Supply Chain Analytics
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Lecture-27
Using Excel Solver for Network Optimization

Welcome back, in our last session we were discussing about network optimisation problems and in that network optimisation problem we discussed about one method of this decision that is gravitational method and by using the coordinates on a graphical plane we thought that where should we minimise the distribution cost as well as the distance and on the basis of that with the help of a numerical example also we discuss this problem.

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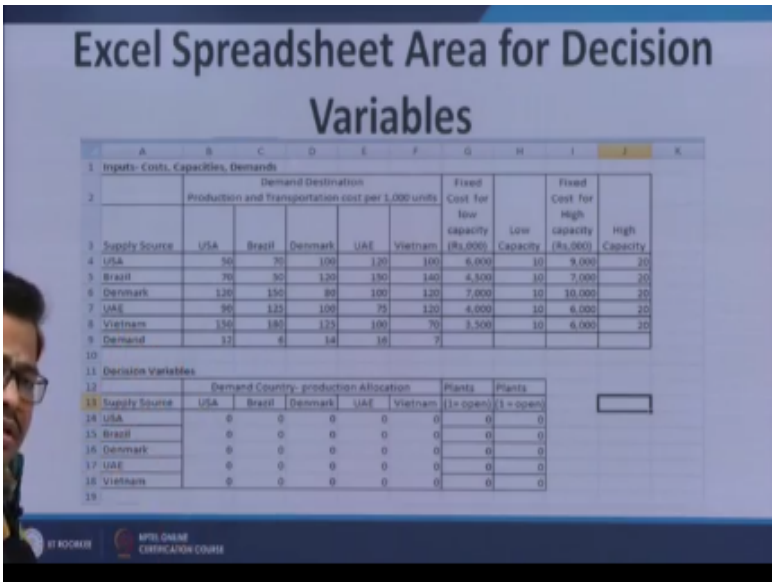

And we saw that out of various market sources and the supply sources where to locate a particular warehouse. Now in that session also we started about discussion of Apollo which is about a global supply chain environment and we have taken some data to explain it on the global environment, but the same can be explained for a national level data also. Now in this case we have 2, 3 major issues to be decided about the configuration of supply chain network.

One is there are certain possible supply locations, so we have listed USA, Brazil, Denmark, Vietnam, UAE, these are possible supply locations and in each of these location you have option either to have a low capacity plant or a high capacity plant. Now you need to decide 3 things, whether to have a plant at a particular location or not to have a plant that is one, second is whether to have a low capacity plant there or to have a high capacity plan there.

So these are the three important issues, one the location of plant and second the size of the plant low or high and then another issue is related to configuration of your supply chain model. In that there are certain demand locations USA, Brazil, Denmark, UAE, Vietnam, same 5 locations are the demand locations also and in each of these demand location these supplied location will fulfill the demand.

So which combination with combination of supply will go to the particular combination of destination, so we need to determine this combination also that from here how many units will be transported to Denmark, from Brazil how many to Denmark, from Denmark, how many to Brazil or how many to USA or how many to Vietnam. So depending upon the capacity which we have decided that we want to have a plant of 10 or we want to have a plant of 20 we will decide this location of capacities two different demand destinations.

So now with this type of problem as I told you in the last session we will build this Excel sheet and I request all my participants to copy this data on your Excel spreadsheet almost in the similar fashion. One you copy this data then if you have some exposure of linear programming, if you know the linear programming we require similar kind of issue in this problem solving where we will see there are certain decision variables.

So there are three decision variables, one is weather to have a look capacity plant, weather to have a high capacity plant or how many units to be supplied from a particular source to a particular destination, so these are three types of variables, these are three types of questions we want to determine and for that purpose we call them decision variables, these three questions or three types of decisions variable.

So this portion of a spreadsheet from 8 value to H10, this version of spreadsheet is basically the allocation of those decision variables and you can see this table and here initially I have kept everything 0000 here, all these values 00 are given by us. 00 means is to begin with low quantity is supplied from a particular source to a particular destination, we are taking binary decision variables as we discussed in the last class for these plants.

If a plant is open, 1 represents the open, 0 represent the plant is closed. So right now initially there is no plant, there is no open plant and all plants are closed and therefore in the next issue we will see that how many units we are producing and how many units are going from a

particular source to a particular destination. So now ones we have decided about the various decision variables and we have a allocated particular cells for this decision variables.

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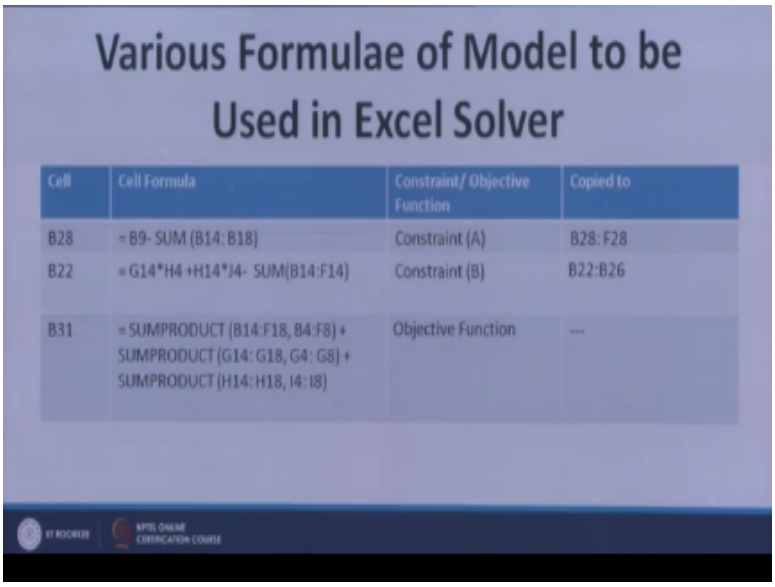

Now moving further we will see that we have incorporated certain formulas in some of the cells and the formula is like this, first we will talk of this formula that we are going to build in cell number B31 and this formula is our objective function. Now objective function is actually the total cost of this exercise, now total cost of this exercise will be if these plants are open, so the cost of these plants will be getting from the multiplication of respective cell with the respective cell of this column G4 to G8.

If high capacity plant is open the cost will be getting from multiplication of H14 to H18 with the respective multiplication of values from iPhone to I8, then the cost of moving and producing particular number of units at a particular source to a particular destination, so that cost will be respective multiplication from cell number B14 to cell number F18 with cell number B4 to cell number F8.

And that is what we are going to write in the objective function, so you see this is B14 to F18 will be multiplied by B4 to F8, that is the cost of transportation and production, G14 to G18 will be multiplied by G4 to G8 that is the cost of opening a low capacity facility, H14 to H18 will be multiplied by I4 to I8, that is the cost of opening a high capacity facility. Now this becomes your objective function.

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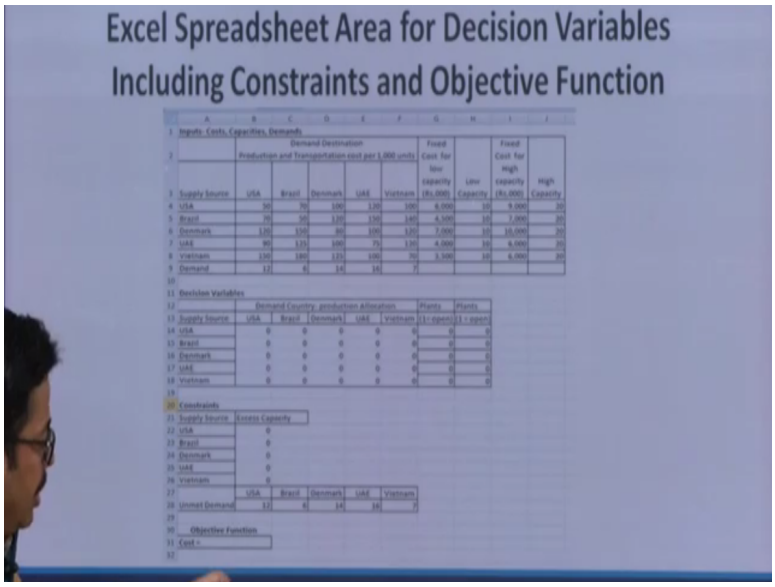

And you see this is that B31, this place is B31 you can also do same thing in your spreadsheet and you put this formula in this B31, please remember always in the Excel all the formula which you are going to build it starts with this equal to sign, so you as it is can write this formula here at this cell at B31, so this will give you the value of your objective function. Now in our last session we discuss briefly about this constraints also.

So here we will discuss in flight detail about these constraints, now these constraints which constraints when we are developing the model in the last session if you remember there are 2 types of constraints one is we want to fulfil 100% demand of each of my demand destinations, so my demand destinations are USA, Brazil, Denmark, UAE and Vietnam. These are my demand stations.

And I want to fulfil this demands which are 12, 6, 14, 16, 7 respectively, so I want to completely fulfil these demands, and another thing is that I cannot supply to each of this destinations more than their demand, so if the demand of USA is 12 I cannot supply 13 there, I will try to fulfil the complete demand of this center, the second is the supply sources, these supply sources USA to Vietnam, right now you have all the values as 00000, the reason I will just explain you.

But we will not to have excess supply, excess capacity of these supply sources. A supply source if it is of 10 units or 20 units, if it is a 10 unit supply stores it cannot supply 11 units from that, if it is a 20 unit supply source it cannot supply 21 units from that, so it can only

supply 18, 19 or up to 20 in case of a 20 unit supply source, it can supply to 8, 9, 10 units in case of a 10 unit supply source.

So what is the excess capacity available right now we are considering in the beginning of this problem that there is no excess capacity and therefore the demand at all the destination is unmet in the initial stage. No just to see the constraints, these are the 2 constraints, one is the constraints coming because of supply and another because of demand, now when we got talking of supply constraints, in this supply constraints you see that we have this cell B28.

This B28 is this cell, so this is the demand constraints, this is the demand constraints, now I want to fulfill this demand 12 here. Now this demand is the result of whatever is available whatever is the total demand of USA that is 12 minus what all is supplied to USA from different sources so USA is getting from USA to USA, from Brazil to USA, from Denmark to USA, from UAE to USA, from Vietnam to USA.

So these are the units which USA is going to get this is this from of B14 to B18, B14 to B18 this sum if I subtract the sum from B9, so that is my unmet demand, what I am trying to say that from B9 where I have written the demand of USA minus from USA is receiving from the B14 to B18 that is what USA is receiving, so B14 to F14 this becomes the value of unmet demand that is this B28.

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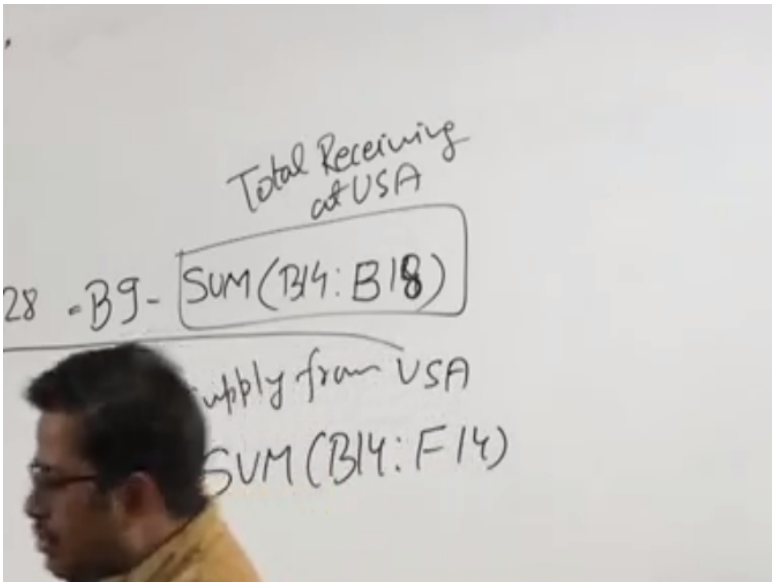

B28 is equals to this, B9 which is presently 12 and in the beginning all these are 000, so the total is this sum is zero, so the value at B28 is coming to 12 and the same logic applies for

Brazil, Denmark, UAE and Vietnam. So I request all my participants of this course that for these values 6, 14, 16, 7 what you need to do the use of need to copy this formula B9-sum B14 to F14. From B28 to F28 and automatically all these values will appear 6, 14, 16, 7.

All these values will automatically appear so that is what we have written that this sum will come here and you did to copy this B28 to F28 and this is B14 to F14 and then you will have these values, now coming to this excess capacity, the excess capacity USA is flying to USA Brazil, Denmark, UAE and Vietnam. USA supplying to all these different location and this formula, if I see when you are supplying from USA to USA, Brazil, Denmark, UAE and Vietnam.

In that case but total supply from USA is B14 to F14, this is the total supply from USA, this requires B14 to B18, this is the total receiving at USA, Now this B14 to F14 which USA is receiving supplying and USA may make wither value related to this cell or maybe value related to cell, so if it is YI or here one that you need to multiply with the values of these two cells, so what we have written hear that G14 multiplied by H4 that G14 this multiplied by H4.

So this makes that you have a low capacity plant plus if you multiply the value of this cell with this J4, j4 that it means the high capacity plant, so either you will be having a low capacity plant or a high capacity plan, so this is what you are producing and this sum of B14 to F14, this is what you are supplied. So this formula if you write in cell number B122 this will give you the value of excess capacity and then you copy this formula from B22 to B26.

Since initially you are having all 00 values so therefore these excess capacity are coming to be zero, so that is why you need not to write these values of zeros and 12, 14, 16, 7, the formula will automatically give you these values that how this zeros are appearing here and how these 12, 14, 16, 7 are coming and then once you have this so at then you also write this objective function formula in this B31 cell.

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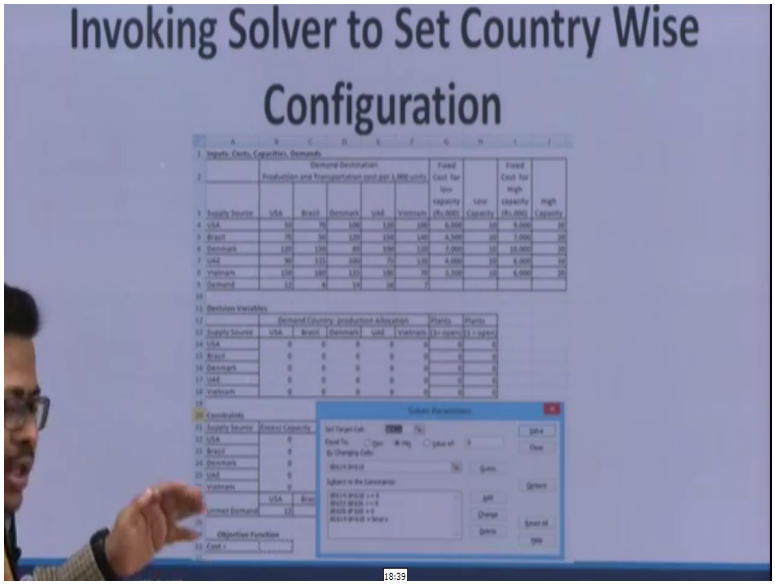

After that now we go to start the solver activity know we go to start the solver activity so I hope all of you have done this building of formula and then copying those formula cells either to B22 to B26 or from B28 to F28, then once you have developed this entire formula into this spreadsheet then we invoke be solver, solver we start and in that case now my target cell is this B31 so here once you have this solver dialogue box so this B31 you write here this is your target cell.

As we discussed in the case of gravity model here also you have option of maximum minimum etc. so we want to minimise the cost, so put this symbol on minimization. Now what you will do by changing the value because this minimization is possible by changing the values of decision variable, so your decision variables from B14, this is B14 may not be very visible, it looks like 8 something, but it is b14 to H18, H18 this cell.

So from B14 to H18 you will change the values of these decision variables and as a result of that in this box you write the equation for the constraints and these equations for constraints are one is the values of B14 to H18 all these decision variables are nonnegative they can be either 0 or any positive value. So the first constraints represents that these are non negative decision variables.

You need to use this add button here for writing the constraints, so that add button you use for item constraints, then certain days B22 to B26, B22 to B26 you can have any positive value of excess capacity, if this positive value of excess capacity is not there if this constraint sign

is reversed the meaning of that can be you can supply more than available capacity at a particular supply source.

So that is not possible, that is not in reality so we need to put this constant that from this source from B22 to B26 you can have any positive value available, no negative value is possible or if a supply source is completely supply whatever is available here then it will be at best with zero, so there is no excess capacity whatever is available you are supplying completely to the to the destination.

Then as we discussed in the beginning that from B28 to F28 this horizontal line, this cell from B28 to F28 which are representing the unmet demand at different destinations since we have assumed we have modelled in such a fashion that you are going to fulfill the 100% demand of each of these situations, so therefore from B28 to F28 we are using this equality sign here, these cells are equal to zero.

In some cases if you feel that you can leave some of the unmet demand, if model suggest that way that even if you are not going to fulfill the 100% demand of some of the destination does not matter. In that case you can have B28 to F28 greater than equal to zero but in that case there will be a big challenge, because we want to minimise we want to minimise the model, so what will happen minimization will lead maximum there if you put that that there can be a positive value of B28 to F28.

So do you think what the potential is risk with respect your model and it is very interesting question that you should understand the potential risk with respect to the model. Because you are allowing positive values here, so positive value can be any positive value it can be as high as 12 it can be as high as 16 for different different location and when these unmet demand are for there.

So the physical significance is that you are not transporting, you are not producing anything and that case it will be very interesting that the total cost of this model will be zero as soon as you change the sign of equality to left hand side greater than equal to right hand side and I request all the participants because it is now very easy for us to do that you just I am writing here equality sign.

But you immediately try the greater than equal to sign here and then this G14 to H18 these two columns G14 to H18, these two columns are with binary sign and the binary sign that only 0 and 1, these two values are possible so these are the four constraints we have put here and after putting this for constraints we put this symbol of we click the solve on button and once you solve this button.

And before I show you the next slide you can see the because you are put greater than equal to sign here and if you put solve quick then in that case you will see that the total cost of this model will come zero and the excess capacity is will remain as it is and unmet demand will remain as it is, because we want to minimise the cost and zero is the lowest possible cost for any model it is a dream type of situation.

So nobody is going to produce anything, nobody is going to transport anything and you are going to have zero cost of your model, and you know that is not the objective of this model. Therefore we are building this type of constrain that left hand side is completely satisfied and there is no unmet demand, yes it is possible in some situation that you do not leave this right hand side totally open.

You can feel, you can make some kind of percentage that you need to fulfill at least 80% demand, you can try some of the variants of this question that I can say that you need to fulfill 80% demand of each of the destination for different different destinations you can say that you need to pull 80% demand of each of the destination or it is also possible that you can have more number of constraints.

And you may say that for USA market and Denmark market you have to fulfill 100% demand, for Vietnam market you should fulfill 80% of the demand or even more than it is very good, for Brazil market again 80%, UAE market 75%, so for different different markets you must set different criteria and all those criteria need to be built into this constraints, so this is a simple generic model but more customised more specific model can be built by writing the constants for that in this constant dialogue box.

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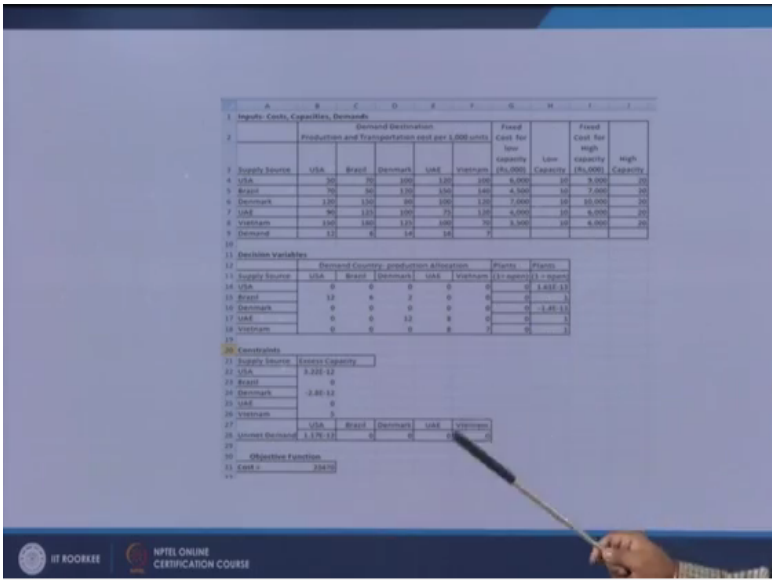

Now going for the ones you have started your solver and the calculations are going on it will take some fraction of seconds to complete the calculation and then this type of model will emerge, this is the solution of the model where you see let us first see where are we going to open the plant, so where we are not going to open any low capacity plants, for all low capacity plants it is 00000 here.

So there is no low capacity plant, you have three once in high capacity plant one for Brazil, one for UAE and another for Vietnam. So you are going to have 3 high capacity plants in these locations, you have some values in these two cells, one for USA and another for Denmark, so these are 10 to the power minus 13, these are because of internal calculation errors in excel, so that is how these are 10 to the power minus 13 both these values.

So these are always you can say equal to zero non-significant, so we consider them also 0, so in fact you will have 3 high capacity plants one at Brazil, one at UAE, one at Vietnam. So that is about the size and location of your plants. Now the second question we want to answer that from which facility how much you will ship to a particular location, now you see in USA you are not going to have any type of plant neither small nor bigger.

So you are not going to ship any unit from USA, so USA to all other destinations it is 00000, you are going to have a bigger plant of 20 units at Brazil, so from Brazil your shipping 12 units to USA, you keep 6 unit of that in Brazil itself because the demand of the Brazil is 6, so Brazil will fulfill all its demand from the local capacity, so 6 will come to Brazil, and 2 will go to Denmark.

So 12 + 18 +220, so the Brazil capacity is no exhausted and Brazil will not supply anything to UAE and Vietnam markets. Now again in Denmark there is no plant, so you are not going to say anything from Denmark to any of the destination, you have one bigger plant in UAE, now the demand of UAE is you see interestingly only 8 units of its own plant will be consumed in UAE and remaining units out of that 12 will go to UAE, 12 will go to Denmark.

And that is how 12 + 8 the UAE capacity will be exhausted and in case of Vietnam again you are going to have a bigger plant, Vietnam one requirement is 7 units, so out of 20, 7 will be consumed at Vietnam itself and remaining 8 will go to UAE and 7 + 8 makes 15 so Vietnam will be left with 5 units of excess capacity that you are seen in the cell number B26 and in another cell USA and Denmark these are 10 to the power minus 12.

So almost equal to zero and for Brazil and UAE also you have zero values, so infant you can say USA, Brazil, Denmark and UAE have no excess capacity and you have a excess capacity of 5 minutes at Vietnam and then you see the unmet demand in case of this B28 here you are showing some kind of 10 to the power minus 12 type of value where it again means non-significant it is zero.

And for all other Brazil, Denmark, UAE and Vietnam these are zero and demands the meaning is that with this model now you see you have three plants your 5 minutes axis and the cost is coming 23470 rupees, so this model is a very perfect type of model where you decided where to locate your manufacturing facility, what will be the size of that were factoring facility and how are you going to configure your supply chain network which facility will supply to which market.

And the customisation of this model as we discussed can also be done depending upon our requirement that if we want to have in this particular case you are making 5 units additional at Vietnam because you wanted to fulfill 100% demand of all these decisions, now you see if it is possible that I do not fulfill 100% demand of some of the location so maybe at Vietnam I can work with a smaller facility.

And in that case I may remain with some of the unmet demand in some of the location and that will reduce my cost of supply chain but it depends upon my supply chain strategy

weather I want to completely fulfill the or I can beer with slightly lower level of service. So I think we can try various versions some of the version which I can suggest you that you should go with the different type of constraint combinations here in this case.

One constant combination you note that we can have you can have any kind of unmet demand available. In that case there was no unmet demand left but the another constraint can be you have sum and made demand left. In that case you will change this sign of equality in to greater than equal to just see the results, the result will be zero cost here. This is case number one.

Now case number 2 you try that the demand at Vietnam did not to be fulfilled 100%, you can have 80% demand of Vietnam to be fulfilled and in the same case UAE only 80% of the demand need to be fulfilled. So you see that you need to apply 2 additional constraints from B28 to F28 it is not that in case of B28 to D28, it will be equal to zero and you need to write two additional constraints one for UAE that is for E28, and another F28.

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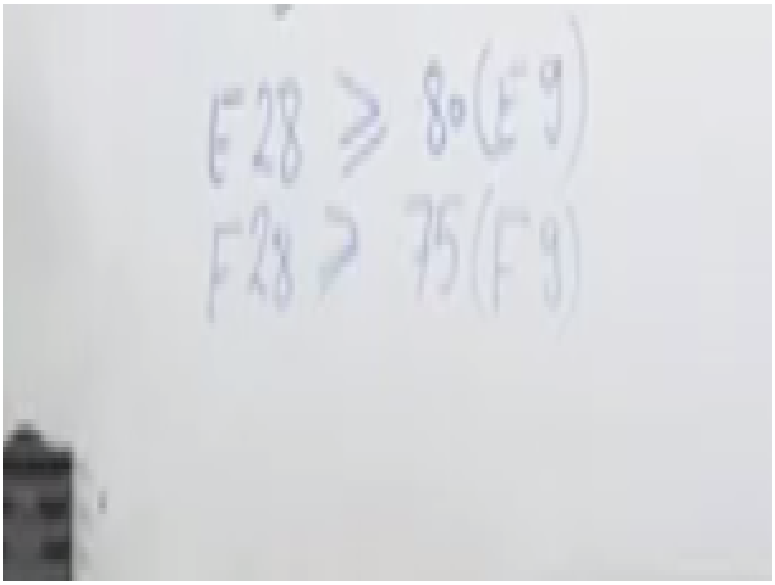

So you see that what will be those two constraints for UAE the constraints will be that B this is E28 should be in this case it is equal to zero, but in this case it should be greater than or equal to we want 80% of the demand to be fulfilled, 80% of E9. Similarly if I want 70% of the Vietnams demand should be fulfilled, so it means F28 should be greater than equal 0.75 of F9.

So you need to customise I am giving you a very generic version but you need to customise this as per the situation and then this solver activity will help you in getting the results very quickly and you can try different type of conditions depending upon the supply chain strategy and then get the results whichever result gives you the minimum total cost that is what we want to have in our supply chain network. Thank you very much.