger, in fact we sometimes called blockchain. Blockchain and cryptocurrency could be you can say cryptocurrency could be a subset of blockchain. Was made possible by the emergence of many innovations, which include the internet.

So, it rests on concepts from cryptography, Game Theory and peer to peer networking. It is a free decentralized payment system. I am now emphasizing only on the bitcoins part, in which copies of the ledger are shared between all participants and a process is established by which users agree on changes to the ledger. So, to make that transactions valid.

Since anybody can check any proposed transaction against the ledger, this approach removes the need for a central authority and thus for participants to have confidence in the integrity of any single entity. How it is done? In fact, this problem is coming

from the medieval times. It is called as the Byzantine Generals Problem. So, people in computer science may be aware of this.

But the main idea here is that it should be decentralized and no single entity have the power to change the ledger.

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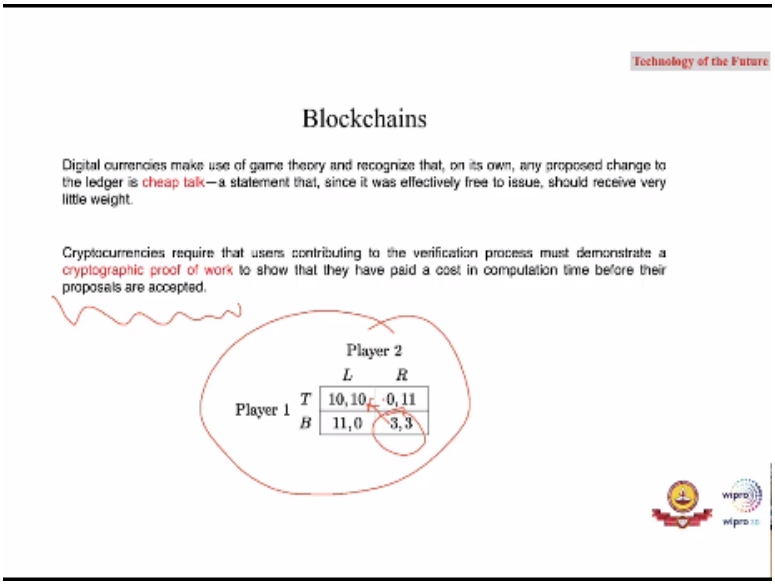

So, as I mentioned that we use ideas from Game Theory and we call it a cryptographic proof of work, which ensures that the agents who are the miners should not be involved in the cheap talk. Let me see whether I have put that thing. This example we already have seen as part of our game theory discussion that players can communicate to each other that we are going to play T, L.

But when the game is played, you again converge to Nash equilibrium. So, you want to avoid this cheap talk of communication, which is T, L. You want to come up with some kind of a mechanism or incentive mechanism, which ensures that you do not do this cheap talk and that is where this cryptographic proof of work comes into the picture. So maybe I will explain it in the subsequent slides, how that thing works.

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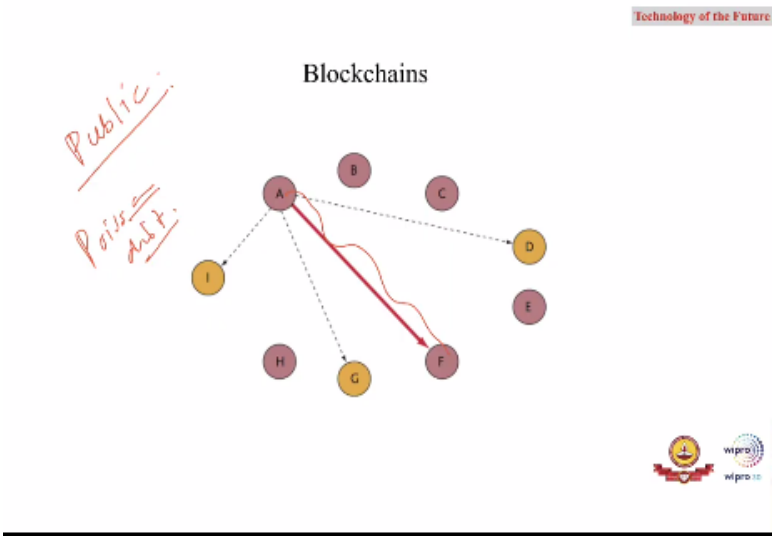

Let us take this as a network. Now, there are all this A B C, D E F, these are the nodes in that network and all these nodes are connected. All these nodes are well connected. Now there is a transaction which is happening between E and F. This red line you can actually see as part of the transaction and D, G and I are the miners in this case. So, the whole ledger actually sits on a tree.

In fact, it should be available on all other nodes also. But these are the miners. So, what they do; they actually do the verification of this transaction, whether A actually has ample money, which can be transferred to F. So, there would be history of how A achieved that money and that is also part of the ledger. Now all this information come as part of blocks.

You cannot change a block unless or until all the miners agree that it can be changed. It means that they actually have to come up with some kind of a consensus to change the ledger. Now the point here is whether they can actually do the cheap talk. To avoid that thing, they actually have to spend some time in. So normally, what is the value of the hash?

It is more like a puzzle for them, which can actually be done by trial and error. The puzzle is developed as part of the network. It follows some kind of a Poisson distribution and it takes about 10 minutes to solve that puzzle. On a average, that is the meantime and once you solve it, you communicate to all the other nodes in the network.

So there is a and then so if it turns out to be correct, your puzzle turns out to be correctly solved. Then you will actually be paid for it. Now this creates some kind of an incentive problem, because you actually have to spend and you may not be the only one and the complexity of the puzzle actually keeps on increasing. That is actually part of the architecture.

Now the point here is that it is not you can say cheap for you to just communicate something that this has been verified. You have to spend something; some effort has to go and you need computing power. All the other nodes are competing because you are actually paid for it. You want to do it as fast as possible and let others also do the verification.

Let me also add that all these nodes are anonymous. In fact, the example which we are giving is of the public blockchain. There would be permissioned blockchains also. In fact, I think Unilever actually implemented the permission blockchain as part of the digital supply network. In this case, we are talking about a public blockchain and in this case, all the nodes are anonymous.

So, you do not know where that replica sits. This actually solves this problem of the incentives to avoid the cheap talk.

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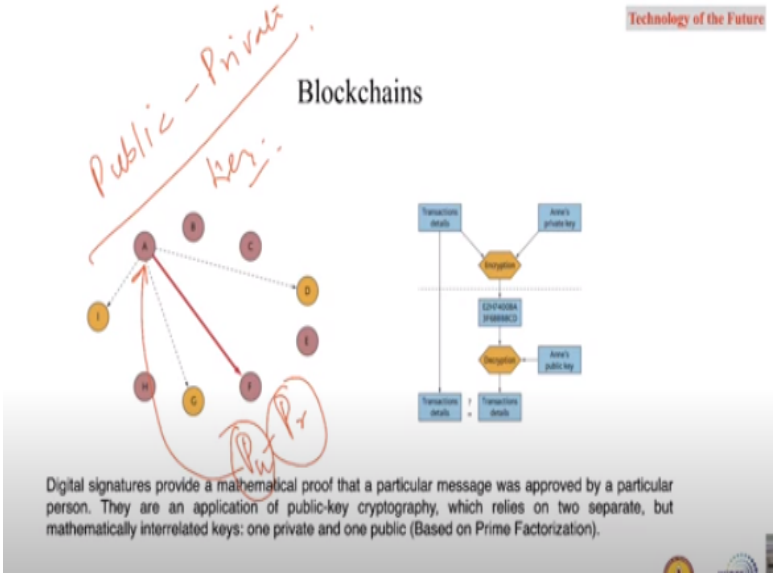

You can actually see, you can think of an example where so I will give you so we are going to talk about public, private cryptography and what happens is, if you assume that you have to do a transaction from one person to other person, like in our case for A to F. F may generate, let us start with F. So, F will generate a pair of public and the private key.

Private key will stay with F and this public key will go to A and A will attach that the digital signature and it would actually come back to F. Now even if someone knows the public key, they cannot actually generate the private key out of it. But if you know the private key you can generate a public key. So, one public and one private key.

So, even if you know the private key, you can generate the public key, but the converse is not true. So, even if the public key is known to all the other agents, they cannot verify, what is or they cannot generate what is the private key. This is something, so I give you an example how this whole thing work.

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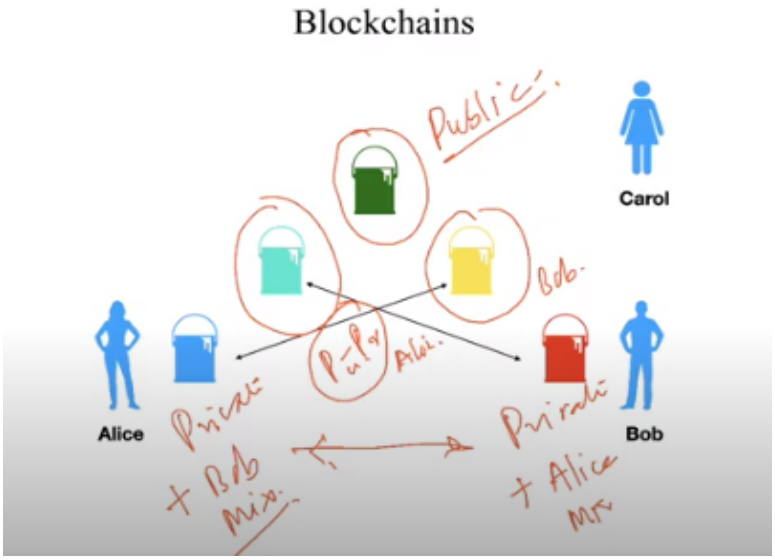

I will take maybe a simple example, which can illustrate this idea of what I am saying of the public and the private key. Let us take two agents. One is Alice and Bob and assume that they have to do some transaction and I am giving this analogy of paint mixing to make a sense of what we are saying. Now, Alice decides a color which is the public color.

When I say public color, so it means that that color is known to everyone including Bob. But then there is a third party or third agent which is Carol and they want that the transaction should be hidden from Carol. So, she cannot make over what actually is the transaction. But this color, which is the public color, which is green is known to all the agents.

Alice and Bob announced that this is the public color and Carol also can observe it, but at the same time uh Alice and Bob, they also have a private color. That is their choice, which is not revealed to even to Alice or to Carol. So, Bob decides red as a color, which is the private color. Alice decides blue as the private color and that is not revealed to anyone.

Now what she does is Alice, she mixes this private and public color and get a private, public mixture. This is let us for say Alice. Bob also does the same thing. He mixes his private color with the public color and come up with a private public key pair which is for Bob and let assumes that he puts so let us say that there is a center place where they put this mixture.

So, Bob comes and put the mixture in the center. Alice comes and put the mixture in the center. But that private color is still not revealed. Now Bob comes and take the Alice mixture and add with his private color and Alice comes and mix the Bob mixture with her private color. Now what we will see. So it contains red, blue and green. It contains red, blue and green.

So, both will know they need not to know what is the private key, but they actually make out what was the final mixture. Both will get the same thing. This is the main idea of this public, private and Carol even if she knows, even if she picks any of those colors, even if she picks the mixture also, she does not know what to mix with that. So, she may not get the same color what actually has been achieved by both Bob and Alice and that is the main idea of the public, private cryptography and that is part of the blockchain.

Now only thing is so this transaction is between C and F. Someone has to do the verification and that verification so as soon as this is done, this becomes as part of the

block and as I mentioned that you can add or you can edit a block only when you do this, prove this cryptographic proof of work and which comes at a cost.

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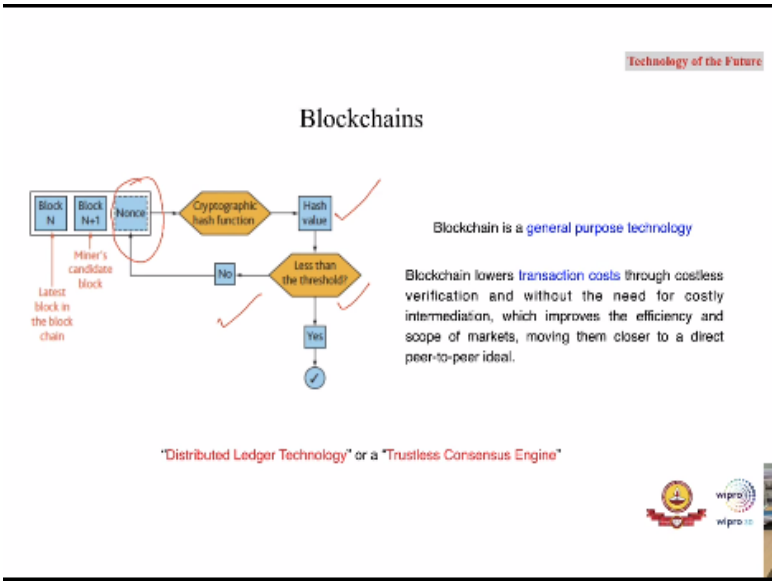

So, this you can actually see in this slide, so there is a latest block, this is the miners block and then this nonce value you have to estimate. Hash value less than the threshold, yes. If no, you keep on trying. Blockchain is becoming a general-purpose technology. It lowers the transaction costs. So, you relate to that idea of Ronald Coase.

Through costless verification and without the need for costly intermediation, which improves the efficiency and scope for markets moving them closer to a direct peer to peer ideal. Lot of things about the transparent, visibility. All these things compliance all these things come part of the blockchain. So, in this case, we are in fact calling it a distributed ledger technology or a trustless consensus engine.

Everyone converge to the consensus, and remember that we are not calling it trustful, we are actually calling it trustless. I need not to trust other person, but I trust the technology because I know that the technology is robust enough that you cannot actually change anything unless or until everyone agrees for it. Miners candidate block will be changed only when you solve this puzzle and that is not cheap, it is expensive.

You have to spend some energy some resources to achieve that. That forms the basis of this. I hope, you got some idea about how these things work and as I mentioned that what they are achieving is they are reducing the transaction cost, and which may lead to a different kind of organization altogether.

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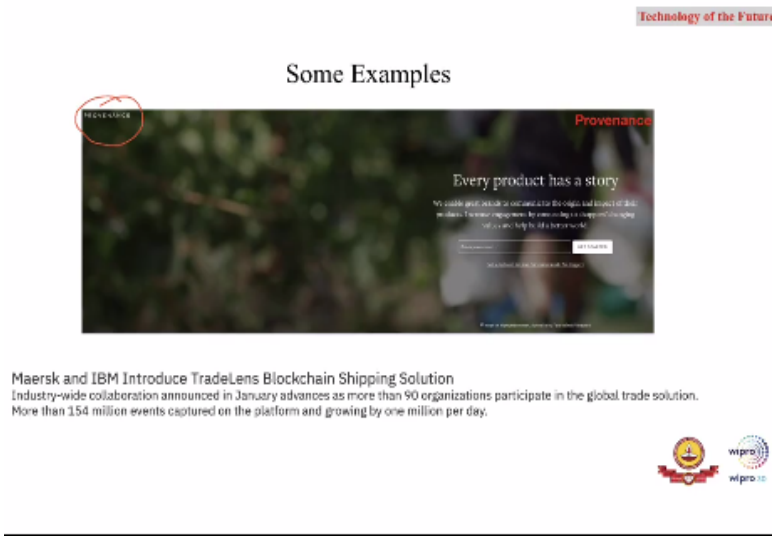

I will give you some examples for this. I think this will give you some idea. There is in fact a company called Provenance. They are actually tracing the food supply chain. You can see that you can actually trace the whole origin of a food product in the consumption and the technology of blockchain is becoming the benchmark for it.

Large logistic company like Maersk and IBM, they actually have come up with a TradeLens Blockchain Shipping solution. They want that industry wide collaboration; it was announced in Jan. Advances as more than 90 organizations participate in the global trade solution. They really want to improve the traceability. They want to improve the compliance.

They want to improve the visibility. So, all these things are becoming part of the digital supply network.

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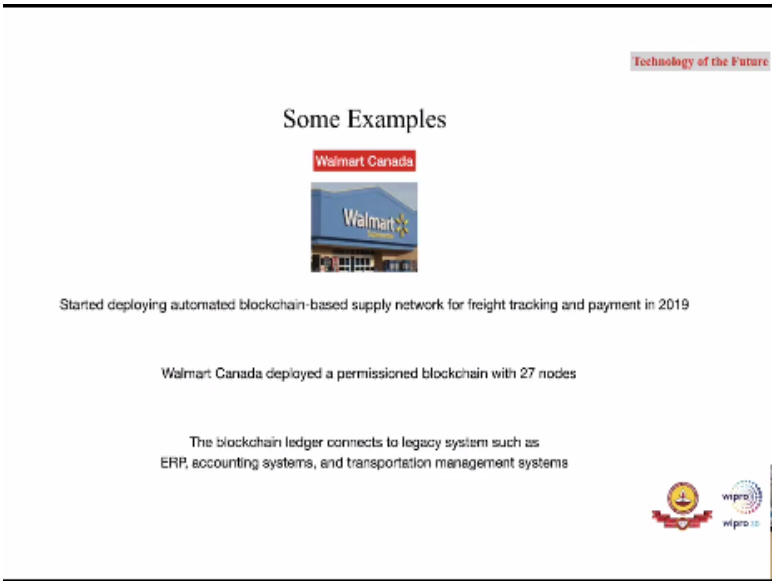

That certainly would have implications for manufacturing also. I will take another example, which is the Walmart Canada, and they have come up with a blockchain based supply network, which is similar to the for free tracking and payment. I give you the numbers. They operate about, they own in fact 2100 trailers and trucks. 70 carrier partners and they transport over 500,000 loads of inventory to about 400 retail stores across Canada.

It is estimated that about $150 billion per day is tied up in the supply chains in US for invoice disputes and that is where I think the Walmart Canada initiative of implementing a permissioned blockchain with 27 nodes. So, this is different from the public blockchain. In permission, you allow who should be the miner but the incentives may be very similar.

So, for a organization like Walmart, I think the permission blockchain seems to be a better option than going for a public blockchain because you may actually sometimes see lot of spurious activity in a public blockchain. So, blockchain ledger connects to legacy systems such as ERP accounting systems and transportation management system. So that has been already done by Walmart. So, this is something interesting as an example that how they are actually integrating.

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Another example, which comes is from Unilever. Unilever is a company which is co headquartered in London and Rotterdam in the Netherlands. They own about 400 brands, sales in about 190 countries and revenues about 50 billion globally and you can actually see that, if you read this, uh this plant makes Dove soap and ice cream and this is a joint offered by Unilever and Microsoft to actually establish a virtual factory to tune up its supply chain.

What they are doing is they are actually using AI or machine intelligence connected devices, harness a stream of data to keep production moving and reduce the cost. In fact, they come up with the digital twin to replicate the physical system. We already have talked about that.

They want to actually make their production more efficient. They are looking for convergence of technologies like IIoT, Cloud, ML and just to give the context that they have launched eight more digital twins in factories across North America, South America, Europe and Asia. They want to name it digital rewiring. Unilever is already doing that. I have taken this as part of a Wall Street report.

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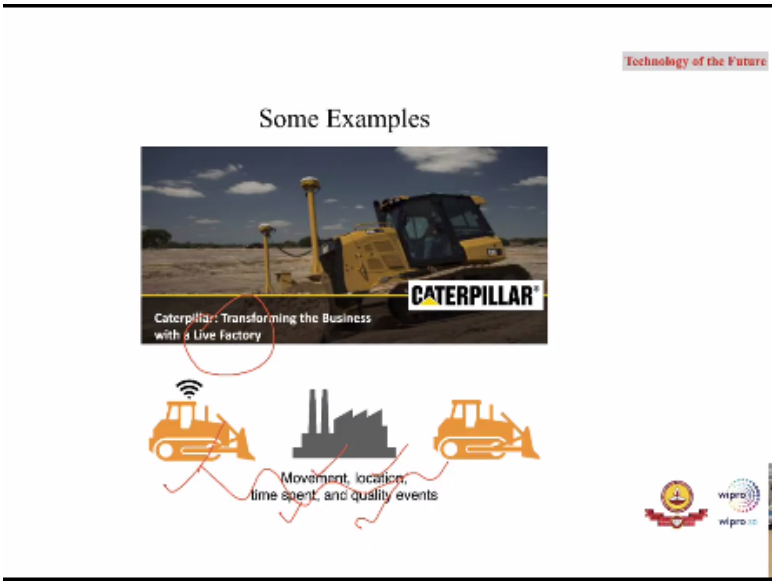

Other company which is doing as part of manufacturing is Caterpillar. They come up with something called as a Live Factory. They are converging. You can actually see this. So, you in this case, we are talking maybe about a machine. You put a sensor on the machine. You track the movement within the factory. You remove the sensor and what it actually does it maps the movement, location, time spent at different processes and the quality summary also. So, the quality defects.

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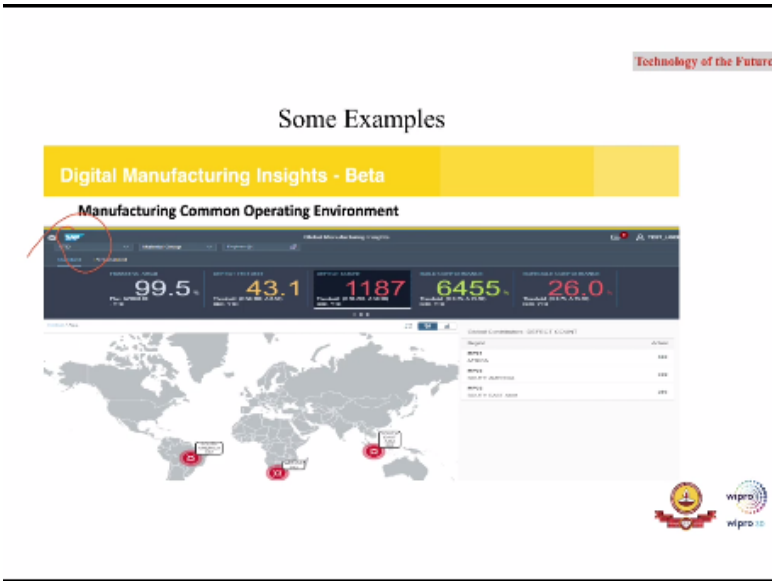

In fact, just give you the numbers. This is a kind of a dashboard, which comes as part of this Live Factory. It is called as manufacturing a common operating environment. You can actually see the defect count defect per unit. The new Live Factory was able to identify $12 million to 18 million in savings as reduced latency, automated

activities and they could actually reduce drastically the inventory cost by $1.2 million, labor cost by about $500,000.

So, this has come as part of implementing this Live Factory, where you are actually converging on all these solutions. You can actually map not just outside you can do it within the factory. You can optimize your resources.

The main idea of sensing, collaboration and optimizing can be seen as part of Caterpillar. They have integrating made with a typical SAP system.

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So, if you look at mass, you can say personalization. Two companies are at the forefront. One is Nike and other is Adidas. Adidas in fact, have come up with 3D printing solutions and you can actually see there is a big change in that. We started this whole course when we talked about manufacturing in China. But now what is happening is this high-tech factory is bringing the production back to Europe.

So, you can actually print it closer to the customer and this customization allows better matching of the demand and supply also.

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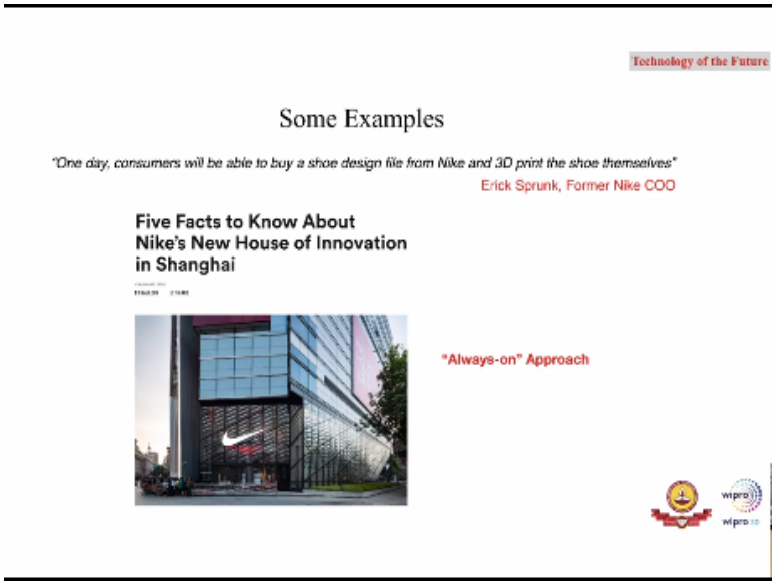

So, as I mentioned about Nike, you can actually see the quotation, One day consumers will be able to buy a shoe design file from Nike. You are not actually buying the shoe. You can actually print the shoe themselves. So that is the kind of innovation you would be looking in the context of manufacturing. We want more customized, more personalized, at least for the apparels and the shoe, that thing is true.

The company has established partnerships to build a 3D digital design system to transform its product creation process enabling capacities such as digital print applications, and rapid prototyping. They have actually brought 3D printing as part of it, and they have established the house of innovation at different cities. This is in Shanghai, and they are actually calling this approach is always on approach.

So, you are actually closer to the customer, you are customizing the products and the point here is it is the convergence of all these technologies. You are not just about the data analytics; you are integrating it with the manufacturing process also. So, in the future what the Nike former CEO is claiming, you would actually see that is true for not just shoes, it may be true for many other products.

This brings me to the closure of this session and this also brings me closer to the closure of the business part of the future of manufacturing. The future sessions, would be taken by Dr. Chandrashekar and would be on additive manufacturing. I hope you have enjoyed this discussion. Thank you.