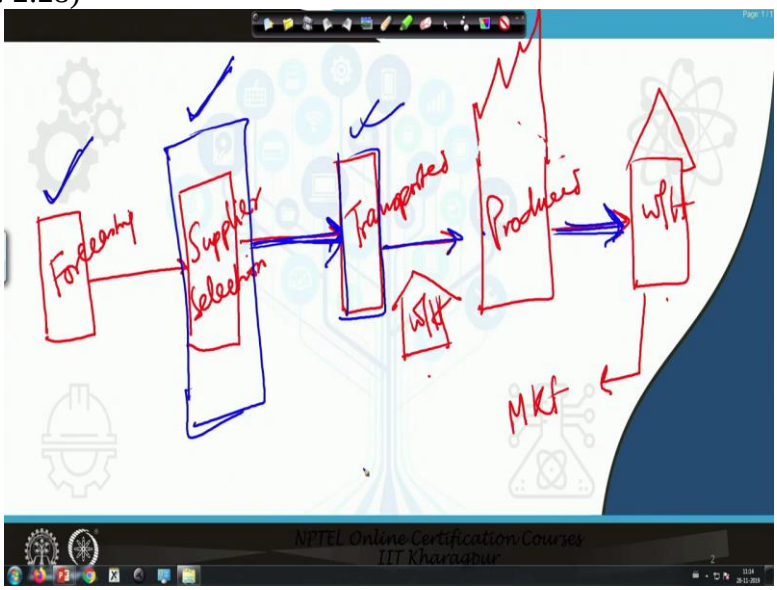
Modelling and Analytics for Supply Chain Management
Professor Anupam Ghosh
Vinod Gupta School of Management,
Indian Institute of Technology Kharagpur.
Lecture 12
Transportation Decisions: How to Take Decisions on Different Issues with Transportation?

Hello, welcome to module 2, and the first part, week one of Modeling and Analytics for Supply Chain Management. Now in module 1, you have been given a brief overview of what a supply chain is and then a broad overview or a broad understanding of how each and every element in the supply chain functions. And there, you also learned what is the role of analytics at each and every node and how analytics can help in building up a sustainable and a competitive supply chain.

In module 1, you also learned that supply chain is basically the enabler to competitive advantage, because products and processes have become so much generic today that the only way by which you can increase your sales of your organization is by reaching the consumer and in the shortest possible time and with the lowest possible market price, that is with the lowest possible cost. How to do that? You cannot reduce your employee costs, you cannot reduce your manufacturing costs. The only way is to reduce your distribution cost.

That is why a lot of focus today is on supply chain and that is why analysts are looking at all the ways by which you can reduce costs and therefore, the role of modeling has come in because it is only through mathematical modeling and optimization techniques that you can reduce cost and yet balance all the activities that you think are important for your organizational functioning. That is why there is a renewed focus and that is why the subject for supply chain modeling and analytics. So, in module 1, you have learned the basics and the advanced reasons why you need supply chain modeling.

(Refer Slide Time: 2:28)



And then we started off with what is supply chain is all about and we said that your supply chain will start from the demand forecasting. Your supply chain will start from demand forecasting. Once you have forecasted demand, then you know how much raw material you need to buy from your suppliers. So next is your supplier selection because when you go to a supplier, the supplier will ask you, the first thing the supplier will ask is how much quantity do you need?

So, unless you have a proper demand forecasting, you cannot tell that quantity to the supplier. So, first is demand forecasting, then is supplier selection and once you have selected the supplier, now the products have to be transported. Now the products have to be transported to the factory. In the factory, there the product is produced and then in the factory the product is produced. And then again the products have to be taken to a warehouse for storing. So warehouse for raw materials storage warehouse for finished product storage.

So this and then the product goes to the market. Then the product goes to the market. So this is a broad diagram of supply chain and this is what you have learned in module one and then we say that though supply chains starts with demand forecasting, though supply chains starts with demand forecasting, we are not looking at demand forecasting because demand forecasting is a subject or is a topic that is very extensively dealt with in operations research.

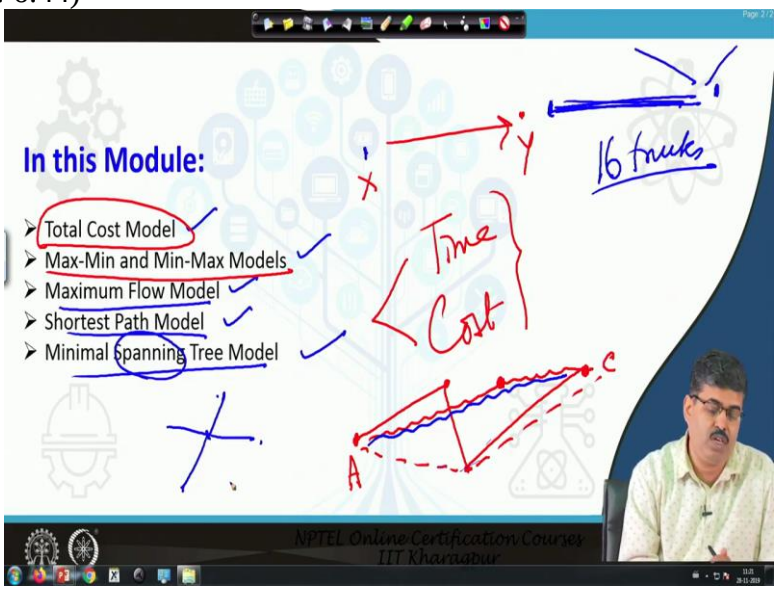
We straight away started with supplier selection, and in module 2 we have learned all the modeling techniques for supplier selection. Now, once you have selected the suppliers, these raw materials have to reach your factory or the warehouse which will store the raw materials for the time being. Now, the same thing applies to once the materials are produced from the factory and they go to the finished goods warehouse.

So there will be no issues by which and the questions by which the questions that will be asked to you from the top management is how will I reduce my transportation cost? How should I reduce? How should I model my transportation network, so that my transportation cost is lowest or reduced to the minimum possible?

So, what is it? Supply chain first starts with demand forecasting, then, once we have forecasted a demand, we need to select the suppliers who will supply me the raw materials and then I need to do transportation modeling because my objective is to reach the raw materials to the factory as well as the finished products to the warehouse in the lowest possible cost.

So, because my company will ask me or rather the analyst should ask himself or herself, what is the lowest possible cost by which I can reach the raw materials to the factory and reach the finished products to the finished goods warehouse. So, transportation modeling becomes an integral part of supply chain management and supply chain modeling and analytics. So, today we will deal with this transportation modeling part of it.

(Refer Slide Time: 6:44)



Now, so, in this module we will take care of total cost model, Max-Min and Min-Max models, maximum flow model, shortest path model and Minimal spanning tree model, what this is all about. Let us see. See, our first objective is to move the products from destination X to destination Y, destination X to destination Y in the shortest possible time and with the lowest possible cost, this is our first objective. So, this is my total cost model.

The products have to reach you in the shortest possible time and the lowest possible cost. Now, however, in this process what happens is like say, if your starting point is A and you will have to go to C, your starting point is A and you will have to go to C, your starting point is A you will have to go to C. Now what you can do is you can take this road, then come here and then go. Alternatively you can take this route, move up to here and then go, alternatively, you can move up to this route and then go.

So, what we want to say is, there are multiple possible points available to move from A to C, to move from A to C. Now, if you just look at this diagram, the lowest possible route is this one. So, if I always move my product through this route, what is happening? I am basically closing off this route. I am not using this route. So I am not taking any local transporter, who is ready to do business in this route. I am ignoring these transporters.

Now tomorrow if there is some problem with this shortest route then what will happen? Then I cannot get hold of any transporter who is operating in these routes. They will not give me business. Why? Because they are already engaged with other companies for whom they are doing business. They do not have any extra vehicles. So, basically, if I take only one route, which my mathematical model tells me to take, in reality, sometimes it might create some problems for us.

We will have to keep the option of two three routes two to three routes open for moving from A to C, this is business prudence. Like say for example, you are getting out of your house and what is the easiest way to come out of your house and reach your college or institute? The easiest way, I am not telling shortest. The easiest way is to take a taxi or take your own vehicle and go.

But if you are everyday taking a taxi or taking your own vehicle, what is happening? You are becoming very comfortable, you are staying in a very comfort zone. Tomorrow by chance if the car is not working, or if the taxi is not available, then you will have to take the difficult route, that is board a bus, get down at some point; again board another bus, get done at some point and then board the third bus and reach your destination point.

But since you are not acquainted with this new bus, multiple boarding points, bus multiple boarding zones, you will not be comfortable and maybe you will not be able to travel by bus. So, what we are trying to say is, if you use only one mode of transport from your house to your workplace, what are you doing? You are shutting off the other routes. So, then when time is, when it is required, then you will not be able to work on those other routes. You will not be able to put the bus. It will be difficult for you.

So, this Max-Min and Min-Max model takes care of this problem. Then is the maximum flow model. What is the maximum flow model? Maximum flow model is for example, I am working in a JIT system, just in time system. Means whatever I need as raw material, if I need them at 8am in the morning in my factory work schedule, the material will be available at 7:50 or 7:55 AM and in American and Japanese systems the material will be available at 7:59 AM.

So, just in time. Now, suppose my just in time requirement is 160 metric ton of raw material. A carrying capacity of a truck is assumed 10 metric tons. So, how many trucks do you need? 16, 16

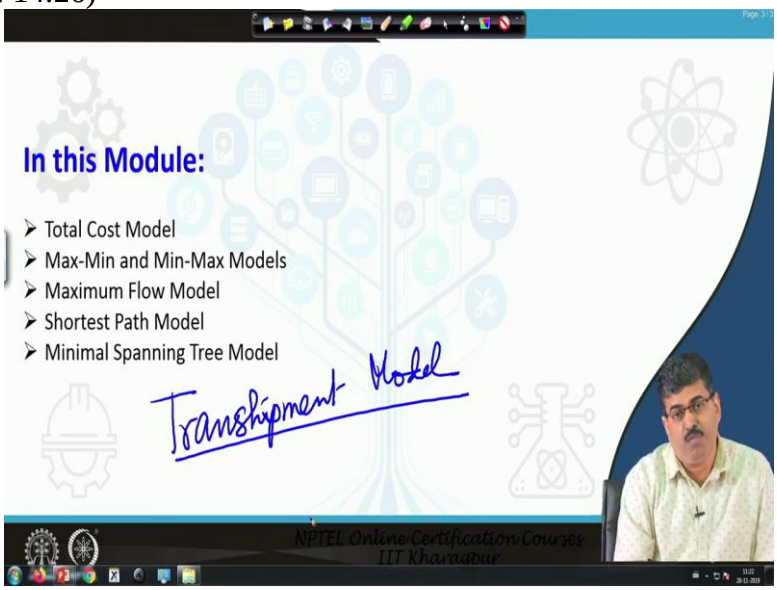
trucks you need. Now, also assume that in 1 hour, 160 metric ton of raw material is used up in my factory. So logically in 1 hour 16 trucks should be able to reach my factory. Because in 1 hour I need 160 metric tons; 8 to 9 AM, 9 to 10 AM, 10 to 11, 11 to 12.

So, in 1 hour, 160 metric ton of load should reach my factory. That means 16 trucks should be able to reach my factory in 1 hour. Now, what is the raw material source? If from the raw material source till my factory it takes more than 1 hour for the 16 trucks to reach then I cannot depend solely on road transport. If in 1 hour 16 trucks cannot reach rather other way if it takes 16 trucks more than 1 hour to reach by road then I cannot depend only on road.

Some portion I will have to bring by rail, some portion I will have to bring by other modes of transport. So, that is how to determine how many vehicles can travel in 1 hour. That is the maximum flow model. The opposite is the shortest path model. How do I reach my factory within the shortest possible time as a supplier and the last one is the minimal spanning tree model.

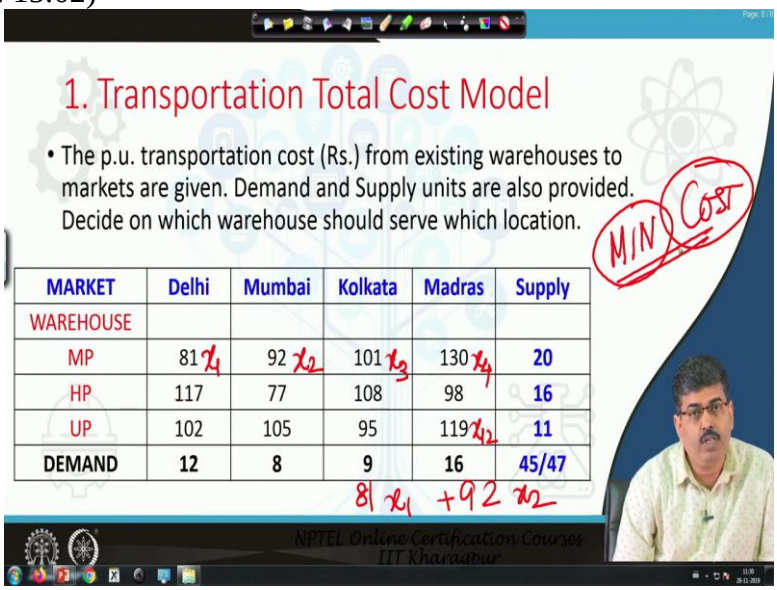
This model tells that if I have multiple warehouses, what is the minimum distance that it will take me to cover all the warehouses? So spanning, I span all the warehouses and what is the minimal spanning tree? So, these are the models that we will take care of in this transportation cost decision making.

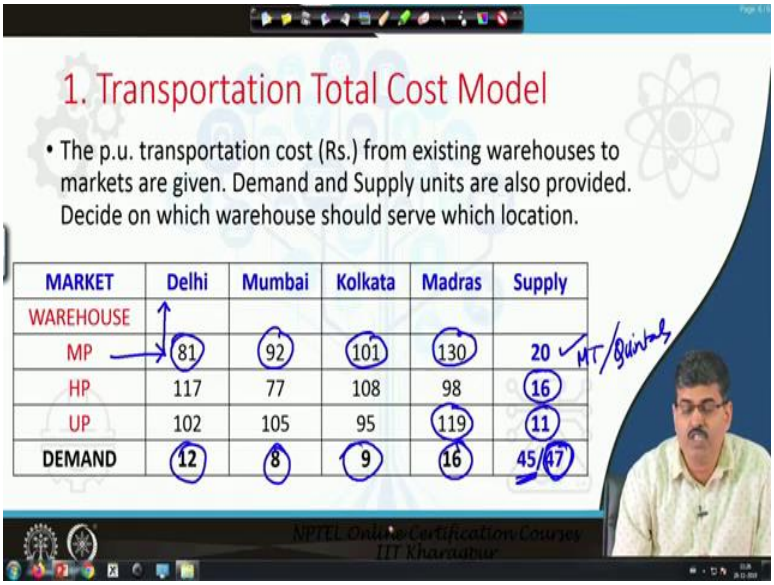
(Refer Slide Time: 14:26)



Now, having said that there is one more model that we will not discuss here; that is the transshipment model. We will pick that up in a later stage when we design the entire supply chain, when we model the entire supply chain. Then we will require this and we will pick up this model then. Now, let us go to the first model that is the total cost model. .

(Refer Slide Time: 15:02)





Now, this is a snapshot of the transportation total cost model. What it says is assume that I have some raw material warehouses or finished product warehouses, let us take the end product supply chain, I have a finished product warehouse or some supplier warehouse in Madhya Pradesh. I have some finished product warehouse or supplier warehouse in Madhya Pradesh, Himachal Pradesh and Uttar Pradesh. I have them already it.

In the next module in warehousing decision modules, you will learn how to locate these warehouses, what are the methodologies by which I can locate these warehouses. So, there

should be a mathematical tool or technique by which I should decide on the location of the warehouses. It should not be arbitrary.

But for here we assume that we already have these warehouses right from the beginning maybe 100 year old we are running these supply sources or warehouses and these are my markets; Delhi Mumbai, Kolkata, Madras. Instead of markets these can also be taken as production centers. These are my supply zones. My suppliers stay here-Madhya Pradesh, Himachal and UP and these are the factory zones and the factories are near to the market that also you can take.

So, basically it has origin destination. Origin is here and destination is here. This is, his origin maybe supplier based, destination is factory; origin may be finished product warehouse, destination is market but essentially it is an origin, these are the markets. Now, what is this? 81, 117, 102, and 12? Now 81, 117, 102 basically are the cost of moving one unit of the product from this place to this place.

That is the cost of moving one unit of a product from Madhya Pradesh to Delhi is 81 rupees. Cost of moving one unit of the product from Madhya Pradesh to Mumbai is 92 rupees. Cost of moving one unit of product from Madhya Pradesh to Kolkata is 101 rupees. Cost of moving from 130 rupees to Madras. Similarly 117, 77, 108, 98 and after this cost of moving one unit from Uttar Pradesh to Madras is 119 rupees. What is the capacity of this Madhya Pradesh warehouse?

Capacity of the Madhya Pradesh warehouse is 20. What is 20? This 20 can be metric ton, this 20 can be quintals, whatever, this is units. Capacity of Himachal Pradesh is 16 units. The capacity, the warehouse capacity, warehouse stock holding capacity or if you can take it as a supplier, it is the supplier's supplying capacity. It is the suppliers supplying capacity. So this is 11.

So, what is the total supply possible? 47 units. What is the demand at Delhi? Demand means end market demand or if you are taking the inbound logistics this is the demand from the factory at Delhi. So, demand at Delhi is 12 units, demand from the factory at Mumbai or from the Mumbai market is 8, 9 and 16. So, total demand is 45 units and normally if you have done OR: operations research problems earlier, you will see that this thing is more or less equal for most of the problems.

That is demand and supply is equal. This is done to make life simple, but in reality life is not simple. So, we will not make it simple also for you, we will not make it simple. We will learn it the way it will happen in the industry. So, here my demand is 45, my supply is 47. Now you will say but then demand maybe more also than supply. For example, when a new movie is released, the demand for movie tickets is much more if it is a hit movie and so movie theaters go housefull.

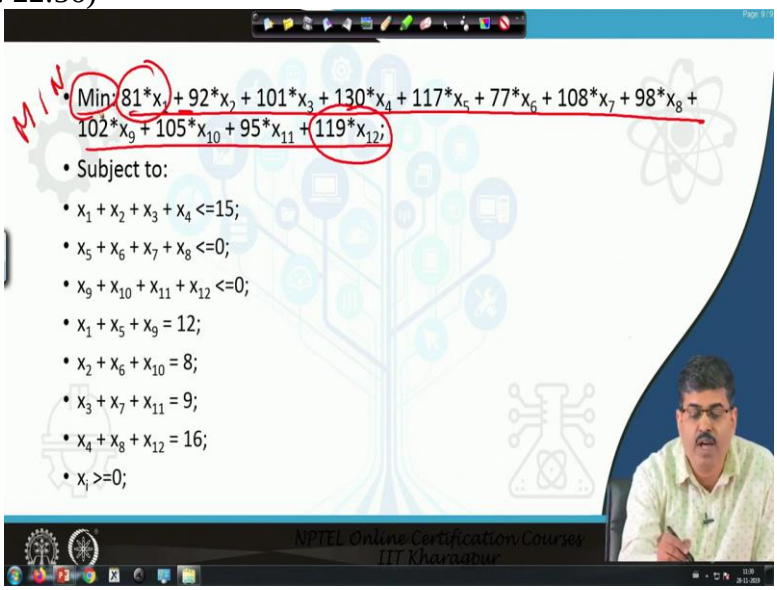
So, demand is more than the supply of seats. That can also happen, yes that can also happen. We will learn that also. So, what I am trying to say is demand will not always equal to supply and that is what is actually will happen in reality. So, this is my cost structure. These are my demands and these are my supplies. So, what will happen? Rather what should I do? Here if you see how should they model it? Now, what is my so, let us first ask this question, what is my objective?

What is my objective as a supply chain planner or as a supply chain designer? My objective is to minimize cost. Agreed. So, how much products I should transport from Madhya Pradesh to Delhi, how much products I should transport from Madhya Pradesh to Mumbai, etcetera. How much products I should transport from Himachal Pradesh to Delhi, how much I should transport from Himachal to Mumbai, etcetera, how much I should transport from UP to Delhi, UP to Mumbai, etcetera, the total cost required for this has to be minimized.

So, how much I should transport? We do not know. That the mathematical model will tell me. How much I should? Transport let X1 be the quantity that I should transport from Madhya Pradesh to Delhi. What is the cost? 81 rupees per unit. So, what is the total cost of transporting from Madhya Pradesh to Delhi? 81 X1. Madhya Pradesh to Mumbai, how much quantity will you transport? X2. We don't know. That will come out.

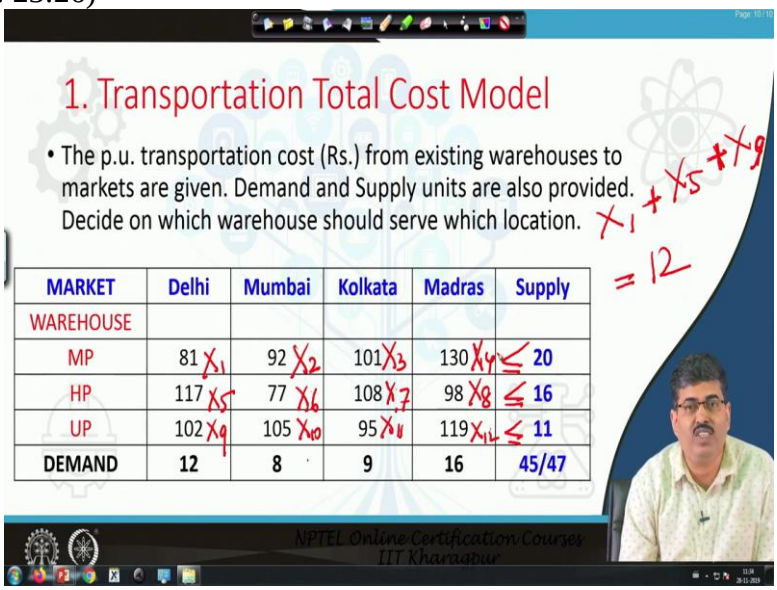
So, Madhya Pradesh to Delhi, sorry Madhya Pradesh to Mumbai, what is the total cost possible? Cost of one unit is 92 rupees. X2 quantity is transported. So, Madhya Pradesh to Mumbai is 92 X2. In this way 101 X3, 130 X4 dot dot up to 119 X12. This is your total cost that is possible and this cost has to be minimized. This cost has to be minimized. . Now, that is basically what we have shown you in this problem.

(Refer Slide Time: 22:56)



That is basically what we have shown you here. This is your total cost that is possible. See, last one was 119 X2 if you remember from the earlier matrix and the first one was at 81 X1. And this entire thing has to be minimized. What are the constraints? Let us go back. So, is this clear? Let us go back and see what are my constraints.

(Refer Slide Time: 23:26)



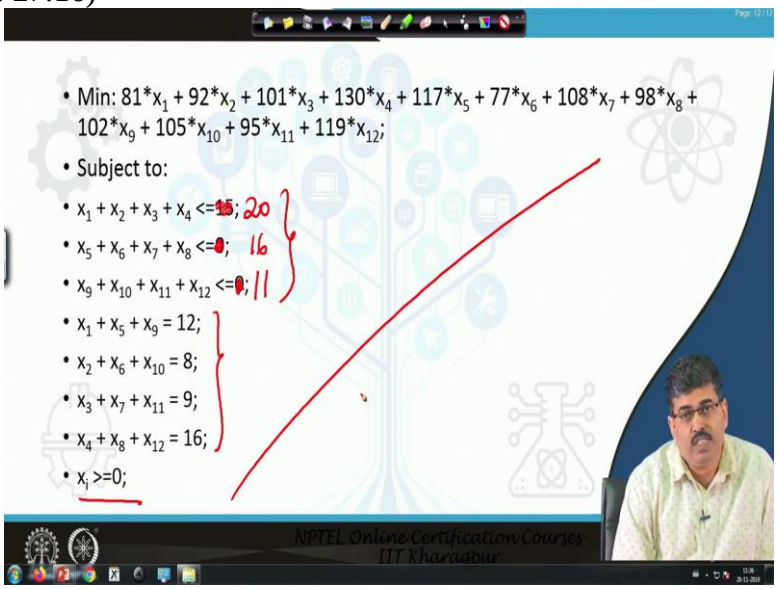
My constraints are let us see this was X1, this was this was X2, this was X3. My constraint was that Delhi demand, demand from the Delhi city or the Delhi factory has to be fully met. So, my constraint is X1 is the quantity to be moved from MP to Delhi, X2 is Himachal to Delhi and X3 is UP to Delhi. So X1 plus X2 plus X3, X1 X2 X3 should equal to 12, that is only when my demand will be met for Delhi equal to… No, we started with X1, X2, X3, X4.

So let us make it, we move this way X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12. So X1 plus X5 plus X9, X1 plus X5 plus X9 is equal to 12 ? X2 plus X7 plus X10 is equal to 8. X3 plus X8 plus X11 is equal to 9. X4 plus X8 plus X12 is equal to 16. These are my first set of constraints. What are the next set of constraints? This is what constraint that we have done demand.

What is the next set of constraints? Madhya Pradesh supply can be maximum 20 units. Why are we saying not equal to 20? Because, not equal to 20 we are saying because a factory cannot guarantee its maximum output every time. There will be machine breakdown, there will be workers who might be absent. Some machines under regular maintenance. So, maximum capacity, a factory may not always attain. Same applies to warehouses. So, your supply will always be less than equal to your maximum capacity.

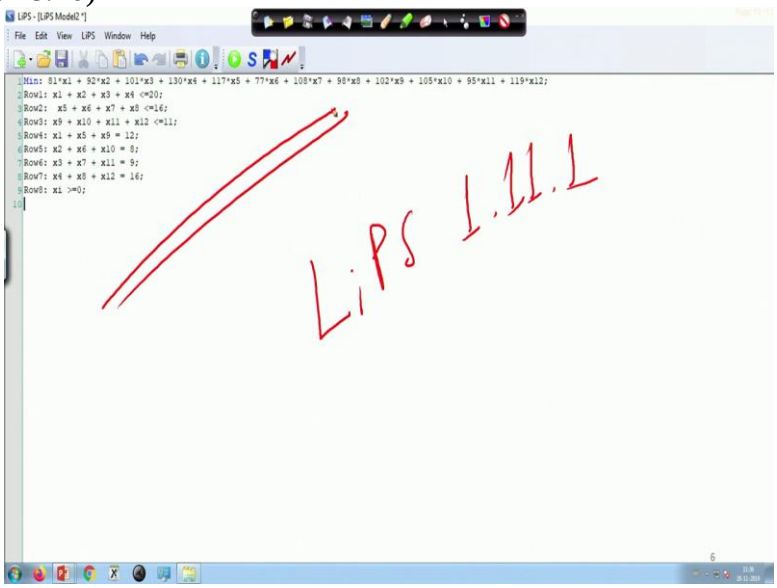
So, what are your supply constraints? X1 plus X2 plus X3 plus X4 less than equal to 20. X5 plus X7 plus X8, this is X6, X7 yes this is X5 plus X6 plus X7 plus X8 less than equal to 16. X9 plus X10 plus X11 plus X12 is less than equal to 11. We are not taking cost. This is only the quantity that we can supply. So 81 will not be taken. It is only the quantities X1 because warehouse deals with quantity. So it is only X1, X2, X3, X4. Don't say 81 X1 plus 92 X2. That is cost. X1, X2, X3, X4, this is quantity. So these are my two sets of constraints.

(Refer Slide Time: 27:16)



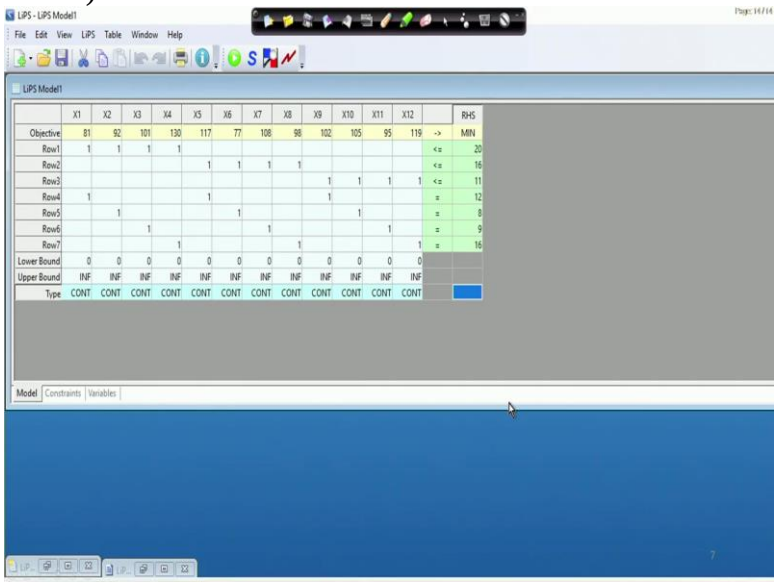
So, this is what we have just now found out from there. X1 X2 X3 X4 less than equal to 15 and these were my demands. These were my demands. There is a slight 20, 16 and so, these were my supply constraints less than equal to and these were my demand constraints equal to and definitely X value should be greater than equal to 0 because quantity transported cannot be negative. So Xi will be greater than equal to 0. So, this is the optimization model that you need to solve. Remember in supplier selection, we had started off with how to solve or how to model the linear programming problems.

(Refer Slide Time: 28:20)



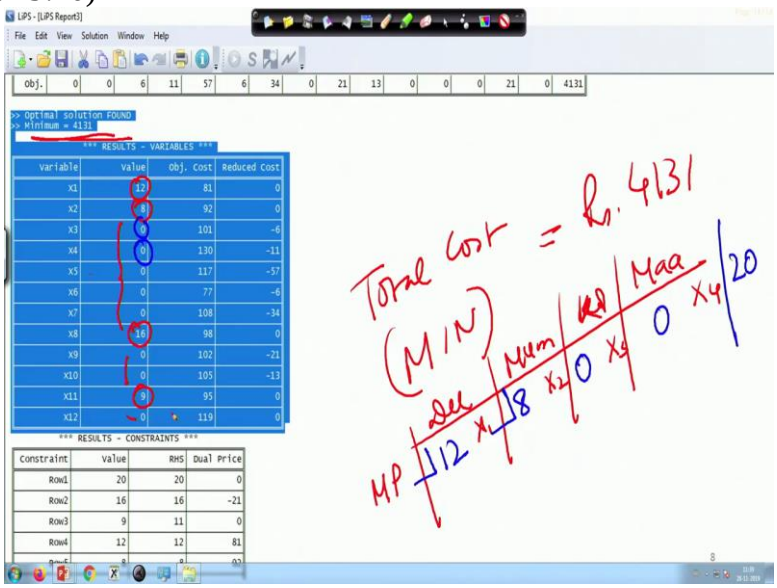
Now, what we have done here is we have given you the same model we have used a software called LiPS 1.11.1. This is available in the net, you can easily download and work on it. It is the same, the beauty of this is we can use, the way we write it in our exercise books, we can use the same manner to model this. So, to write this model actually, in the same manner, we can write this model. So this is the screenshot of just the writing of the same thing in a model format.

(Refer Slide Time: 29:00)



And in case you are using Excel, this is the Excel based model for the software. You can just write the numbers.

(Refer Slide Time: 29:10)

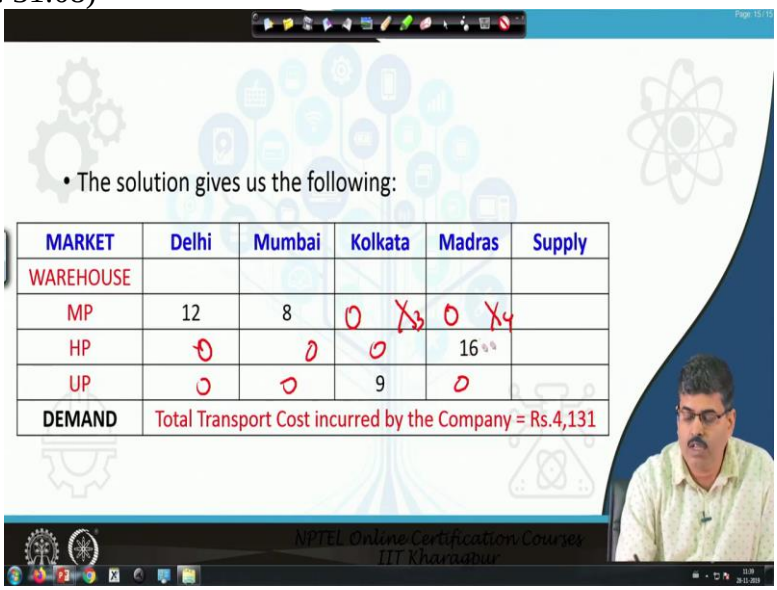


And what you will get is you will get something like this. What it says is your minimum is 4131, that is your total cost which our objective was to minimize that is 4131 rupees and what it says is X1 is 12, X2 is 8. That means, if you see we had Madhya Pradesh and this side we had Delhi, Mumbai, Kolkata and Madras and we had X1, X2, X3, X4 remember? X1, X2, X3, X4.

So, what we are saying is X1 is 12, X2 is 8, X3 0, X4 0. So here 0, 0? That means that 12 units should we move from mother Pradesh to Delhi, 8 units should we move from Madhya Pradesh to Mumbai. What was my capacity of Madhya Pradesh? If you remember it was 20. So, this is also satisfied. So, this solution or this this type of programming gives us the quantities how much should we send from where.

So 12, 8, 16, 9, remember, remember these quantities 12, 8, 16, 9 because we will again come back with a situation which is in the next part, what we want to say is see X3, X4, X5, X6, X7, X9, X10, X12, all are zeros. That means, no quantity should move from these locations. No quantity should move from these locations. That means from this warehouse to these market, no quantity should be sent. If you send my cost will be higher.

(Refer Slide Time: 31:08)



So, this is basically, so this is what your solution is 12, 8, 9 and 16. So, X3 if you see X3 is 0, X4 is also 0 and these are all 0s. So nothing should be sent. Sorry, this is 16. Nothing should be sent here, nothing should be sent here. So, this is basically my transportation cost model. It tells us how much we should send.

So, this gives us the minimum cost that is incurred by the supply chain network for transportation purpose. Now in the next week we will come up with a situation that is a bit modification to this model and that is one which you will actually face in the day to day supply chain modeling, planning and design, thank you.