Modelling and Analytics for Chain Management
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Lecture 18
Warehouse location models - III

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Hello, welcome to week 4, module 3 of the program Modelling and Analytics for Supply Chain Management. In week 1 and 2, we have learned how to locate a warehouse based on certain available information. For example, when we do not have any numeric information, when our decisions have to be purely based on experience, as well as perception, we would use the factor rating model and we will also use the factor rating model when the total number of warehouses to be set up is less and limited to a particular geographical region.

When we have full cost information then we can use the Break-Even Model and when we have, when we can break up the cost into fixed cost and variable cost, as well as where, we have to decide on a range of materials and the range of quantities, which has to be stored in our warehouse. So, basically one is perception based decision making, factor rating model. The second one was cost based decision making that is the Break-Even Model. The third one was when we did not have cost information, but our market demand was given.

When market demand was given and we already knew the established markets and we needed to have one warehouse, we had used the centre of gravity model. So, no cost information was given only market demand was given, we knew the geographical location of the markets. So,

we located the warehouse at a central point of all the surrounding locations. So, that was the centre of gravity model.

That is where the word centre of gravity has come from and centre of gravity model, we showed only the first iteration this will continue second third iteration till the locations do not change from the earlier iteration do not change much from the earlier iteration. Today, we will cover another method of warehouse location and this method that we will cover is equally applicable for store locations. Now, assume a situation when there are 4 markets, which we will have to serve and ideally, ideal situation will be we will have 4 warehouses.

But that is not always possible financially as well as it is not economic prudence also let the business grow, let us understand how the market will improve in the near future then only we can take a decision for locating as many number of warehouses. So, right now we are faced with this situation that there are quite a few markets and, in these markets, we will have 1 warehouse first, then we take the decision to open the second warehouse, then the third, then the fourth. Where we will have this type of a problem?

Assume that we are going into a new country we do not want to invest in 14, 15 warehouses across the country, we want to invest in 1 warehouse first, see how the market is behaving, see how the local relations, local economics is behaving then only be go on to decide to the second location, then the third location.

Let us take another situation. We are retail chain and we want to set up a retail chain in Mumbai, Kolkata, Delhi, etc. Then, we do not want to setup all 15, 20 chains all together. We first set up 1, then second, then third and then proceed. So, how to decide on this sequence? 1, 2, 3, 4 how to decide in this sequence? This method is called as Ardalan Heuristic it is a heuristic and ardalan heuristic is the method that we follow.

So, just a recap, when do we use it, when we have plans to build up warehouses 1 after the other. But, then we need the sequence that is which warehouse to build first, which warehouse to build second, which warehouse to build third. This is true for both the domestic market and when your business is in a new country. You want to set up one warehouse first and then second, third, fourth this model is also applicable for store location, store in the sense retail store location. Now, how will we do it? Let us check up.

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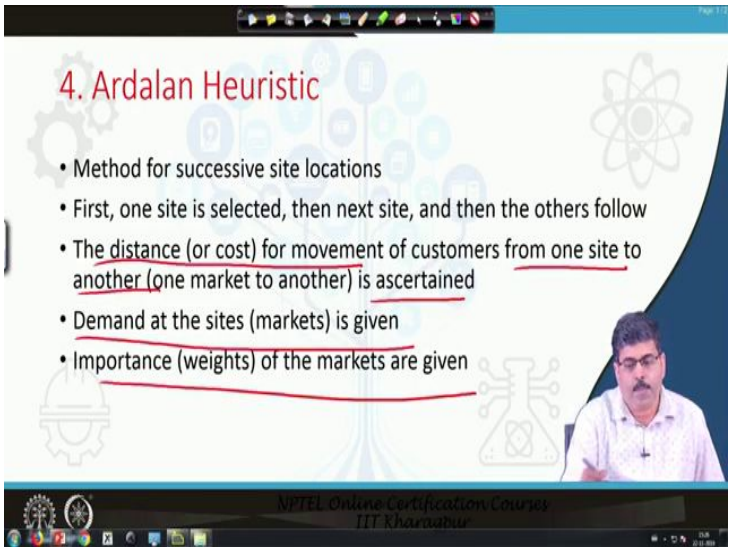

This is what we have already mentioned. First one site is selected then the next site and then the others follow. Now, the distance of one site or one market to the other is given, or we have to ascertain. The distance or cost for movement of customers from one place to another is given and we also know the market demand and the importance of the markets are also given.

So, we know the distance which is easily available, we need not depend on the company of the organization for this information. We know the demand has to be provided by the organization and the importance of the markets has to be provided by the organization. Remember the earlier two methods, we did not give importance or weights other than the factor rating where some other weights given.

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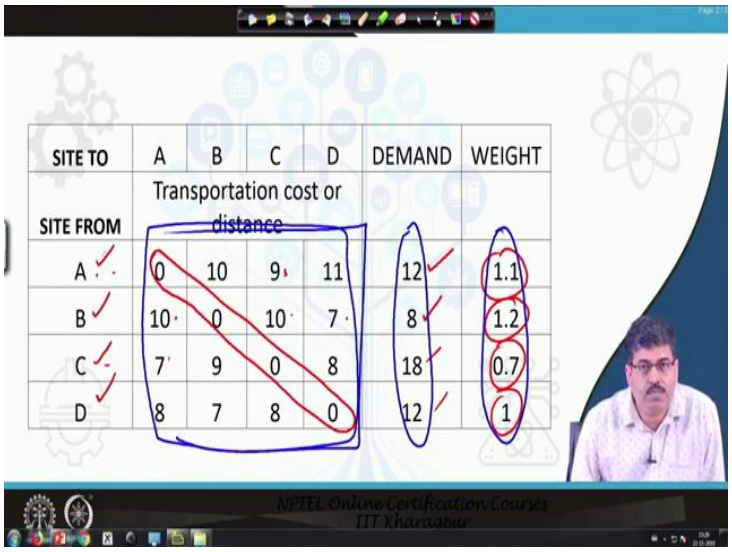

Now, this is the model that we are looking at, remember this model can be expanded we are showing a small snapshot of it. What are we saying, that there are 4 markets A, B, C and D. Now, distance, which is equivalent to transportation cost per unit distance from A to A to A is 0. Definitely, distance from B to B is 0, C to C is 0. So, this is the distance matrix distance from A to B is 10 kilometres, 100 kilometres, 1000 kilometres, whatever.

So, distance from A to B is 10 units, A to C is 9 units, A to D is 11 units, B to A definitely 10, B to C is 10 and, in this way, it is moving. Now, what is the demand at market A or site A? Demand at market A is 12. Now, just a word of caution before, we move on see, distance from A to C is 9 kilometres. So, distance from C to A should also be 9 kilometres. Distance from A to C is 9, so from C to A is also 9, Not necessarily, this you must understand that given the city conditions, some roads are one way, for entering the city you use 1 set of roads, for exiting the city you use another set of roads. So, sometimes road distance is to and from the city may not match.

So, these numbers on the row side may not match the numbers the column site as A to C is 9, but C to A is 7, so this may not match. So, do not worry about that. Now, so demand at A is 12 units, demand at B is 8 units, 18 and 12 units maybe 8000, maybe 80,000 and the importance of the city for this particular company that is the weights given, importance of the city for this particular company.

So, how do you proceed? This is the information that you have. So, just to recap, what information do you need from the organization or the company you need this information and you need the importance of these markets, this information. This cost structure or the distance matrix you can easily collect on your own. So, how do we precede? Let us see.

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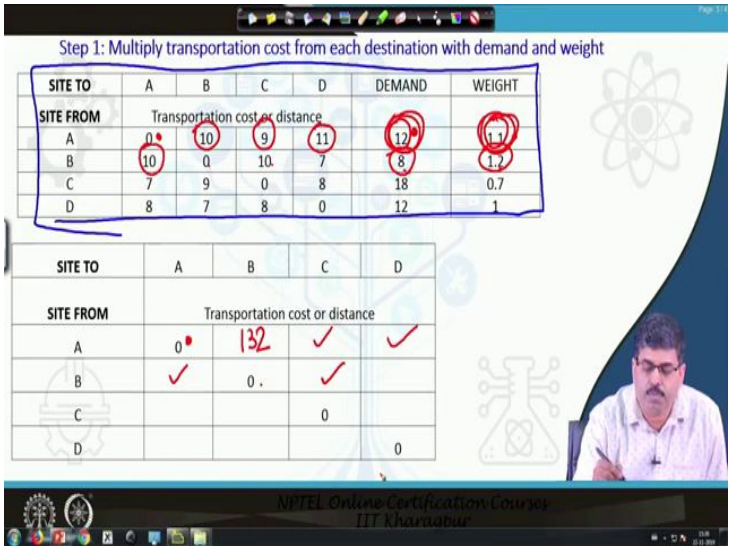

First step, this matrix was already there, this we have just brought it from the previous slide, this matrix was already there. Step one; we have to multiply the distance with the demand, with the weight multiply the distance with the demand with the importance or weight. So, 0 into 12 into weight, is what? 0. Next, B distance 10 into demand 12, 10 12 za 120, 120 into 1.1 is 132 I presume. Similarly, 9 into 12 into 1.1, 11 into 12 into 1.1, now 10 into 8 into 1.2, 0 into 8 into 12 0, 10 into 8 into 1.2 again here. Let us see fill them up. 10, 8 into 1.2 is 9.6, 9.6 into 10 is 96. Similarly, here also 8 into 1.2 is 9.6, 9.6 into 7. So, in this way you will have to calculate all the values. So, this into this into this, then again this into this into this, this into this into this. So, what does this matrix look like now?

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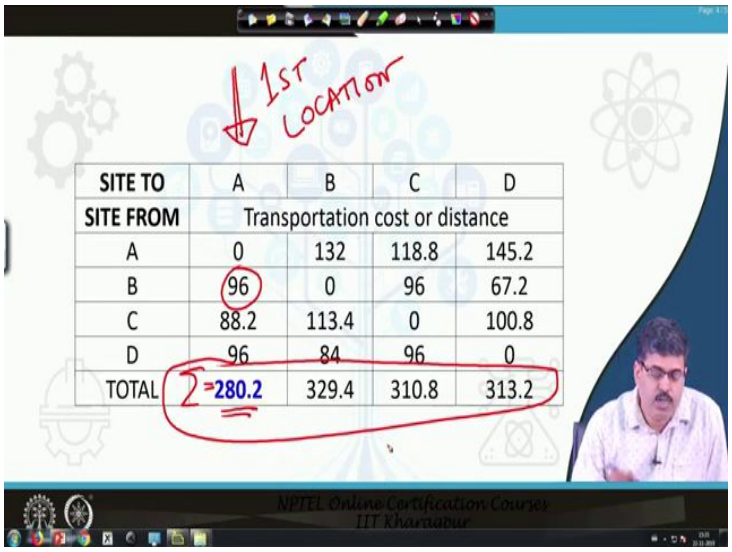

The matrix will look like now this, once you have multiplied and put the scores, remember we just put 132, we had just put 96. So, in this way if you calculate, you will get the score. Now, with total we do a summation and once we total all the cities or all the columns the lowest one you see in the blue is 280 this is my first location the one in blue, I will remove them so that you do not get confused. This method Ardalan Heuristics, just while I am erasing let me tell you this method at one time has been extensively used by banks and post offices to decide on mathematically where to locate a bank branch or a post office centre.

Then this concept was borrowed for supply chain, to decide on warehouse location. Now, it has been borrowed by organizations, who are opening chain stores this method is pretty time tested method. So, we multiply and we total the columns and the one with the lowest total is the first location this is the first place where we locate the warehouses. Then, now just pay attention what we are doing.

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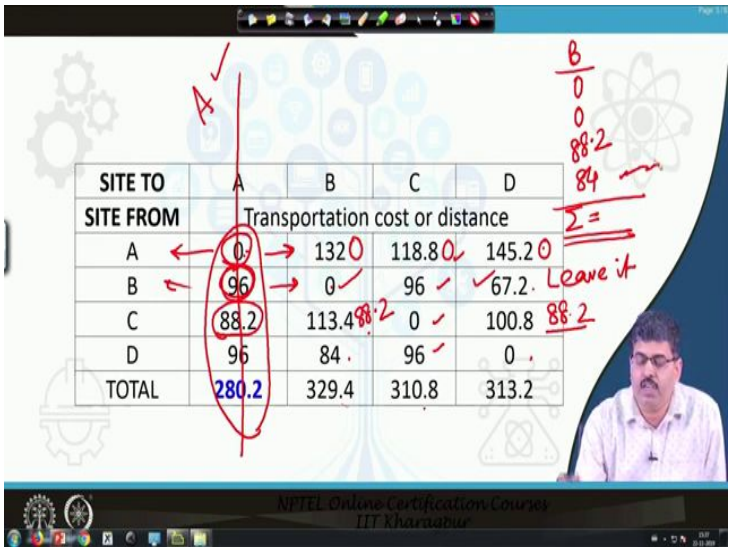

This is my first location. Now, look at this column be very careful, look at this column this particular cell 0, the first element in this column is 0 move row wise. If any value in the other cell is more than this value, I am repeating first cell of this lowest cost column, the first cell move right ways or left ways, whatever, move row wise, if any cell value is higher than this value, make this cell value equal to this value. So, 132 is higher than 0, so make this cell value equal to 0.

Similarly, 118 is higher than 0 make it 0, let us go to the second one, 96 is the value of this, if any cell value is higher than this value you will have to make it equal to 96, but here no cell value is higher than 96 it is equal or less than 96. The second rule is if some cell value is not higher than this value, if it is lower or equal than this cell value. So, if any cell value is lower or equal to this cell value if it is higher you will have to make it equal, if it is lower, if it is higher this one if it is higher than you will have to make it equal, here it was 0 so, you made all zeros if a cell value is lower or equal to like 67, 0 than this cell leave it as it is. Let us take the 88.2, 113.4 is higher than 88.2. So, what should we do? We will make it 88.2, 0 is lower than 88.2 leave it as it is, 100.8 is higher than 88.2 make it 88.2, getting it? 96, 84 is lesser than 96 leave it, 96, 96 same? Leave it. 0 less than 96? Leave it.

So, what are we left with now, if you notice, we are left with now, I am writing down here, we are left with now, A is already selected. So, forget A, A matrix is gone now, A as a location is the first location. Next, we are left with B C D. So, what is the new cell value look at B 0, 0, 88.2 and 84 see 0, 0, 88.2, 84 total it. Similarly, for C 0, 96, 0, 96 total it. Similarly,

for D 0, 67.2, 88.2, 0 we have done it in the next slide. So, after you have redrawn the matrix after you re numbered the matrix you total the matrix again, after you re numbered the matrix you total the matrix again, this we have done in the next slide.

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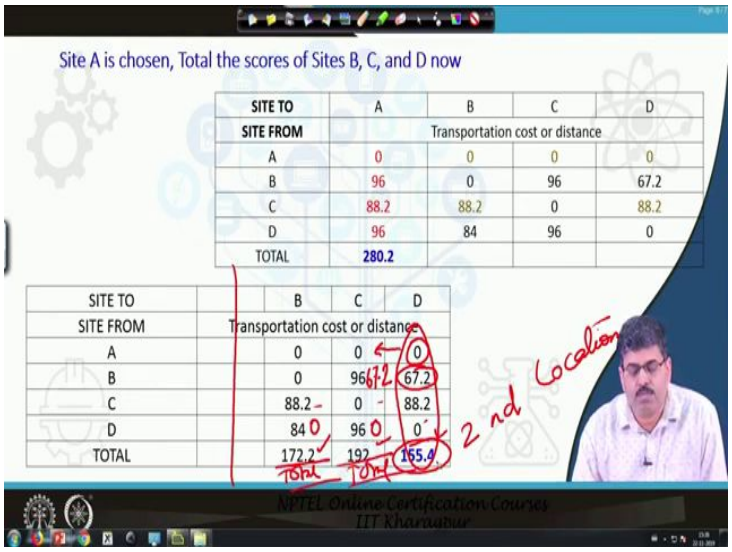

See here, site A is gone and site 0, 0, 88.2, 84 we have just done this here you total this matrix. Now, which is the lowest? 155.4, so 155.4 is your second location. Now, what is the next exercise? Go through this column, cell is 0 all these values should be either less than or equal to this value. So, 0, 0, 0, 67.2 all the values here should be either less than or equal to 67.2, 0 is less 96 is more. So, we will make it 67.2. 88.2 equal, no problems 0, all will be 0 done. So, an again we will do a total.

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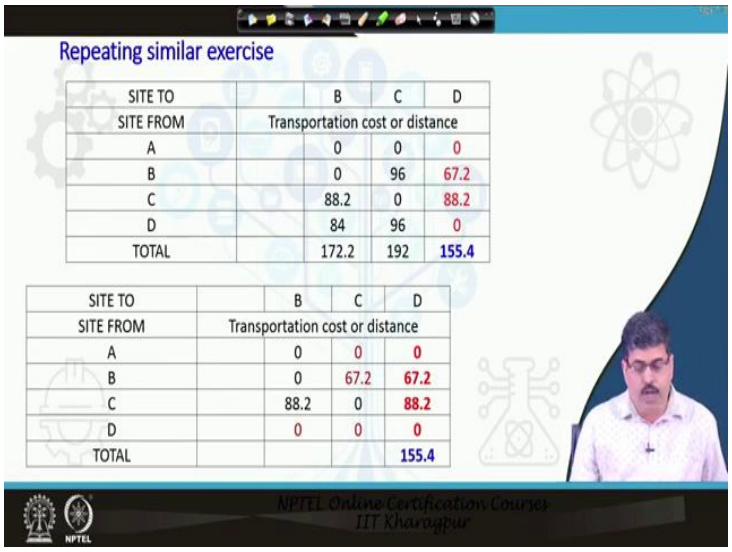

We have just mentioned this we have made all the values 0.

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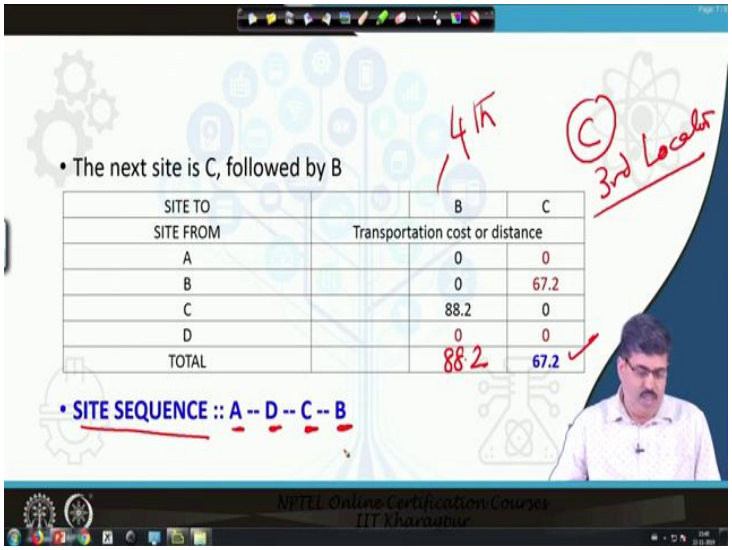

Now, we have again once we total, we get 67.2 as the less and this one is anyway 88.2. So, C is your third location and what remains is B. So, B is your fourth location. So, what is the site sequence A then the last one came D now came C and the last one is B. So, if you are locate. So, what is the moral of the story, if you are locating the warehouses the sequential manners do not have that much of finance at the same time.

We are looking at the best alternative among with all the possible constants of finance etc. You do not have cost data only have distance data you do not have fixed cost data you do not have a variable cost data you only know the demand of the market, then and you have a constraint that you have to open the store not at the same time, but one by one. So, then you will have to use Ardalan Heuristic and this is the sequence, this is the manner in which you get this sequence. So, this is the Ardalan Heuristic.

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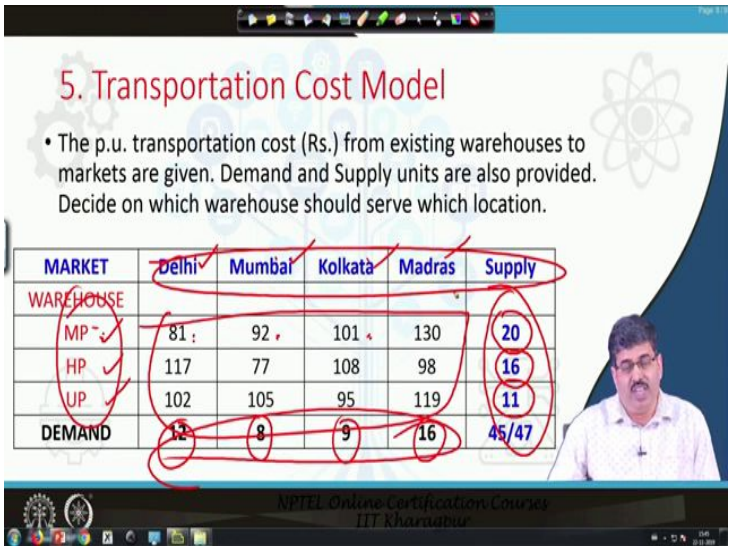

Now, the next one is fixed cost is fixed, you cannot change it. And let us assume another situation all along, we were saying that we will set up a warehouse we will, that means we had no warehouse, we are a new business and all our warehouse are gone, demolish they have become very old torn tattered everything. So, now we are in a situation that you have joined very recently in that organization the warehouse is a running since last 50 years and these warehouses are very strategically located.

For example, let us say if you have come to Kolkata, you will see once you are moving out of the Howrah station and moving past the river Hooghly, you will see lot of warehouses. Now, what and many of them are storing things, many of them are not storing things.

Now, why are those warehouses there? If, the goods are coming by train they should be on the site of or beside the Howrah railway station, but these warehouses are on the other site of the river, Howrah is on one site of the river and the warehouses are on the other side of the river. Why this is happened or why this is happened, this is happened, because even up to 50,

60, 70 years back, lot of transportation used to happen by river route and river route even today is the cheapest mode of transportation.

So, lot of bricks which are used for house building are still transported by river, mud is transported by a river. In Kerala, a huge amount of tiles used in houses for construction purpose a transported by the back waters. So, lot of transportation happens for heavy products bulk products and where the response time required is not that much quick. So, you can move it slowly their water transport is still very important.

So, in Kolkata also, when water transport was there a lot of these warehouses were built up, just beside Howrah to take care of the entire market of Kolkata and Eastern India. So, the warehouses there are standing since the British period, since last 150 years 200 years. So, what I want to say is you will encounter situations when the warehouses already there and they are there either for some geographical benefit geographical reasons, etc.

So, there the warehouse locations are given to you, you cannot change the warehouse locations and the markets are also given for example in India the most popular market where you can really sell things are the metropolitan cities.

There also you cannot change anything. So, if you look at this matrix that is there in front of you on your screen. The markets we have considered is let say Delhi, Mumbai, Kolkata and Madras this markets are also given you cannot change the market because these are the places were a majority of your population lives and as we mentioned the warehouses are also already set, maybe last 100 years this warehouses are there. So, when markets are given warehouses are given you cannot change. The decision that you will have to take is, now just a break here in the sense that, the market have given and you also know the demand from these market.

Because that comes in from forecasting and you also know the capacity the holding capacity the storing capacity of these warehouses and you also know the transportation cost per unit of the product from every warehouse to every market, transportation cost for every warehouse to every market, every warehouse to every market.

So, what we have said is, you have no control over the market, you have no control over the warehouse, you have no control over the transportation cost also, you have no control over the demand also and you have no control over how much the warehouse can store. Because

these warehouse the area the square feet the square meter all are there from last 150 years. So, what do you have control on? What decision can you take? The decision that you have to take is the demand and supply is given

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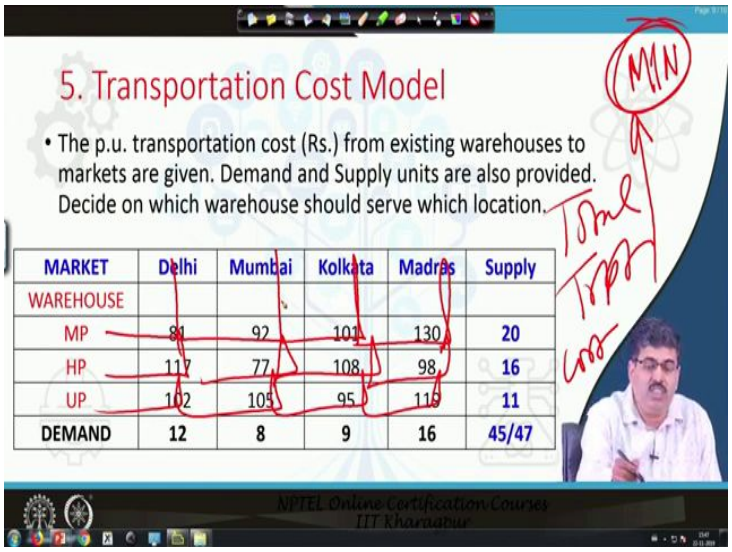

MARKET	Delhi	Mumbai	Kolkata	Madras	Supply
WAREHOUSE					
MP	81	92	101	130	20
HP	117	77	108	98	16
UP	102	105	95	119	11
DEMAND	12	8	9	16	45/47

How much will I send from which warehouse to which destination? So, that my total transportation cost is minimum that is the decision that you have to take, earlier cases you are talking a decision as to where you will locate the warehouse. Now, it is the warehouse location are give to you, earlier you were taking a decision where I will locate. Now, warehouse is already located you will have to decision that from where I should send how much quantity of goods. So, that my total cost remains less.

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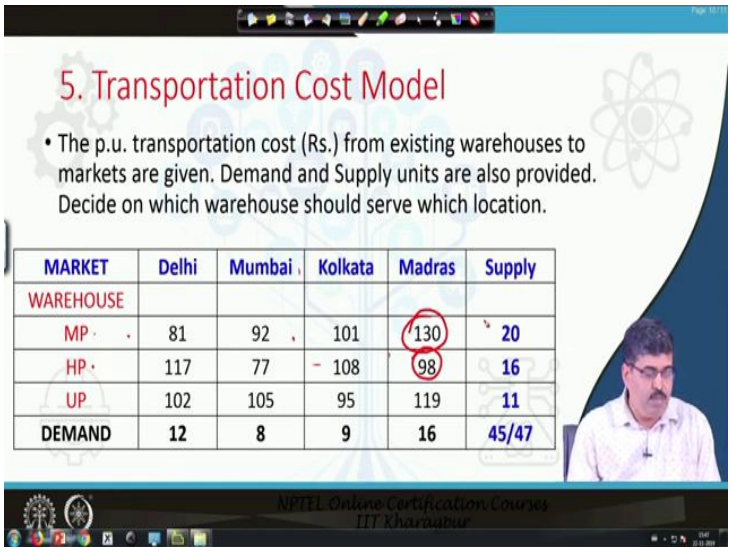

For example, if you look at this matrix, just see from Madhya Pradesh if I send some goods to Madras or Chennai per unit transportation cost is 132 rupees. But if I am sending the same goods to Chennai from Himachal Pradesh, my per unit transportation is coming do the to 98 rupees. So, I should send the goods to Chennai from Himachal Pradesh. So, this is what, this model is all about. Demand is given supply is given, how much quantity I should send from which warehouse to which market. That is the decision you will have to take.

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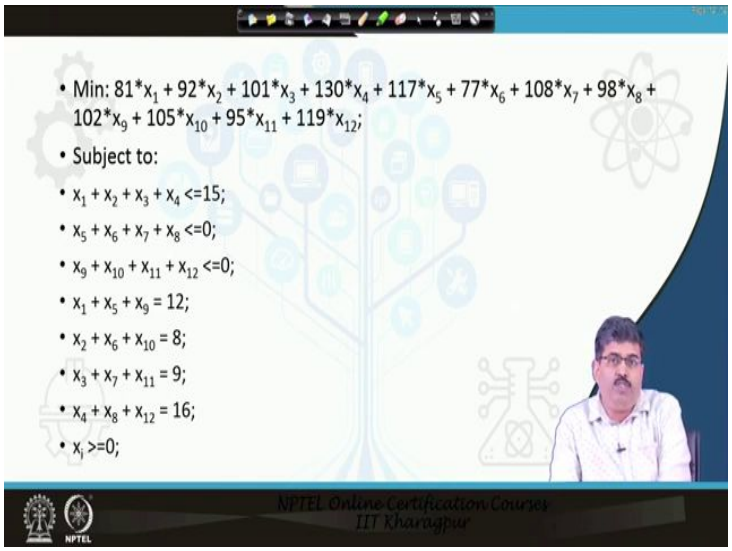

Now, how to do it, let us see we will form as we mention in the module 2 we started with a linear programming our objective is to frame this as a linear programming model.

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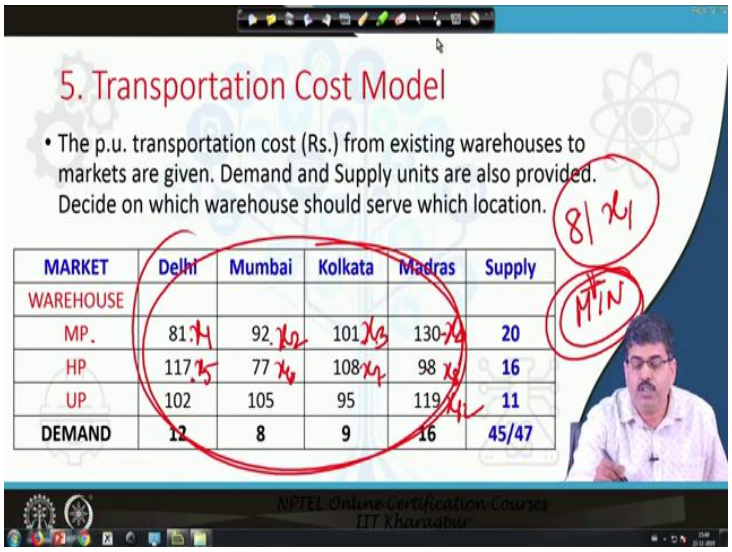

How much quantity we will supply? We will supply from Madhya Pradesh to Delhi we do not know x1, how much you will supply from the Madhya Pradesh to Mumbai x2, how much we will supply x3, x4, x5, x6, x7, x8 in this way up to x12. What is the total cost for moving goods from Madhya Pradesh to Delhi 81 per unit cost into x1 units. So, 81 x1 is the cost of moving goods from Madhya Pradesh to Delhi plus what is the total cost possible in this model 81 x1 plus 92 x2 101 x3 130 x4 117 x5 77 x6 as said.

So, this is the total cost that is possible, this much cost will not be incurred. Because, not all of goods will be sent from every place you will send to those places where the cost is the cheapest, but this is the total cost possible 81 X1 plus 92 X2 103 X3 etc. And what is my objective? My objective is to minimize this total cost. So, that brings us to this equation.

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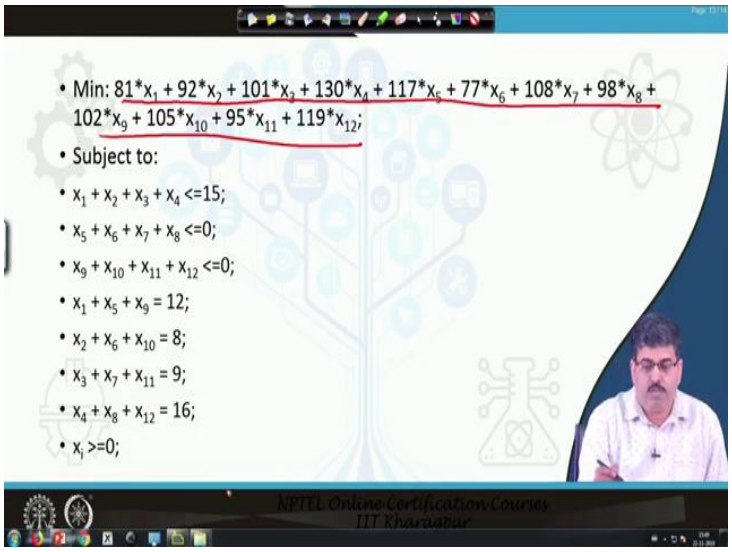

Minimize 81 x1, 92 x2, 107 x5 up to x12 remember? We had x12 there were that was the matrix. So, minimize this up to x12 total cost possible what are the constraints? Let us go back, what are the constraints?

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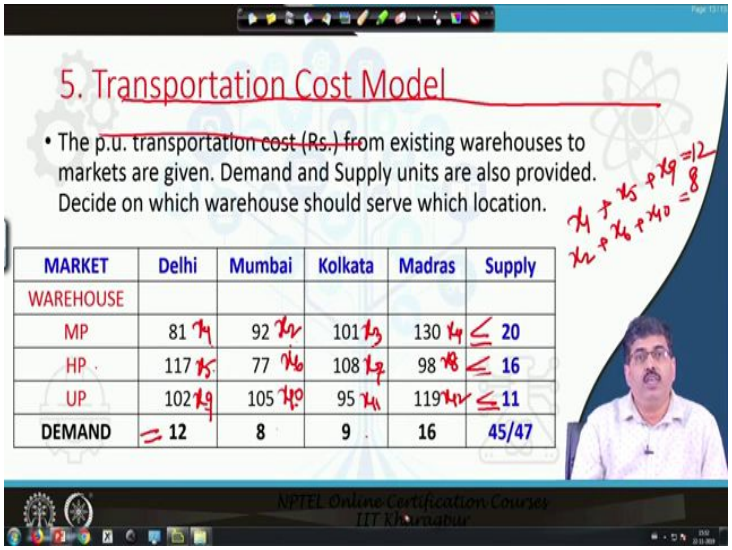

Constrains is.. this was the model. What is the demand x1 plus x5 plus x9 is equal to 12. Similarly, x2 plus x6 plus x10 is equal to 8. x3 x7 x11, so, x1 plus x5 plus x9 should be equal to 12. Because, the demand from the Delhi as to be met. So, x1 is x5 x9 is equal to 12 x2 x6 x10 is equal to 8 x3 x7 x11 9 as this. What is the supply? Not 81 x1 81 is the cost x1 is the

quantity. So, x1 plus x2 plus x3 plus x4 is less than equal to 20 units this is the warehouse can store the 20 units that is the maximum capacity.

Sometimes, though that is the capacity we may not be able to keep that maximum capacity in the warehouse. So, supply normally is less than equal to 20 we use a less than equal to sign. So, what is the capacity of supply from Madhya Pradesh warehouse x1 plus x2 plus x3 plus x4 and that capacity is less than equal to 20. Similarly, Himachal Pradesh x5 plus x6 plus x7 plus x8 less than equal to 16 that is Himachal Pradesh's capacity. Uttar Pradesh x9 x10 x11 x12 less than equal to 11 that is Himachal Pradesh's capacity. So, what are we doing? We are just formulating this as a linear programming problem.

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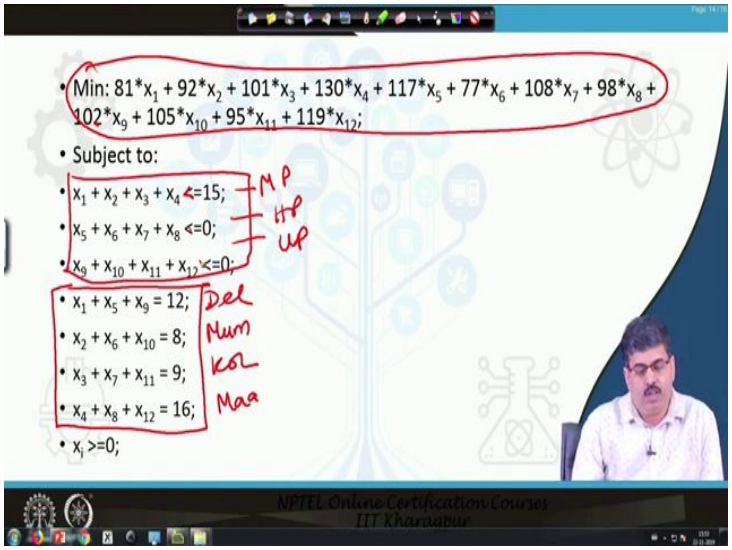

This is the total cost model minimize the total cost. Subject two, if you remember? We just spoke off this was my demand these were the four cities. This was Delhi, Mumbai, Kolkata and Madras. This is the supply constraint of Madhya Pradesh, Himachal Pradesh and Uttar Pradesh less than equal to remember. We just spoke a less than equal to.

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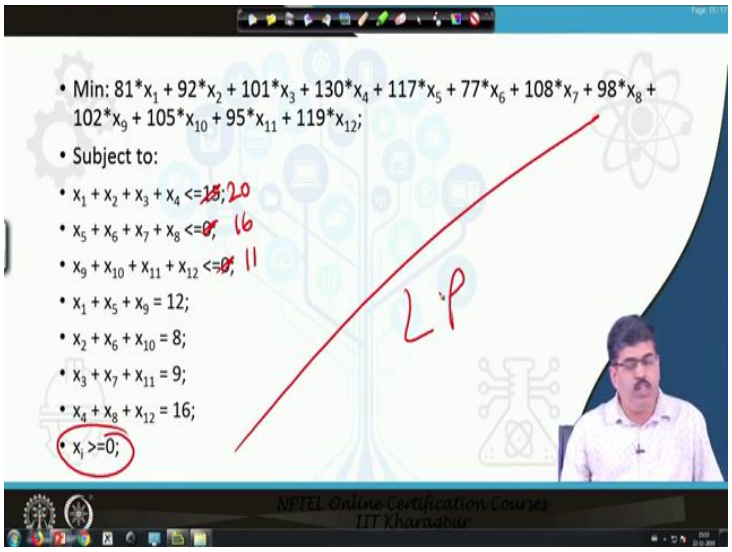

We just used it for other programs with other software. So, this numbers will change a bit, but this is less than equal to 20, 16 and 11 as you mentioned. So, an xI is always greater than equal to 0 because quantity can never be negative. So, this is my linear programming model how to solve linear programming model you can use Excel you can use Simplex technique you can use, so many other techniques.

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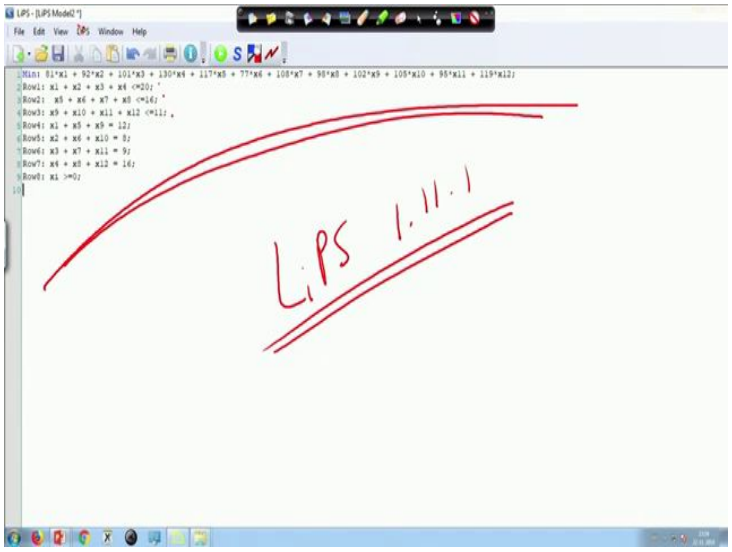

We have used software called LiPS 1.11.1 this you can download and we have just done the same thing 20, 16, 11 that was that is the number we had put 0 there for the some programming purpose. Anyway, same model nothing no coding same model we have put in

we have went into LiPS, LiPS then when you move go into click this LIPS, the word analyze will come click on solve and it solves your problem.

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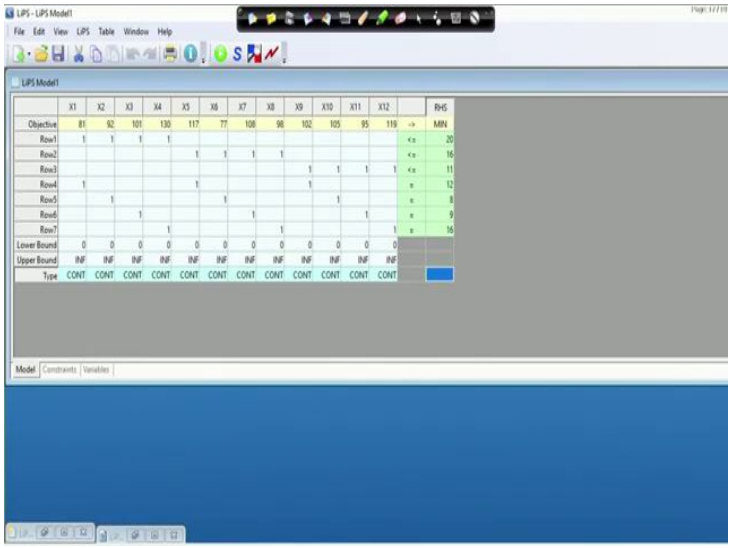

You do not need to input this data like this it looks like an Excel, but just input the numbers or you input the equation choice is up to you input the numbers or input the equation look at this all my supply and demand constraints are there.

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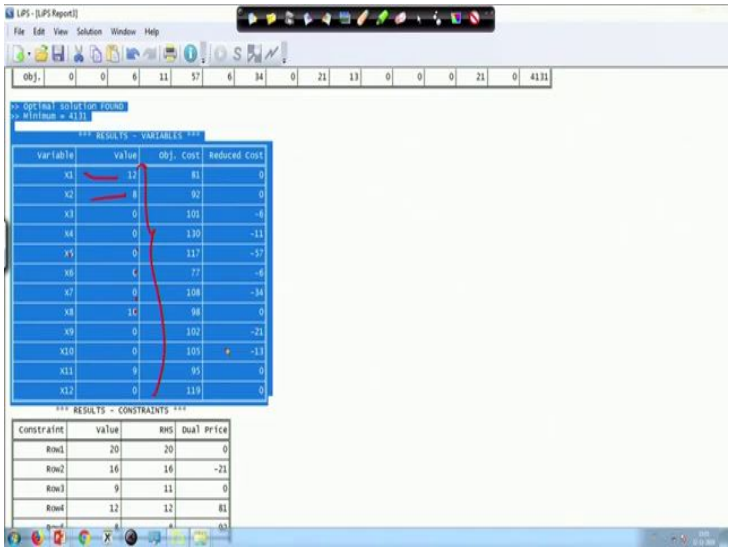

And it gives you the solution. It gives x1 as 12 that means 12 units should move from origin A to destination A 12 units should move from origin, 8 units should move from origin A to destination B that is x2. No units should move from origin A to Kolkata and Madras, no

units should move from origin B to Delhi Mumbai Kolkata only it should move to Chennai remember you were speaking of Chennai being the less least cost from Himachal Pradesh it should move. So, in this way the system will give you how much of units should move from which Warehouse to which market. So, this is my transportation cost model.

Transportation cost model, when do we use it, we use it when you have demand information you have supply information, but you have no control over where to set the warehouse. Warehouse is already set you only need the distance chart or the transportation cost. Whatever, distance we can convert it into equivalent transportation cost units you only need the distance chart or the transportation cost and then using linear programming minimize cost and get the units which can move from one origin to another one. With this we end this week's session next week we will take up a situation where we will have the option to have a small warehouse or a big warehouse.

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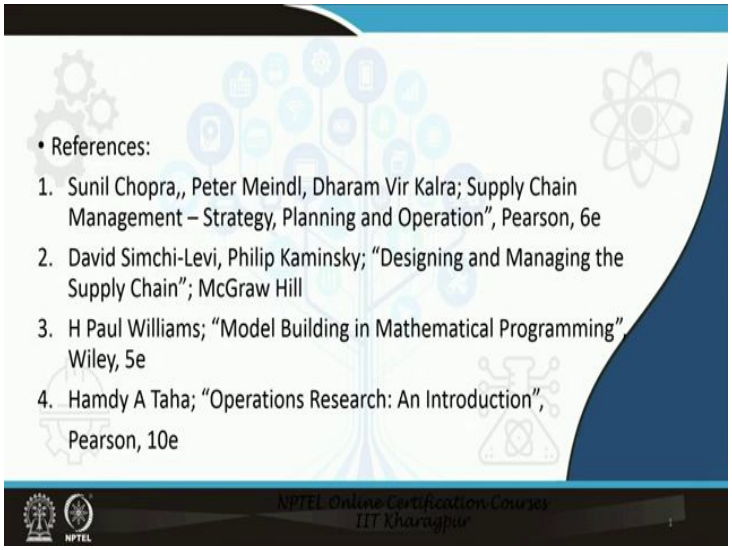

And, the fixed cost will differ. So, then we will use the mixed integer linear programming to solve that problem. Thank you.