Modelling and Analytics for Supply Chain Management
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Lecture 54
Queuing in Coordination; Measuring the Degree of Coordination

Hello and welcome to Modelling and Analytics for Supply Chain Coordination. We are in the coordination part of modelling, modelling and supply chain and in the previous 3 weeks we have learnt about how we can use numbers and methods in coordination. We learnt how to calculate the Bullwhip effect.

We learnt how to use and measure the level of sigma, that is application of six sigma in coordination and we also gave you an introduction to queuing theory in coordination and if you remember, we were, we have just drawn some diagrams that the vehicles are standing in queue in a warehouse, in a warehouse gate and then they are, from the trucks the products are being loaded or unloaded.

Now the vehicles, if you also remember, the vehicles can come in any time, and they will come in from two, three directions. So, the arrival of vehicles is a Poisson distribution. But the service time at the warehouse that means the loading-unloading time of a truck is fixed. Assume it takes 30 minutes, so truck 1 will take 30 minutes to load and unload, truck 2 will also take 30 minutes to load and unload, maybe 2 minutes this side, that side. Truck 3 will also take 30 minutes to load and unload. So loading-unloading follows a binomial distribution, loading-unloading follows a binomial distribution.

But your truck arrival, your vehicle arrival follows Poisson distribution. So, in fact, that is the essence of queueing theory, vehicle arrival and the service time, arrival and service, just recollect, just try to, just try to assimilate. Arrival means what? Vehicle arrival. What distribution? Poisson distribution because vehicles can come in any time.

Whenever they get empty roads or green signal, they can come in. But service rate, means loading-unloading, checking, etc, that will take a fixed time, so that is a binomial distribution. So two things, arrival rate, vehicle arrival and service rate, means loading-unloading. So, these two are very important in coordination.

Question is, what can you control? Can you control the vehicle arrival rate? To some extent. How? Because vehicle arrival, before arrival of the vehicle, the truck driver is supposed to call at the warehouse office saying that, this is truck number so and so, this is truck number so and so, this is coming from this plant in Tamil Nadu and this is the challan number or voucher number which has the list of the products that this truck is carrying. So, in the warehouse what you will do, you will check it that whether this is a genuine truck or genuine bill, etc and then you will ask the truck, okay, please come.

Now that, okay, please come, that is when you can actually make to some extent the Poisson distribution and normal distribution or a binomial distribution. How? Now, based on your service time, that is 30 minutes we took, 30 minutes, roughly for loading-unloading, based on your service time, you give a truck an entry time which is every half an hour, that is when the truck driver 1 calls you, you tell, that, okay you come at 8 AM.

When truck driver 2 calls you, you say, okay, you come at 8:30. Truck driver 3, we say, okay, come at 9. Truck driver 4, you come at 9:40. So somewhere, the truck, the trucks coming in from different direction at any point in time, that Poisson distribution, you are trying to make it a binomial distribution, by giving them a particular entry time in your warehouse or in your factory.

Service rate, that is loading-unloading, etc, there any way is a binomial distribution, means it is fixed time. So, if so how will you coordinate? How can you use numbers? So once you understand that it is a Poisson distribution, you try to make it a binomial one and then, you can easily predict how many vehicles will come, how many vehicles will go, etc, etc.

So, then your coordination becomes very easy. So queuing theory helps you to understand, what, what is the role of queuing? Queuing will help you to understand, how many vehicles will come, what is the probability that a vehicle will come and accordingly you can plan the vehicle arrival rate and the vehicle departure and the service rate.

Now, our job is not to teach you queuing theory. Because, queuing theory is a part of operations research. What we are saying is, how can we apply queuing for coordination modelling that is what we are planning to do.

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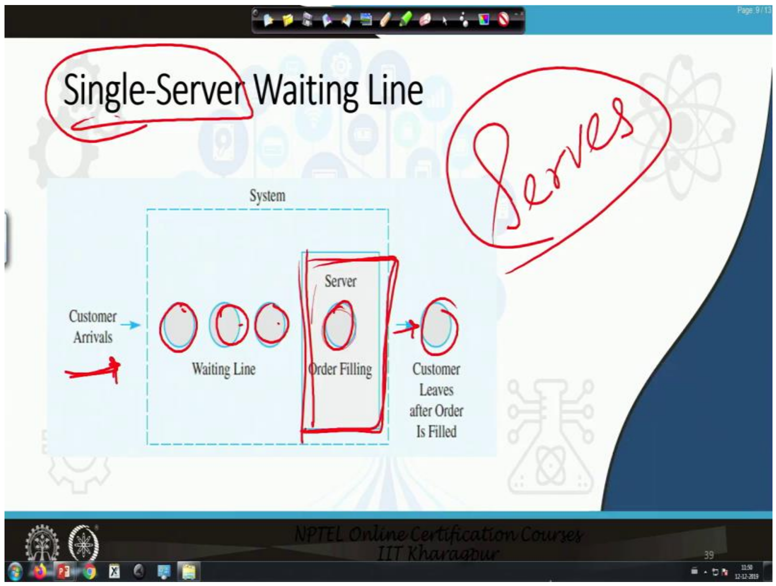

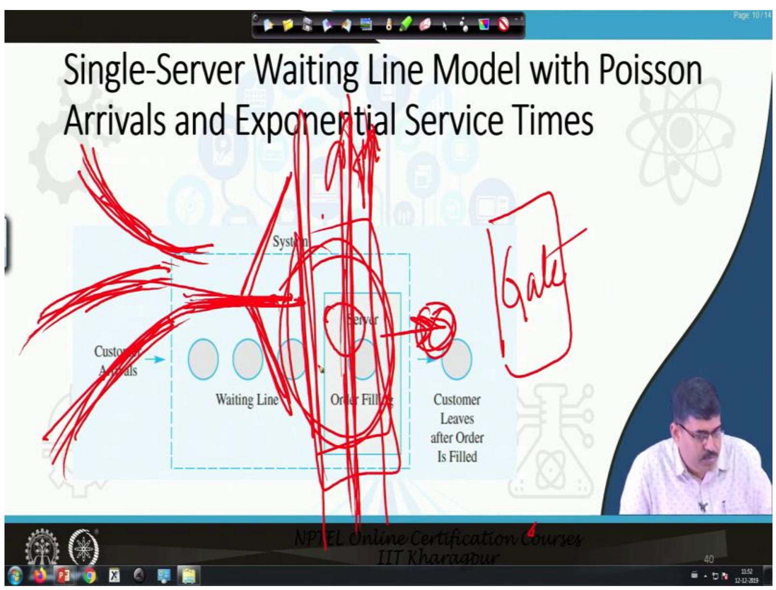

Now see, just a recap, this is, this is the diagram of a single-server waiting line. What is happening here? What is happening? Customers are arriving. Who are the customers here? The trucks. The trucks are arriving, just like I drew the diagram, they are waiting and here is a single warehouse gate which is loading or unloading the goods and then the trucks are leaving.

This is so, this is a single-server waiting line. Server means, one who, server means, one who serves. So, who serves in the warehouse? The loading-unloading department. This is called as a server. Server does not mean the computer server, server does not mean the computer server. Server means, one who serves you. So who is serving you? The loading-unloading staff. So that is a server.

So the vehicles are coming, waiting and then they are being serviced and then they leave. So, this is a single-server waiting line. Now, is this too much of a problem? Yes, it is too much of a problem also, because where is the bottleneck? The bottleneck is here. Because trucks will come in from many directions and then they are in queue, so the queues behind are also increasing.

You know what this is basically? Anyway and queues behind, but then this person is a single person, he will only handle, he will only handle one by one, one after the other. So, it will take a fixed time here, it will take a fixed time here, but the vehicles will come in from all directions. You know what is this? Just think of this as a traffic signal, this is a traffic signal.

Vehicles are moving this way, vehicles are moving this way. So what is happening? All the other vehicles coming in from other roads are standing in queue. Once this signal becomes red, then they will pass, then they will pass. Once the signal becomes green, they will pass. When this signal becomes red and this signal becomes green, then they will pass.

So what is happening? Unnecessarily the vehicles are getting jammed up behind and that is what we call as a traffic jam. So queuing is, you can relate it to real life, this is what is a traffic jam, one after the other the vehicles are waiting, why? Because this server or this particular road that is moving in the opposite direction, this has a capacity, this is a maximum capacity.

So, only these many number of vehicles can move in 1 minute. So this road takes time to clear and only then we will get a green signal and these vehicles will move. So this, so, if, so now let us come back to the warehouse. If there is too much of waiting here, for the trucks, what will you do? What is the solution? Your entire coordination is going haywire.

You will try to have one more server, means one more gate, means are baap re means one more gate. You will try to have, you will try to have one more gate. So two servers. Then what will happen? They will stand in queue and then whichever server is becoming empty, they will go there. So, if, while doing a coordination modelling, if you find that there is a too much of time blockade here, with the single-server, what will be your recommendation? Your recommendation will be, to go for two servers. So, this is one thing that is there. Now, is it clear? Should be, because it is not rocket science.

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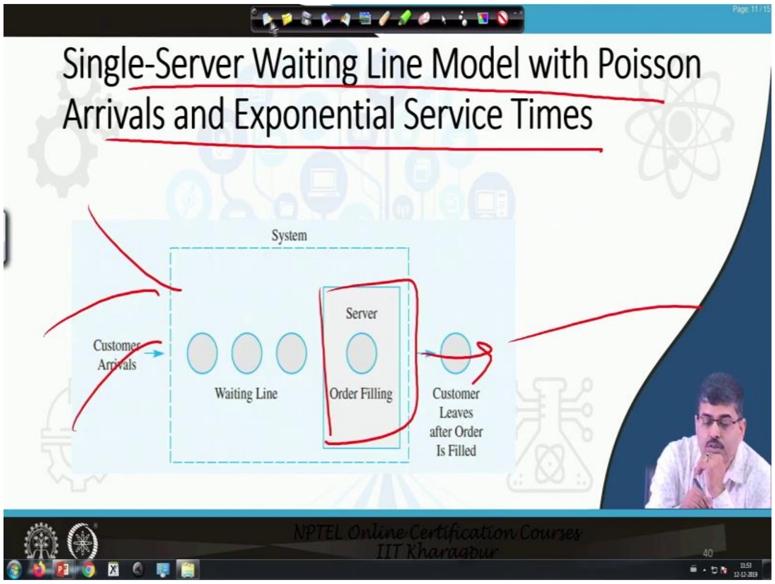

Now, this is what we were talking about, the see this, this is, yeah. This is what we were saying, Single-Server Waiting Line Models with, oh what happened. Single-Server Waiting Line Model with Poisson Arrival and Exponential Service Time. Arrival can be from any direction, and service time is similar and then it moves. Now, what is the other, other point, what is the other, other dimension of it?

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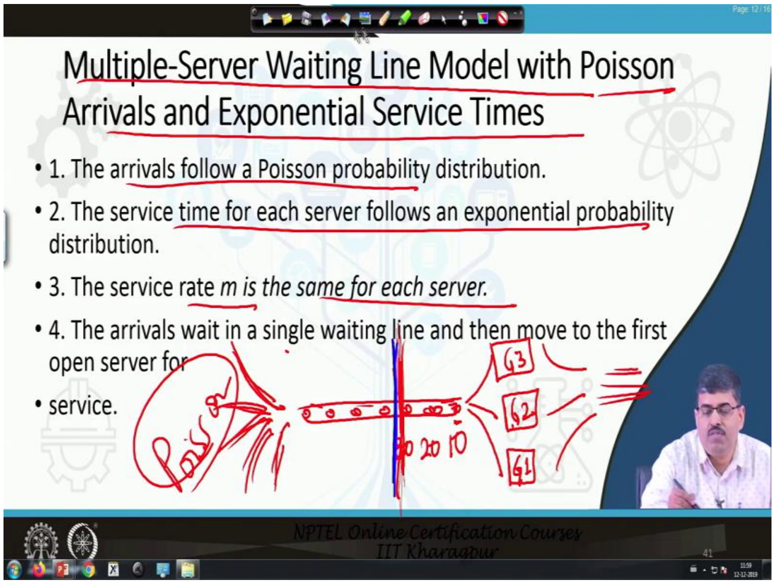

Multiple-Servers, Poisson Arrival Exponential Service Time. What is this? Let us see. Multiple-servers means, gate number 1, gate number 2, gate number 3, server 1, server 2, server 3. What is happening? Vehicles coming in from different roads, standing in queue and then as and when one-one server is getting emptied, the vehicles are moving. So, what is the arrival rate?

The arrival rate follows a Poisson, what is this service rate as we said, each gate is taking 30 minutes. How many gates? Each loading-unloading taking 30 minutes, each gate is taking 30 minutes. How many gates? 3 gates, how many, each gate is taking 30 minutes, how many gates? 3 gates. So what is the waiting time for this truck? What is the waiting time for this truck? Average, 10 minutes, next truck, 20 minutes; next truck, 30 minutes. So, what you see is if your gates increase, the waiting time comes down.

In the earlier diagram we said, 30 minutes per vehicle, now it is 10 minutes per every vehicle gate, per gate. So then again, it moves out, then again it, then again it moves out, then again it, then again it moves out, again it moves out of the main road. So, this is what we call as multiple-server, multiples, this is multiple-server waiting line model with Poisson arrival and exponential service time. So, these are your multiple-servers, these are your multiple-servers, G1, G2, G3. Arrival of the trucks from all directions, Poisson arrival and the service time required at every gate is 30 minutes, so exponential service time.

What is there, the arrival follows a Poisson, service time is exponential. Service rate is m, is the same for each server that means each server or each gate takes the same time and the arrival waits in a single waiting line, the vehicles wait in a single waiting line and then moves to the first open server for service.

So, this is your multiple-server waiting line. Now, I have a question, here what is happening? The number of gates are given to you, so there are 3 gates, look at it. Number of gates are given to you, there are 3 gates and these many vehicles are waiting behind, each gate is taking 30 minutes to perform an activity. So, what is the waiting time for this vehicle? 10 minutes, next one? Another 10 minutes, next one? Another 10 minutes. So, 10, 20, 30. So, this is it. 3 gates are given to you.

Now I am reversing the situation, what I am saying is, I have enough space and enough number of gates. I have 20 gates, 20 gates I have, but all are shuttered down, means I have downed the shutters because I do not need so many gates. I am saying now, that how many, it is the other way around, how many gates should I keep open?

How many gates should I keep open, so that there will not be more than 3 trucks in front of every gate? How many gates should I keep open so that there will be not more than 3 trucks in front of every gate? So, it is the other way around, I have reversed the situation. How many gates will I keep open so that there is not more than 3 trucks in every gate?

If you see, this is very, like, something very important. Why you know? I will tell you something, all of you have travelled by railways, local train. All of you have travelled by railways. Now, in the ticket counter what happens, in the morning, too much of a queue and the passengers will keep on shouting, please open another counter, please open another counter, please open another counter. That means what? There is a threshold beyond which if the queue is extending then, another counter has to be opened.

Same thing applies to warehouses also, there is a threshold of waiting, beyond this another gate has to be opened. Now we are doing it reverse. Assume railways say, I do not want to, know the length of the queue, what I want to know is or what I want to say is, I do not want more than 7 people standing in front of every counter.

So, I want to know how many counter should I open. Same thing in warehouse, I do not want more than 3 trucks waiting in front of every, because then when the truck gets delayed, my next consignment gets delayed, so that coordination aspect, becomes a problem. So, I do not want more than 3 trucks, so how many gates should I open. This the second problem.

So this, again, is a trial and error. This again is a trial and error, you will have to do a trial and error and then decide on the number of gates. There is no formula for this. First you put 2 trucks, then you have 3, then you have 4 and see what is the length of this queue and what is, how things are changing. But as wise mentioned we are not going into the mathematical modelling of this because queuing theory is something that we have already done, we are only showing you how you can apply queuing theory for this portion, for supply chain coordination.

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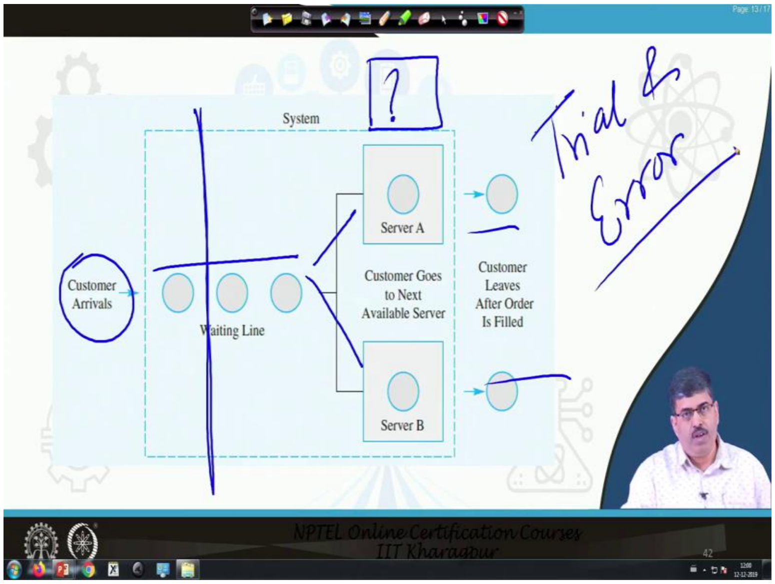

As we were saying, this is the diagram. Customers are arriving, customers are arriving in a Poisson, they are waiting and then as and when whichever server is opening, they are going there and then they are leaving. We are saying an opposite, we want to know how many servers should be there if we want no more than 2 trucks in front of every server, 2 trucks in the queue. So, this part is a trial and error. This part is a trial and error.

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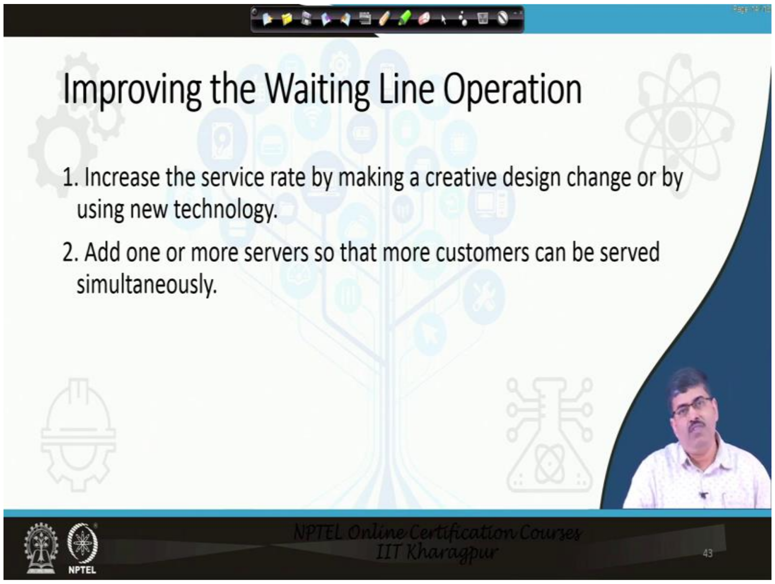

So, how will you improve? How will you have better coordination? Increase the service rate, by making a creative design change, improve the service rate. We have said 30 minutes for loading and unloading, improve it. Add one more server, so that more customers can be served. But then that is a cost, there is a manpower, so somewhere down the line as a analyst you need to take care of that also.

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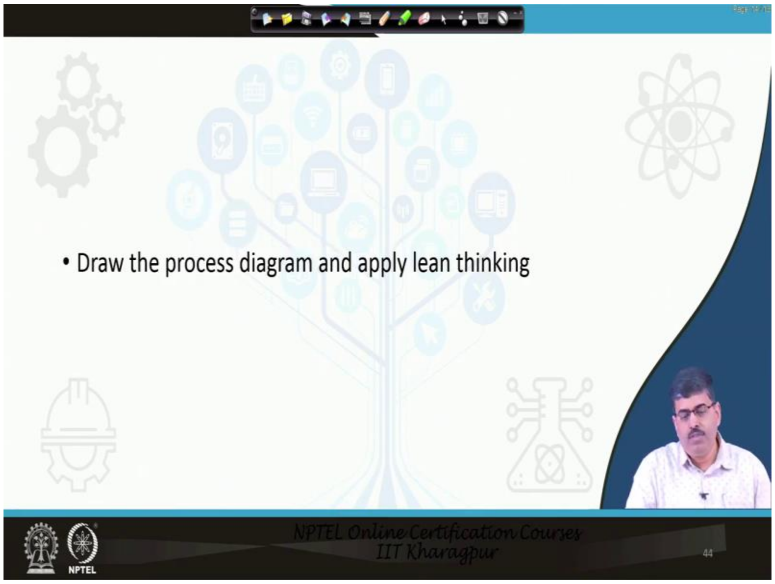

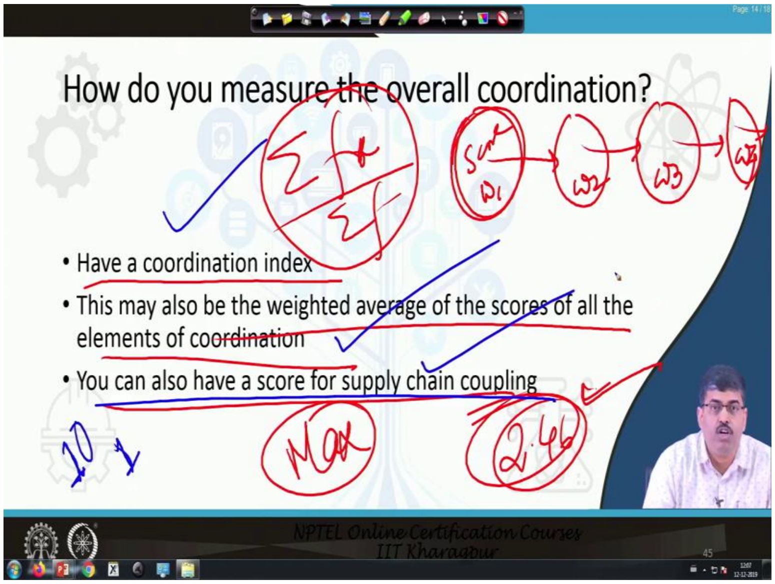

Draw the process diagram, apply lean thinking. Now, we come to the next question. The next question is pretty much like, how do you measure the overall coordination. All along we have learnt, how, the tools to coordination, six sigma, queuing theory, that was process specific. Warehousing only, transportation only, supply selection only, now we are saying overall coordination. Earlier models was warehousing coordination, now we are saying overall coordination. Right from supplier to the extreme end customer.

How do you measure overall coordination? I will tell you something. Whenever measuring is difficult, have an index, have an index. Whenever you are dealing with so many types of things, unrelated, related, measurement in different units, etc, etc, you get too much confused and then the only way and the most simple way is to develop an index. So in coordination also, supplier has supply, right from the raw material supply, supplier has a time, supplier has a quantity, EOQ quantity which we have already learnt, supplier has a EOQ quantity, if supplier is given discount then he gets, his supply is more it is not EOQ now.

So, so many complexities and then, production has a time, suddenly your, your no demand, no market demand so you will reduce production. Then there is idle time, then there is workers are not there. So, production has a problem, supplier has a problem, transportation again, sometimes vehicles are not available, road blockade, so transportation has a problem. So coordinate each one has its own problems which are really, really, really bothering. So, to solve it, to have a coordination index is a better way. To have an index that incorporates all these multiple, variedly measurable units.

So, how do you measure, that is the next part. So, how do you measure the overall coordination? Have a coordination index. Have a coordination index. How? This may be the weighted average of the scores of all the elements of coordination, very simple. Keep it simple. Always remember we have mentioned, keep things simple so that your juniors understand it.

Because you will not implement it, your juniors will implement it, so keep things simple. Second, if you keep things simple, if it is understandable, there is no ambiguity. Third, when you are dealing with people who are not that much knowledgeable, there is always a fear. You bring in mathematical models, you bring in machines, there is a job fear, I will lose my job, I will lose my job.

So, when you make things simple, then they understand that these techniques are not for losing jobs. So, always keep things simple. So, you have a coordination index, simple way to have it is create a weighted average of all the scores of the elements of coordination. So supplier, so your supplier to transporter, transporter to factory, factory to warehouse, warehouse to market, for everything you create a score, create a score and give weightage, give importance to raw material supply, some weight, give importance to transportation, some weight, importance to production, importance to end product market.

So, give weighted scores, keep on giving weighted scores and then it is something like your summation f x by summation f, something like that. So, it is a weighted score. So this, once you get a weighted score, that gives an overall coordination index. Now, you will get some number, assume you get a number called 2.46, what does that 2.46 mean?

Too high, too low, etc, etc. Look at the maximum that is possible and then look at what you have got. So, look at the maximum that is possible, look at what score you have got and you know where you are supposed to go. You can also have a score, there is another way, you can also have a score for, there is another way to measure the overall coordination, there is another way to measure the overall coordination. That is, you can also have a score for supply chain coupling, how integrated you are in supply chain design etc, etc.

So how integrated is your supply chain, how coupled it is. You have seen railway wagons? When, while shunting, one wagon bangs against the other, so and it auto locks, that is what is called as coupling. That is what is called as coupling, that is, so how much is the coupling strength, degree of supply chain coupling, you can take the maximum score as 10, you can take the maximum score as 1, but you have to know what is the degree of supply chain coupling. So, have a coordination index, get a weighted average if required and you can also have something called supply chain coupling.

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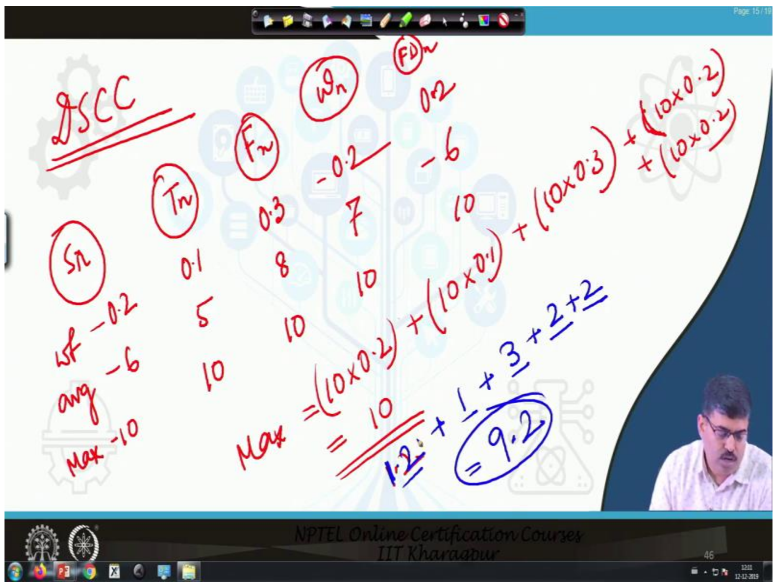

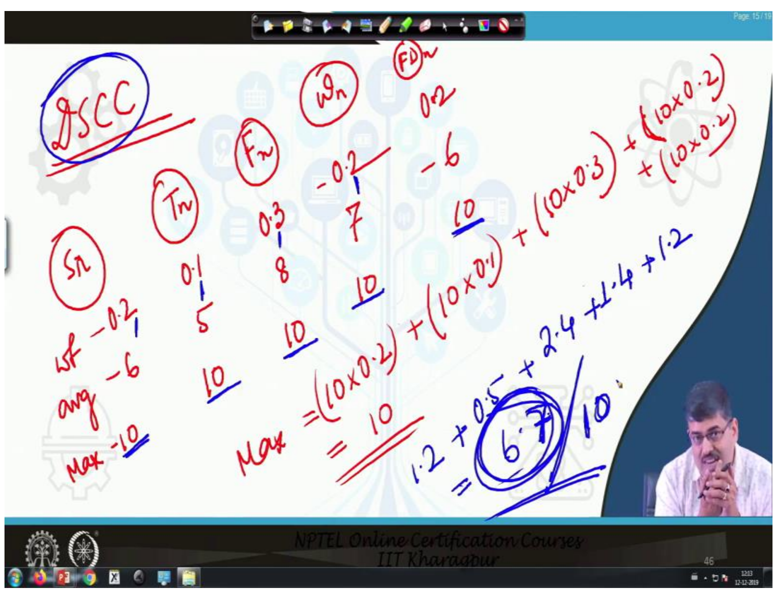

So, now, let, this supply chain coupling, we will discuss some for a few minutes. Degree of supply chain coupling. Degree of supply chain coupling. Now what is this degree of supply chain coupling? We have mentioned what, supply chain coordination create a weighted average. Now, what was this weighted average? Weighted average was, here was your supplier. This supplier, supplier n, lot of suppliers. So, here was your supplier coordination, here was your supplier coordination, agreed? So, you had a weight and you had an average score that is supplier rate, this is supplier performance score.

So, supplier performance, maximum is 10, you got an average of 6. So, supplier performance max is 10 and you got an average of 6 and the weight given to this is, let us say 0.2. Then what is there? You got transportation, what is the weight given for transportation, let us say, 0.1. What is the average score for transportation for your organization? Let us say 5, we are not good in transportation. Maximum value 10, then is your production, what is the weight? Most important. What is the average score? Pretty well in producing all machines, maximum, this.

Then is again your warehousing. What, warehousing weight is also. Warehousing weight is, warehousing aid, warehousing weight let us say is 0.2. What is your function ability? Maximum, is this and then, again your final distribution, FDn. Final distribution is very important, customers will get it or not get it and you are pretty much there. So, what is your degree of supply chain coupling? Let us see, what is the max possible? 10 into 0.2 plus 10 into 0.1. So that means, 2 plus 1, 3, plus 3, 6, 7, 8, 9, 10. So your max possible is basically 10.

What is your score? 1.2, 6 into 0.2, 6 into 0.2, what is your score? 1.2. We will use blue color for this, what is your score? 6 into 0.2, that is 1.2 plus 10 into 0.1 is 1, 3, 2, 2. So 3, 4, 5, 6, 7, 8, 9.2. So your score is 9.2, am I correct? No, no, no. I made a mistake here, this is, I multiplied by 10, I was a bit skeptical, am I giving correct answer, yeah.

So what is your score? Your score is, your score is 6 into 0.2, that is, 1.2 plus 5 into 0.1. 0.5 plus 8 into 0.3, 8 into 0.3. 8 into 0.3 is 2.4 plus 7 into 0.2 is 1.4 plus 6 into 0.2 is 1.2. So, that comes to 1.7, 2.1, 4.1, 4.5, 5.5, 5.7, 6.7. So this is your coordination score out of 10. This is your coordination score out of 10, 6.7, this is how you calculate the coordination index.

In the same way you can calculate the degree of supply chain coupling. Normally I will say degree of supply chain coupling this max value is taken as 1, max value is taken as 1. But you can take it as 10 also, there is no problems. So, this is how you can calculate where you are exactly. Now the question is, where I am exactly is fine, but what do I need to do to make it 10. Because that is the element, that is the utmost, ultimate for coordination.

How to do it? Six sigma, queuing theory, six sigma and queuing theory, etc will help you to attain a coordination score almost equal to 10 and when you can attain 10, then, you know everything is very, very well coordinated and that is where your supply chain efficiency lies. So this, applying queuing theory, applying coordination, your supply chain coordination will become very, very helpful and this is again how you need to model, how you need to, it is not done, how you need to model supply chain coordination. So, with this, we end this particular week on Supply Chain Modelling for Supply Chain Coordination. Thank you.