

**Modeling and Analytics for Supply Chain Management**  
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**Lecture 60**

**Designing the Global Supply Chain : Flexibility & Total Cost**

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Hello and welcome to Modeling for Analytics, Modeling and Analytics in Supply Chain Management. We are in the week 12 that is the last week of this course that is designing the global supply chain. This has different components in designing the global supply chain, first we learned about how the taxation systems and the taxation rates are impacting the designing of the global supply chain.

Just to have a brief 1 minute recap. We will say that if you see I will not move my products through a country where there is high taxation. I will not have a manufacturing facility in a country where there is high taxation. I will not have a warehousing or a transportation hub in a country where there is high taxation.

So, that is why what companies are doing as we have seen in the earlier two lectures is, companies are routing or they are doing the route planning in such a manner that the hubs that is the cross docking facilities, the hubs all are in no tax countries or very less tax countries and come, and countries have also realized that if you can have such an economic hub then it generates lots of employment.

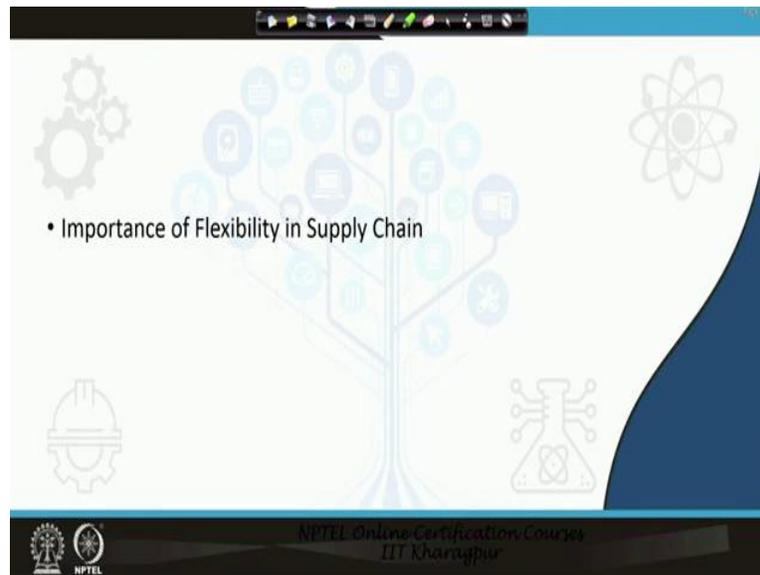
That is why many countries which are bordering the seacoast areas are developing the Free Trade Zones or the free trade areas. So, our first part of designing the global supply chain, the first modeling part was how to model the supply chain based on taxation and we gave you a brief overview and a holistic explanation of how the taxation systems impact the design ((2:04) what you should be careful about.

The next thing that we learned in designing the global supply chain that is the part 2 of designing; first one was taxation aspects, second is transshipment and we said that in the entire supply chain, the objective is to have zero inventory in the system. That is your products should come in and the products should move out. So, products should come in and products should move out.

That is to say in the factory raw materials should come in and finished products should move out. In a warehouse, finished products are coming in and moving out to wholesalers and distributors. So, material in is equal to material out that is basically the transshipment part of it. Today, we will do the third aspect. That is when you are designing the supply chain, you should be very careful.

That is supply, supply chain should be flexible. That is designing the flexibility and the second thing is in all these things you should keep in mind that your total cost should be as low as possible. So, total cost should be minimal. So, if you see your sub, so, there are two as, another. So, first aspect was taxation, second aspect was transshipment, the third aspect is flexibility and the fourth aspect is keeping all these three in mind your transshipment, your taxation, your flexibility, your total cost should be minimum. So, fourth aspect will be total cost. So, now, let us go to the third aspect that is flexibility for some time.

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Let us see, why is flexibility important in supply chain? If you see the very recent examples of organizations and corporations, you will see that Toyota has done lot of recalls of their cars, which in marketing you call as product recall. So, Toyota has done a lot of recall of their cars, because there was some flaw in the manufacturing system in one of the component parts of the car most probably the engine part.

Now, this is one aspect, if you see Nokia also had a huge quantity of product recall, because of its battery, there was a overheating of the battery, Nokia phones. So, you see, your supply chain is not necessarily like moving the finished product to the consumer. Your supply chain should be flexible enough, adaptable enough to accommodate these sudden changes, these sudden things, understood?

So, what we are trying to say is, your supply chain is not a one way thing, your supply chain is also needs to be very, very flexible, needs to be very very molded in terms of the demand of the time. So, flexibility is very very important in supply chain. Let us take an example of the classic example of Indian Car Company, which is as well known as the Maruti Suzuki, Maruti.

Now, we commonly still call it as Maruti though the name of the company has changed to Suzuki motors, but then we in India commonly call it as Maruti. So, I will stick to the name Maruti though on record, I just want to say that the name, the logo is Suzuki and the name of the corporation it is basically for all purposes it is controlled by Suzuki. Now, Maruti, let us take

Maruti, let us take Tata Motors, what is flexibility? Assume you had forecasted a demand of 1 lakh cars, you have forecasted a demand for 1 lakh cars.

Accordingly the suppliers of different components have been instructed to supply 1 lakh components in a phased manner, in a phased manner as per the production schedule. Suddenly, there is a revision of the forecast and suddenly you feel that the sales might dip or vice versa the sales might increase. Now, what will happen immediately the entire list enters the range of supplies and the suppliers have to be informed and they will have to immediately modify their production schedule and production quantity.

What will happen? So, if I was supposed to manufacture 1 lakh cars means 1 lakh engines will come from some supplier. So, accordingly the transporters have been informed for a particular delivery schedule and a particular vehicle capacity also. The moment this 1 lakh projection or forecast is reduced to let us say 80,000, the moment is reduced to 80,000 then immediately your production schedule changes, immediately your raw material procurement schedule changes, quantity changes, your transportation planning also changes because now you might not need a very big truck, you might need a normal 20 metric ton or 40 metric ton truck.

So, you see, but then if your supply chain is very rigid that means if your supply chain you have designed in such a way that it can handle 1 lakh pieces, you only have big vehicles you do not have the medium sized vehicles. So, what will happen with this sudden lessening of the demand? Now, you will send the big trucks. So, the per unit transportation cost increases, lesser number of units are going by the big truck, so the per unit transportation costs increases.

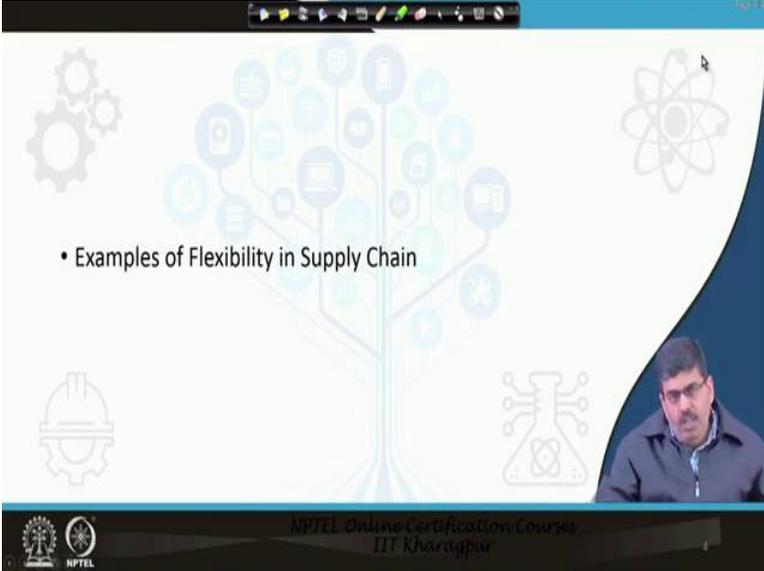
Had you have small vehicles, were you able to combine the consignments then your per unit transportation costs would have come down. So, why this problem has happened? Because your supply chain was not, is not flexible. You have only big trucks because you have anticipated this, this, this demand and this will continue for the next 10 years. So, your supply chain has to be very, very flexible. And the classic example of flexibility is your just in time systems etc, etc, whatever we that that is a separate topic, we are not going into that, the supply chain has to be flexible.

So, if your supply chain is not flexible, what happens, what is that, that is what we were trying to say, importance of flexibility. If your supply chain is not flexible, problem that happens is there

is a rise in cost. That is it, there is a rise in cost and in today's days, when everywhere you are competing, based on cost, then it cannot afford to have a rise in cost, look at any product around you, go to supermarket and look at the prices, every brand has the same price, sometimes similar same, sometimes 1 rupee this side, 1 rupee that side, but every brand has the same price.

So, that is the level of competition you are talking about. So, lesser the cost higher is your margin, because market price is same. So, you cannot afford to have a higher cost. So, your supply chain if it is not flexible, if it is not able to inculcate these sudden changes, inbuilt the sudden changes, then your supply chain design will not be of any use. So, the third, that is why third phase in modeling is the flexibility part of it.

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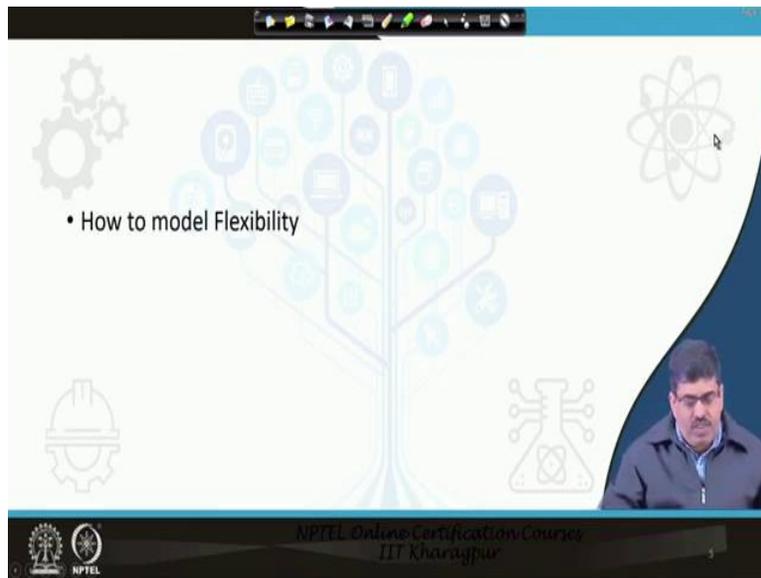


• Examples of Flexibility in Supply Chain

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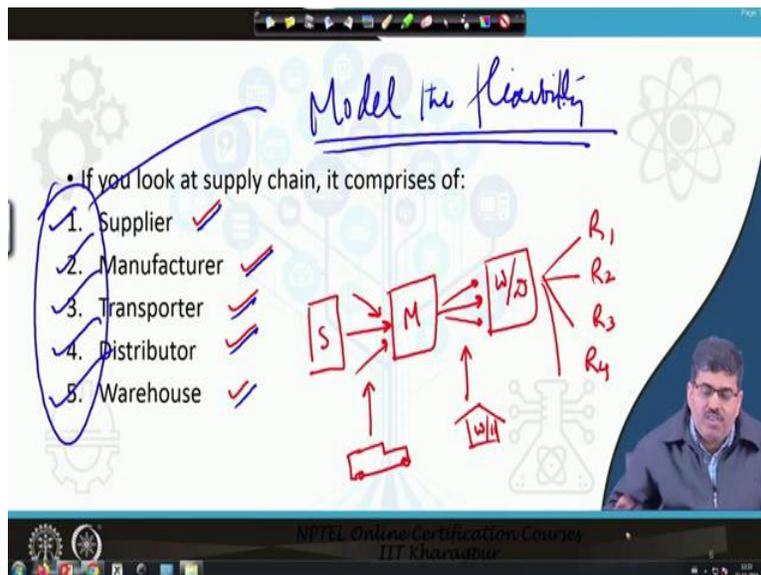
We have just spoken about these examples of flexibility in supply chain.

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Now how to model this flexibility?

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See, if you, how to model this flexibility? It is very very simple, it is very very very simple, how to model this flexibility. If you see, if you see, if you look at supply chain broadly it comprises of supplier, manufacturer, transporter, distributor and warehouses, agreed? Because remember the supply chain diagram, here was your supplier from then it came to the manufacturer or the factory, from factory it went to the wholesaler and the distributor and from distributor it went to the retailers.

If you remember this was your supply chain diagram from the suppliers to manufacturer, from the suppliers to the manufacturer, from the manufacturer to the warehouses, yeah, there will be multiple arrows I am just giving and then from warehouses to the multiple retailers. What was in between? In between was the vehicle that was taking your consignment. There was the vehicle that was taking your consignment.

So, the transporter and in between there was something called a warehouse, also there was something called a warehouse. So, when, where you were storing the products, after manufacturing, after manufacturing there was warehouses. Now, so when you are looking at a supply chain, you are looking at this entire set of things, you are looking at this entire set of things supplier, manufacturer, warehouses, warehouses, wholesalers, transporters and the retailers.

So, when, so that that is that is what we are saying your supply chain comprises of supplier, manufacturer, transporter, distributor and warehouses. So, so and so, when you are looking at, when you are modeling the flexibility, you should model the flexibility of your supplier, of your manufacturer, of your transporter, of your distributor and of your warehouses. If you can model the flexibility of these 5 things, then you have been able to model the flexibility of the supply chain.

If you have been able to model this entire thing, all these five separately and then comprehensively, then you have been able to model the flexibility of the supply chain as simple as that. Flexibility modeling is not very very difficult.

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• So you have to model the flexibility of all of these players

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So, you have to model the (flex) as we mentioned, so you have to model the flexibility of all these players.

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• FLEXIBILITY OF SUPPLIER CAPACITY PERTAINING TO PRODUCT  $i$

= Supply capacity for raw material  $r$  by supplier  $s$  if supplier  $s$  is selected (-) demand from customer zone  $m$  for product  $i$

$= S_c - D_m$

Flexibility

+ve  
-ve

100  
20 F.

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Now, so as we said the first flexibility is of the supplier, remember the first flexibility is of this supplier. So, how do you model the flexibility of the supplier? Suppliers capacity, suppliers capacity is equal to what? Supply capacity for raw material  $r$ , by supplier  $s$ ; if supplier  $s$  is selected minus demand from customers zone  $m$  for product  $i$ . So, basically it means supply

capacity minus demand from the particular market. So, basically, it means supply capacity minus the demand from the market.

If the supply capacity is more then what will happen? If the supply capacity is more, then your flexibility is positive. The supply capacity is more than your flexibility is positive, what will happen if a supply capacity is less, less than the demand, supply capacity less than the demand and flexibility is negative and definitely you can give a score for it. It can be converted into numbers.

So, supply capacity is 100 and your demand is 80. So, definitely what is your supplier flexibility? plus 80 sorry, sorry plus 20 sorry, your supply capacity is plus 20. Have you understood? So, your supply capacity is 100. Demand in the market is 80. So, your supplier has an excess capacity, which is equivalent to his flexibility, it can tweak suddenly, if the order increase, if the orders, if the orders are rising then how much extra can the supplier supply? This 20, this 20. So, that is his flexibility that is that is the amount to which it can twist and turn itself that is supplier capacity, agreed?

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• FLEXIBILITY OF SUPPLIER CAPACITY PERTAINING TO PRODUCT  $i$

= Supply capacity for raw material  $r$  by <sup>in</sup>supplier  $s$  if <sup>out</sup>supplier  $s$  is selected (-) demand from customer zone  $m$  for product  $i$

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After supplier what did we see? This from this factory, from the suppliers it is coming to the factory, from the supplier the product is coming to the factory, from the supplier the product is coming to the factory. So, from the factory, next is the flexibility pertaining to, just give me a second.

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• FLEXIBILITY OF PLANT CAPACITY PERTAINING TO PRODUCT i

= production capacity at plant p if plant p is open (-) demand from customer zone m for product i

$Sc = +20$   
 $Cp = +20$

$Cp - D = 100 - 80 = 20 + v$

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Yeah. Then this is, yes, from the supplier it is coming to the factory. So that is your plant capacity, what is the plant capacity? Production capacity at plant p, production capacity at plant p if plant p is open, remember we did integer programming in warehouse location modeling, if plant p is open minus demand from the customer zone for product i, production capacity at plant p minus demand from customer zone for product i.

So, my production capacity, do not confuse it for 6 sigma, my production capacity minus the demand. So, again let us go back my production capacity is 100, demand is 80. So, what is my flexibility, (remem) I am repeating, my production capacity is 100, my demand is 80. So, what is my flexibility?

My flexibility is 20 positive, my flexibility is 20 plus. So, my so, even if so, what was, what is the meaning of this, what is the meaning of this flexibility? That means if the product, if the product is, if the if the product is suddenly the demand has increased, if the product demand suddenly has increased, then how much extra can the factory produce? How much extra can the factory produce?

The factory can produce 20 extra because its capacity is 100, demand is 80. So, remember so, so, understood. So, this is very simple. So, up till now what have you learned? We have learned supplier just in the previous example, my supplier capacity was a positive 20, supplier capacity

was 100, we just took an example, we just took a simple example, supplier capacity was 100, my demand was 80.

So, what is this flexibility? Plus 20. Here we are getting factory. What is the flexibility of the factory again? Capacity 100 demand is 80. So, capacity. So flexibility is 20. So, supplier we have learned. Factory or plant capacity we have learned. So 20, 20 just remember this, just remember.

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• FLEXIBILITY OF DISTRIBUTION CENTRE CAPACITY PERTAINING TO PRODUCT i

= capacity of distribution centre k if k is open (-) demand from customer zone m for product i

$S_c = +20$   
 $C_p = +20$   
 $C_d = +10$

$C_s - D = 90 - 80 = 10+$

$(70) - 80 = -10$

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Next is flexibility of the distribution center, distribution center basically means the warehouse, distribution center is the warehouse. Flexibility of the distribution center, capacity pertaining to product i, capacity in the distribution center minus demand from the customers zone, capacity of the distribution center minus demand from the customer zone, so the capacity of the distribution center minus demand. Now, here let us see, demand is fixed, demand is 80 that was the forecast so, demand is 80. But now, we are saying the capacity of this particular place, of this particular this thing, distribution center is 90, capacity 90 demand is 80.

So, what is the flexibility of this warehouse or the distribution center? The flexibility of this warehouse is 10 positive, 10 positive. So, flexibility of the distribution center, is it clear? Flexibility of the distribution center capacity pertaining to product i capacity of the distribution center minus demand. Had the capacity been only 70 and demand is 80 then what would have happened?

It would have been a minus 10. Capacity is 70, demand is 80 so, minus 10. So, that would have been my flexibility that means my demand is more I am not able to supply because my warehouse does not have any space, then I have to rent more warehouse space. So, right now, what did we get? My supplier capacity was plus 20. My production capacity was plus 20. Here I get my distributor capacity is, distributor capacity is plus 10, this much we have got. Let us move to the next one.

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• FLEXIBILITY OF CROSS DOCK CAPACITY PERTAINING TO PRODUCT i

= capacity of cross dock j if j is open (-) demand from customer zone m for product i

$S_c = +20$   
 $C_P = +20$   
 $C_D = +10$   
 $C_w = +20$

$100 - 80 = 20 +$

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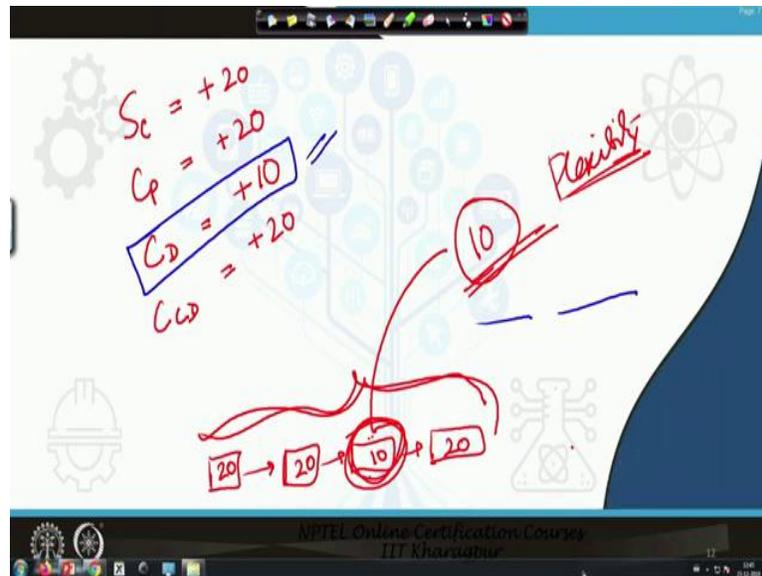
Facility of the cross dock, then distribute, cross dock here again it may pertain to the warehouse, it may pertain to any place in between. For flexibility of the cross dock, flexibility of the cross dock. Capacity of the cross dock minus demand as simple as that, capacity of the cross dock minus demand.

So, now see your capacity of the cross dock is 100, this one is a bit more and your demand as you already mentioned was 80. So, capacity of the cross dock is 100, demand is 80. So, what is happening to your flexibility? Flexibility is 20 positive. The capacity is 100, demand is only 80. So, you can augment your if there is sudden rise in demand, you can give space to 20 more units.

If there is a sudden increase in demand you can give space to 20 more units. So, what have you got? Supplier capacity was plus 20, production capacity was plus 20, capacity at the distributor level was plus 10 and capacity at the cross dock is equal to plus 20, this is from the example we

have got this. From the example you have got this. So, what is my total capacity? What is my total flexibility now? What is my total flexibility? Can by looking at these numbers.

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So, we just now learned that my supplier capacity was, my supplier's capacity was a plus 20 that means the supplier can supply me 20 more. My production capacity was plus 20 that means my factory can produce 20 more units if demanded if required, my distribution center capacity was 10 more, that means the distribution center can handle 10 more units and my capacity at the cross dock is again 20 more that means the cross docking facility can again accommodate 20 more units.

So, if you look at it and this was my supply chain, remember this was my supply chain, this was my supply chain. So, if you say what is the flexibility of this entire supply chain? What is the flexibility of this entire supply chain? If we ask you this question, what is the flexibility of this entire supply chain? You see this one is a plus 20, 20, 10, 20 then what is the flexibility? The flexibility of this supply chain is suppose they can manage, they can handle 20 more, this can handle 20 more, this can handle 20 more, but this can only handle 10 more, this can only handle 10 more, so 20 more, 20 more, 10 more, 20 more.

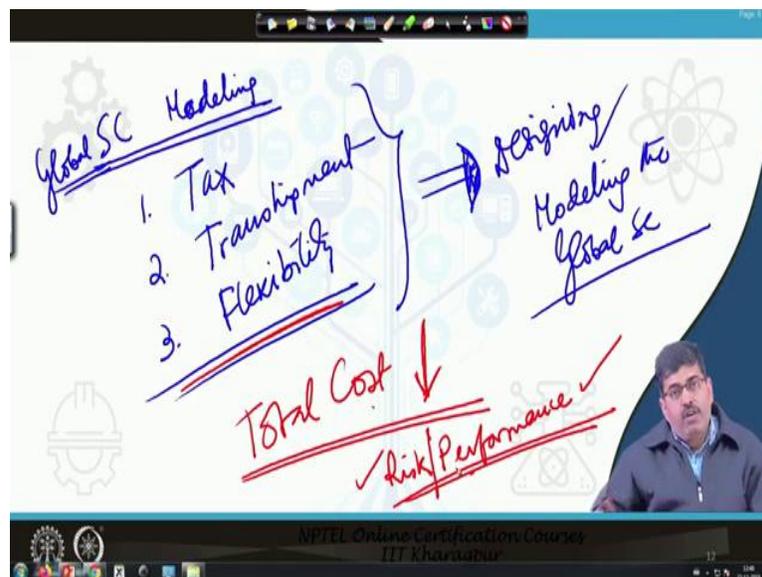
So, what does it lead to? What ultimately leads to? It leads to that your capacity, your flexibility, your flexibility to handle more is 10, flexibility of the entire supply chain is 10 units, why? Because this can handle more, this can handle more of it, this can handle more of it, this handle

less. So, your entire supply chain is limited by the capacity of this particular unit. So, flexibility of a Supply Chain gets blocked here 20, 20 it gets blocked here at 10 units and then it again moves on.

So, you see so 10 units is your flexibility. Now, how then the question is that entire supply chain suffers because of this particular unit because if you see entire supply chain is suffering because of this particular distribution center capacity. So, what do you do now, how to increase the flexibility? Maybe you will have to look at the transportation planning, how to have more vehicles so that material comes in material goes out very quickly.

Material does not stay in the warehouse, if material does not stay in the warehouse, then what will happen? Your warehouse space is fixed. Now, material does not stay, so you can handle more material. So, bias by redoing or re planning your transportation modeling, you can easily remodel the flexibility of the supply chain. So, this is another aspect this, this is a aspect of flexibility in supply chain. This is the aspect of flexibility in supply chain.

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Now, next what we see, so you see ultimately what have we done till now, what are we done? In this supply chain modeling, global, that is the full blown network designing in the global supply chain modeling. We have first modeled the, we have first modeled the tax because tax impact impacts my supply chain design. Next we modeled the transshipment, third, today we modeled

the flexibility, if you see all these things what is it, what are they leading to? They are ultimately leading to designing or modeling, designing or modeling the global supply chain.

But all these, but all these have to be or will be successful if your total cost is minimum, if your total cost is minimum. This we will pick up in the next module. This we will pick up in the next module, next module in the sense the next lecture, that how, what is the total cost Supply Chain? And then we will go in to design a full supply chain network.

Now, with this total cost in supply chain we will also bring in something little, little bit we will because we have a separate module, because we have already done it this and we will do it a bit later and also the risk, risk modeling just a recap and we will also do something like performance.

We have to build in this, risk also your study, we have finished it, performance also we have finished it. But then your total cost modeling you will have to do this and then we will be ready for one full blown network design model. Thank you for today and we will meet in the next lecture.