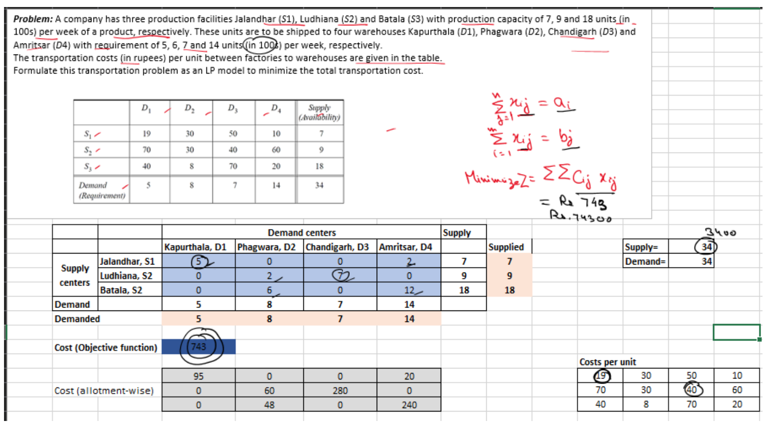
Advanced Business Decision Support Systems
Professor Deepu Philip
Department of Industrial Engineering and Management Engineering
Indian Institute of Technology, Kanpur
Professor Amandeep Singh
Imagineering Laboratory
Dr. Prabal Pratap Singh
Indian Institute of Technology, Kanpur
Lecture 24
Transportation Model (MS Excel Demonstration)

Welcome to the MS Excel demonstration session on the Transportation and Transshipment problems.



So, I have taken a problem for the transportation here, you can see, this is a problem statement that is given for the three production facilities. These are the production facilities for the machine tools, I would say the ancillary units for the machine tools are located at certain places and they provide to different cities the small components of the machines. So, there are three production facilities at the cities in the Punjab, Jalandhar, Ludhiana and Batala denoted as the sources S1, S2 and S3 which are there in the state of Punjab in India with production capacity of 7, 9 and 18 units. That is, these many hundreds of the units are the production capacity per week of a product. These units are to be shipped to four warehouses which are at Kapurthala, Phagwara, Chandigarh and Amritsar and requirements are 5, 6, 7 and 14 units in hundreds of the units per week respectively.

So, these demand centres are D1, D2, D3, D4 and supply centres are also given S1, S2 and S3 for which, the costs are given per unit of the shipment and the supply and demand is also available the question itself. So, the transportation cost in rupees per unit between factories to warehouses are given in the table formulated transportation problem that is, LP model to minimize the total transportation cost. Just to recall the Transportation problem is the formulation of the just to recall transportation is just an extended part of the Linear Programming, where we are trying to take the decision variables and we are trying to take constraints. So, these constraints are to be formed and we will try to use the solver only the way we use for the Simplex program.

$$\sum_{j=1}^{n} xij = ai$$

$$\sum_{i=1}^{m} xij = bj$$

And, we were to minimize Z=

$$\sum \sum Cij\ xij$$

So, using this analogy, only we will try to formulate this problem and try to solve this question.

Now, let us try to see how to formulate this problem. So, here we are given the cities D1, D2, D3, D4, the names of the cities are also given which are the demand cities and supply cities also there. So, let me put the names of the cities, we have Jalandhar, Ludhiana and Batala as my source cities and I have destination cities or I will get demand centers, which is Kapurthala. It is suggesting the column widths, so that the city names to come, I have to only put them once, Chandigarh D3 and I have fourth name is Amritsar D4. Now, for them, I have been given this cost matrix.

This is 19, I am just putting the data into the Excel program, so that I can try to solve the program 50, 40, 70. Everything center aligned here, I will unbolt them and I will put them into boxes, that is the borders would be put here. These I will put here, these are my demand centers and these are my supply centers. So, what is the supply limitation that is there that is, 7, 9 and 18. Similarly, I have my demand limitations which are 5, 8, 7 and 14.

Now, first thing I need to see is, whether the equation is balanced, equation is balanced means, the demand and supply is balanced or not. This is the first and the foremost things that the problem has to be a balanced problem. For that, let me put into one cell. I will say supply is equal to, so here I will put the total supply, this total supply is sum of these values. So, I have to say here this is equal to sum of these values which is 34 and total demand, this is equal to sum of the demand centers requirement (enter) which is again equal to 34.

That means, we are up for solving the Transportation model using MS Excel and solve the program in it. Now, the data is now just entered into the MS Excel program and we have only got the data into the cells where, each cell is labeled and we have also seen that the transportation model is balanced in the terms of the equal demand and supply. Now, to try to solve this problem statement using the analogy of xij is equal to ai and xij is equal to bj and to minimize the total cost which is the product sum of the cij and xij is. I need to start this program and try to formulate the xij is at the left hand side of the constraints and ai is on the right hand side and I need to formulate the problem statement accordingly. So, I will just put here, so what is actually supplied? I will just take this to a little right, I will here say supplied.

So, what is actually supplied? For that, I will just say total supplied is the number of units, which are supplied from these cells. These cells as of now, it is given only the cost. Let me take the cost separate because I need to solve this for the variables because in the transportation model, which I showed you in the presentations, when I showed you the key in the Transportation model that I showed you a single cell, in which the Decision variables were given, Opportunity cost was given, the cost for the transportation per unit was given, those all cannot be put in a single cell into the MS Excel. So, I have put the cost at a separate side. So, these are the costs per unit which are given. So, this table, I will keep separate here, but this table would be used.

Now, here are my decision variables, that is my xij would be put here. So, these xij because those are put here and these are would be calculated using solver, I will color them like I did in the previous programs as well. I will say, this color is to be solved and also the borders would be given. So, let me start by any value, if I even put value 0, if I even put value 555 in each, I can put any allocation, but solver would finally come to the optimal solution only.

So, let me put any value. I will start from 0 only for each of the cells. So, these 0 would be copied to each of the other cells in this matrix center aligned. So, these are all my decision variables. So, this will put as a constraint that in the xij matrix is now ready.

So, this is now ready xij. ai and bj, I need to keep ready. What is ai and bj? ai and bj is the total sum of xij should be equal to ai that means, this total sum for the supply center 1 that is, Jalandhar should be equal to 7. So, in the cell I18, I would say this is equal to sum of the rows enter as of now, 0 allocation is there. So, this is showing 0 only.

Similarly, I can put either the sum of the rows or I can just drag the formula down to have the formula for the each of the rows here. So, this formula becomes the sum of the cells for each of the respective rows. Similarly, I would like to have this for the columns, I would say demanded. Demanded values that is my bj. Now, this has to be sum of the column values of the decision variables.

This is equal to sum of the column values, enter. This formula in the cell G22 is copied to each of the right of the cells that is, we take it for all the four cities D1, D2, D3 and D4. I will just center align it. So, my xij were ready, ai is ready, Bj is ready. So, these things are ready that means, the constraint work is all ready.

Now, I need to understand the cost. So, this cost, that is the total cost is my final objective function, that is to be built to be entered into the solid program. How do I build this program? So, I would say first, the cost cell wise or I would say allotment wise, I will build up a matrix here. So, I will just prepare a box of 3 into 4 cells similar to the number of cells I have in my problem statement and I will say, this is equal to the product of the number of units taken into the cost per unit. Again, recalling the cost in that cell is the number of units that is allocated to that cell into the cost per unit of the cell if allocation is there.

If allocation is there, the cost would be positive, if allocation is not there, the cost is 0, the cost would remain 0. So, this is again, I would repeat the cost that is given in the cell D25 is equal to the number of units which are from here into the cost per unit, which is from here that is, 19 units that is, 0 into 19. As of now, this cost would remain 0 because the number of units which are there are 0 here in the cell for the city of the Jalandhar to the destination of Kapurthala.

So, this is 0, I will just drag this formula to each of these cells in this matrix first for the rows, then for the columns. Now, this is my allotment wise cost for each of the cells that I have gotten in this matrix, but my objective function is to minimize the total cost.

So, let me just check whether the allotment wise cost is correct or not, just I will pick a random value, this should be the product of the cell for the source 2 and demand center 3 to the respective cost, which is correct here. This is multiplied to this here, so this is correct. Now, the cost I will just move it little down, so I put my cost here, I would say cost only, word cost is put here because this is the total cost or objective function.

So, this is equal to the sum of the total cost as we did for the total cost wherever the allotment is there, the total allotment into their respective cost were taken and their sum was taken. So, this is just equal to sum of the cost in the matrix below and this is equal to sum of these cost and enter.

This is my objective function because this is also to be optimized. I will give it a darker color because here only, the final value would come right and allotment by cost would also vary. So, things that would vary when I try to solve my solar program, I will just color them. So, these colored cells now would be put as an input to my solar program.

So, whenever I am working with any computer program, there are certain steps, first thing is, identifying the data, second thing is data entry, data is entered, third thing is

Data cleaning, I am finished till this point then only the processing happens, processing is that, we input the data variables into the program and we try to get the output, that we will try using the solver program or solver analysis of the MS Excel program here.

Data cleaning is when I tried to balance, it was already balanced, if I try to balance it, if I take data suppose, if I had to add a dummy column or dummy row, then it would have been further step in data cleaning only. Now, data cleaning is ready, data is ready to be added in the solver program.

Now, similar to as we did in the Simplex program in MS Excel, we will go to the data tab here and try to see the solver program. The solver program is not even here. Now, we can add the solver program one way was, we did it while going to the file menu, then we went to the options, we selected the add-ins and from the add-ins, we check the box for the solver.

Another way is, I just right click the data analysis because analysis ribbon is already here. So, in the analysis ribbon here, I will right click this data analysis ribbon here and say customize the ribbon and it will ask me whether to add in something, I will select add-ins from here. This is one of the other ways to select add-ins and I will say, I will also need to see this solver add-in here.

So, solver add-in would also be added, it is being added, yeah! solver add-in is there now data analysis and solver, both of them are there. I will click on the solver and this is a program that is already there, I will just delete everything, reset all is a button that helps you to try to reset everything.

Now, I will set my objective. One thing is, this is a minimization problem. I select minimization, I will select the objective function, the objective function is that, the cost that is my cell D24 here, this is my objective function. I will press enter button on the computer objective function is added my purpose is to minimize, then the changing variables if the which variables are to be changed, they say I will select the variables that are to be changed, the variables which are to be changed are my xij which is the light blue matrix that I need to enter here.

So, these variables I will select the whole light blue matrix at the xij are the variables which I need to work upon and I will press enter from my keyboard.

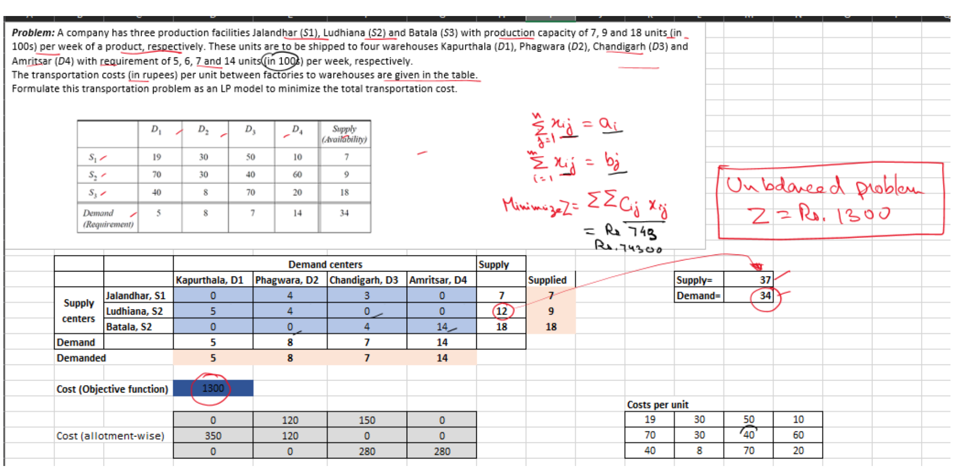
These variables are added here. Now, I need to add the constraints. To add the constraints, we have to add xij is equal to ai and xij is equal to bj. So, for that, I need to add a constraint that, all the xij values which are given, that is the sum of the xij which are demanded values here, these are all the sum of the xij already given.

This is my left hand side and this I have to select the sign is equal to here is exactly equal to which is my Transportation model as it is given here, you can see here, this is exactly equal to the ai. So, this should be exactly equal to 5, 8, 7 and 14 that means, whatever allocations are made in the respective columns, the total allocation has to be 5, 8, 7 and 14 for the respective demand centers D1, D2, D3 and D4.

I said okay, I add another constraint in the similar fashion, that is my row constraint. The sum of the xij in the rows should be exactly equal to, I select the sign equal to here, the values that is supply values 7, 9 and 18, I say okay. Now, my program is set the solving method is Simplex LP, only whole fit will try to solve my problem, if I just click the solve button, let me try, yes it has now said that you can keep the solver solution, I say okay in the single step. We have solved the Transportation model where the allocations which are given are 5 in the cell S1, D1, 2 in the cell S1, D4, 2 in the cell S2, D2, 7 in the cell S2, D3, 6 in the cell S2, D2 and 12 in the cell S2, D4 and the cost is also calculated here that means, the objective function is minimized here, this is equal to rupees 743. If I consider in hundreds as well, this can also be multiplied by 100 that is equal to rupees 74300 or so, this is the cost for supplying the number of units which were 34 units that is, 3400 units if those are supplied.

This is a Simplex approximation or formulation of the Transportation model and we try to formulate it in an Excel program and try to use using the solver. So, we have got the solution here. The minimum value of the objective function as 743. So, let me take a case where the supply and demand is not balanced. So, I have just copied this whole sheet to another sheet.

Now, here and this is the solution that is already taken from the transportation one model that we try to solve in the transportation one sheet. So, here what I will do, I will just try to change this supply. So, let me change this supply of any point or maybe demand of any point or the problem is not balanced.



So, I will change the supply for the city Ludhiana or from the city Ludhiana, I will just make it 12. So, what has changed in the model? You can see, I am just deleting these points.

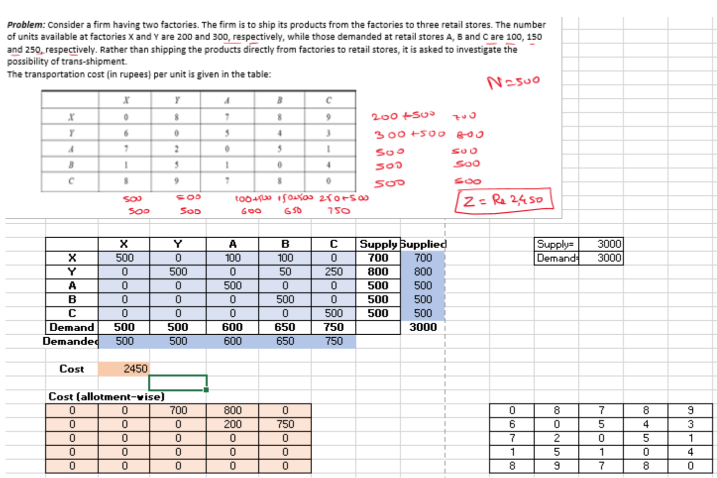
So, this when it is turned 12, supply is now 37, demand is 34. What we did in the matrix formulation on the paper? We will try to add a dummy row or dummy column to balance everything and put the required allocations for the row or column to balance the overall equation. Here also, we can do the same, but in solver is that even required let us try to see. So, if I have put this as 12 and now supply is 37 and demand is 34, so I will again set everything to 0 that is problem is now set to start from region. Yes, everything is at 0, only the supply and demand is changed.

So, this factor is now updated based upon this. We have now supply as 37. Now, let me try to again solve this problem using my solver. In the solver, I will again put my objective function. Objective function is this and the change variables are these, enter and I will add the constraints, that is first for the demanded.

All the demanded that is the xij is equal to the ai. The ai are these, the demand, enter. Another constraint that is my xij is equal to the bj supply, I added, I said okay. Now, these two constraints are added with again, I will select the minimization function, let me try to see how does the solution change, I will say solve.

It says okay, it has given this value 1141.33 so because in the solver, I did not select the Simplex linear Program, it was selected as GRG Nonlinear. So, all the decimal places values were given here. So, I will correct this, I will put it as Simplex program and try to solve it again, I say okay.

Using the Simplex program, you can see the cost is now increased and there are three allocations that would be left because this is 37 and this is 34, so this is the limiting number 34 maximum allocation that could be put is 34 and the cost is change to rupees 1300 now. So, here for unbalanced problem, I have g is equal to rupees 1300. This was the Transportation problem. Let us now try to discuss the Transshipment problem.



Problem: Consider a firm having two factories. The firm is to ship its products from the factories to three retail stores. The number of units available at factories X and Y are 200 and 300, respectively, while those demanded at retail stores A, B and C are 100, 150 and 250, respectively. Rather than shipping the products directly from factories to retail stores, it is asked to investigate the possibility of trans-shipment.
The transportation cost (in rupees) per unit is given in the table:

	X	Y	A	B	C
X	0	8	7	8	9
Y	6	0	5	4	3
A	7	2	0	5	1
B	1	5	1	0	4
C	8	9	7	8	0

N=500
200+500 700
300+500 800
500 500
500 500
500 500
500 500 100+500 150+500 250+500
500 500 600 650 750
Z = Rs 2450

	X	Y	A	B	C	Supply	Supplied
X	500	0	100	100	0	700	700
Y	0	500	0	50	250	800	800
A	0	0	500	0	0	500	500
B	0	0	0	500	0	500	500
C	0	0	0	0	500	500	500
Demand	500	500	600	650	750		3000
Demanded	500	500	600	650	750		

Supply=	3000
Demand=	3000

Cost 2450

Cost (allotment-wise)

0	0	700	800	0
0	0	0	200	750
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

0	8	7	8	9
6	0	5	4	3
7	2	0	5	1
1	5	1	0	4
8	9	7	8	0

For the Transshipment problem, the problem which we tried to solve or I just showed you the solution of this problem, this was the same problem which was given here there are two factories, the firm is to ship products from factories to three retail stores. The number of units available in factories X and Y are 200 and 300 respectively, while those demanded stores A, B and C are 100, 150 and 250.

The same problem I have put here only it is missing the total demand and the total supply that I will put here. So, this was 200, this is 300 and for ABC, it is given as 100, 150 and 250, I will add 500 to it.

So, this is 500, 500, 600, 650, 750 and for the rows it is 700, 800, 500, 500 and 500. So, I have already put the data here in the Excel format where all these values are given here and only I need to add the supply values. Supply values here are 700, 800, 500, 500 and 500. I will write the word supply and this is my demand.

Again, similar to the fashion, we did it for the Transportation model, I will create a decision variable matrix and this cost matrix would be taken aside. So, this cost matrix is, I will say, I will take all these costs here and here I will just put the values zeros which are my decision variables, five zeros I will just drag these values here so that the whole matrix is coupled with these zero values center align and these are my decision variables which are having values zero as of now.

I will also have a sum of them that is, I am preparing the table for data entry or the constraints objective function, the expression entries to my solver. This is equal to sum of the column entries, enter. So, this is copied here for the columns, this is demanded and I have supplied which is equal to sum of the row entries and I will again copy the formula here and also yes, total has to be calculated, so supply total and demand total. So, this is coming as sum of the total supply and demand is equal to sum of the total individual demands that is a total demand, I will obtain here which is 3000 that means, the problem is balanced but this is also the total demand given here.

So, now my variables table is ready. Constraints could be built here and we know the expressions equality signs are to be also put cost metric spending. Now, let me try to put the cost similar to the previous Transportation model cost would come here something, this cost would come from where, I will say the cost allotment wise.

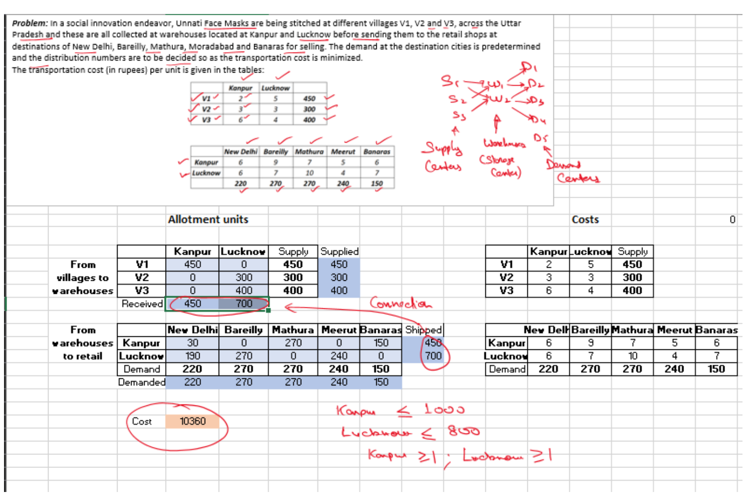
So, I will create a matrix of 5 into 5 here. This, I will just put in the front of this. So, I will just say, for the cell B29, this value is equal to product of the number of units that is, cell C18 times the cost for that, the cost is 0, enter.

So, this formula is copied to all the rows and columns and we have obtained the cost allotment wise, the total cost is equal to sum of the allotment wise costs, enter. So, I will just color wherever the variables or values would change when I run my Excel program. So, these variables would change, these are the decision variables. I will put some light color here, a little darker color to the demand sheet and supplied these values would change and also allotment wise cost would also change.

Cost I will make little darker. Let me now try to enter the data in my solar program, reset all okay, so now, I will try to enter the data into the solar program, where my objective function is the cell C26 and my objective is to minimize the cost the change variable are in the matrix here that is, the decision variable matrix 5 into 5, 25 change variables area, enter and I need to add the constraints, constraints are added similar to as I did for the Transportation model.

So, I would say, all the demanded variables sum that is, the allotments should be equal to the respective demand, enter. I need to add another variable for the supply, all the supplied units should be equal to the respective supply available for the sources, I say okay, all the constraints are added and the program that is selected, is simple program. So, make the unconstrained variables non-negative, this is also important. Unconstrained variables are to be made non-negative, this is to be checked all the time when you try to run this program.

So, Simplex Linear Program is already selected and I will try to solve this. Yes, it has solved the problem, the solution that is obtained is 2450 and if you recall the solution which was given in the slides when we try to showcase the Transshipment problem solution, there it was also rupees 2450. So, we have got the solution here that is, we have C is equal to rupees 2450. So, this is solving the transportation problem using the Transportation model itself, this is how we do only that point is the value n that is, value capital NU value that is, n that is added to each of the rows and columns, here n is equal to 500.


Problem: In a social innovation endeavor, Unnati Face Masks are being stitched at different villages V1, V2 and V3, across the Uttar Pradesh and these are all collected at warehouses located at Kanpur and Lucknow before sending them to the retail shops at destinations of New Delhi, Bareilly, Mathura, Moradabad and Banaras for selling. The demand at the destination cities is predetermined and the distribution numbers are to be decided so as the transportation cost is minimized.
The transportation cost (in rupees) per unit is given in the tables:

	Kanpur	Lucknow	
V1	2	5	450
V2	3	3	300
V3	6	4	400

	New Delhi	Bareilly	Mathura	Meerut	Banaras
Kanpur	6	9	7	5	6
Lucknow	6	7	10	4	7
	220	270	270	240	150

Allotment units

From villages to warehouses

	Kanpur	Lucknow	Supply	Supplied
V1	450	0	450	450
V2	0	300	300	300
V3	0	400	400	400
Received	450	700		

From warehouses to retail

	New Delhi	Bareilly	Mathura	Meerut	Banaras	Shipped
Kanpur	30	0	270	0	150	450
Lucknow	190	270	0	240	0	700
Demand	220	270	270	240	150	
Demanded	220	270	270	240	150	

Cost	10360

Costs 0

	Kanpur	Lucknow	Supply
V1	2	5	450
V2	3	3	300
V3	6	4	400

	New Delhi	Bareilly	Mathura	Meerut	Banaras
Kanpur	6	9	7	5	6
Lucknow	6	7	10	4	7
Demand	220	270	270	240	150

Now, there is another transportation problem that I will try to showcase here which is a transportation problem with warehouses. So, as I said, there could be sources, there could be warehouses and there could be destinations. So, here sources which are given in this problem statement, let us try to say, so there could be multiple connections, we do not know how the connections could go.

So, this is a kind of a transportation problem which is connected through the warehouses. So, these are warehouses or I would say storage center and the supply center, then demand centers are already there, this is supply centers, these are demand centers. But the problem that is given here is in a Social Innovation Endeavor, Uniti face marks, which was an initiative variety.

Kanpur was stitched at different villages V1, V2 and V3 across the state of Uttar Pradesh and these are all collected at warehouses located at Kanpur and Lucknow before sending them to retail shops at the destination. Destinations are New Delhi, Bareilly, Mathura, Moradabad and Benaras for selling. The demand at destination cities is predetermined and distribution numbers are to be decided, so other transportation cost is minimized.

So, we have three villages, V1, V2, V3 where the women empowerment social innovation case is taken and women stitch the face marks, which face marks are having specific fabric and they are colorful mask and they were first trained at IIT Kanpur and these marks were stitched. So, three villages, the groups of the stitching centers are there at villages, where manufacturing or I would say, processing or the stitching and packaging of marks happen.

So, these villages sent the mask to distribution centers, one is located at Kanpur, another one is at Lucknow for which, the cost are given. So, these are the cost for distributing mask from village 1 to Kanpur, village 2 to Kanpur, village 3 to Kanpur and so on, these costs are there and these are the supply that, these villages provide to the distribution centers.

Now, these two distribution centers, in turn, ship the mask which are received from the villages to five cities New Delhi, Bareilly, Mathura, Meeerut and Benaras for which, the associated cost are also given and the demand that is there for the mask is already predetermined and that is also mentioned here.

I have put this problem into the cells here already. Let us now try to see how to solve this kind of the problem, where the warehouse is connected in between the supply centers that is, the sources and the destinations.

So, two warehouses are there to solve this problem, I have this supply here already I will just try to see what do, I need to supply. So, these are the cost available for the supplies. So, I will just copy this and put it somewhere here because I need to add the allocations here. These I would say are my I will put it in the center, these are my costs and here the left, I have my allotments. I am just putting them in a bigger font so that, we understand the two set of the matrices that we have.

They represent the different things here. So, here the cost I am just deleting this because these are the number of units. The supply is already there given and I would say, supplied this is equal to sum of the rows that is, I am again doing xij is equal to ai, these are supplied and also I need to put this sum for the allotments in this column, that is from Kanpur, what I have received and from Lucknow, what he has received from the three villages. This I will say received.

So, demand is here from the destination centers not the warehouse, warehouse means, only store whatever is supplied. So, I will just put the total demanded that is, the variables which is equal to sum of the column elements, I will just drag this so that, this formula is copied here center line and the total supply that is received from now, the warehouses that also should come here, this is equal to sum of row elements, enter.

I would again put the same word here received from the warehouses. Now, cost here is affected for both the elements, so we need to have the sum of the cost, it means the product sum of the cost from the supply centers to the warehouses and from the warehouses to the demand centers.

So, I would just say directly here, cost is equal to sum product of the units supplied in these warehouses with the associated cost bracket close and another sum product of the units supplied from the warehouses to the destinations that is, the retail stores with their respective costs, enter. So, since the cost which are taken here as of now are 0, but I need not to start from 0 cost only, I can put any values because solver will definitely try to solve the problem.

So, I would like just put like some cost are here, I can say may be 5, 2, 2 so on, any cost could be put here, which will give the supplied values or so. But I will still start from 0 because I wish you all understand the fundamentals of the problem statement with warehouses.

These are the variables. I am ready with my matrices and I will try to put the data in the solver. Now, little care is to be taken so that, all the variables are connected. Now, for this, first thing is my Objective function, it is directly given here which is sum product of the respective matrices here, I will press the button enter on my keyboard. The problem selection mode is minimization that Objective function is to be minimized.

Then we have variable cells. Now, I will put variables from both the matrices here that is, I will put here, this is from villages to warehouses. And, second set of the matrices are from warehouses to retail stores. So, now it will be more clear when we talk about the terminology also, let me try to color wherever the cost is going to be changed. This is the final cost that is going to come. These variables would change and also received and supplied quantities that is, the sum of the quantities would also change.

Now, let me try to solve the problem choosing my solver analysis window. I will just reset all first. Now, Objective function is my cost Objective function is to be selected here which is the cost function, which is the cell data T1. I will press enter after selecting this. The objective function is to be minimized.

I will click on this radio button minimize. Now, change variables means the decision variables now to are to be entered from both the matrices that is, from villages to warehouses and from warehouses to the retail stores. So, how will I will enter them? I will first select the change variables here these are entered, I will put comma and space and select the change variables from the warehouses to the retail stores, enter. Now, both the matrices are entered here in the change variables, you can see. Now, I need to add the constraints.

The constraints would be added similar to what we did in the Transportation model. So, we will say the total supplied is equal to the supply that is available. Then, I will add another constraint that is, the total demanded variable that is sum of the xij should be equal to the demand that is there from the stores.

I would say, ok, now two constraints are added, but now one constraint is to be added that whatever we have received from the villages to the warehouses should be equal to what is to be shipped from the warehouses that is, the units in the warehouses has to be finally 0. What are we received that will be shifted or shipped to the retail stores. So, this case I will add here that whatever is received is equal to whatever is shipped, I will say ok.

So, these constraints are added now the program should be ok, I will say ok. It has to be a Simplex Linear Program and I will try to solve it, it says ok. Now, I will put a word shipped here, so these were shipped. Now, we have obtained a cost which is a minimum cost and you can see whatever is shipped is equal to whatever is received from the warehouses and the supplied are equal to what was the supply available.

So, this is how we try to connect the warehouses that means, we had the two sets of the transportation models in which, whatever is received from the first set is equal to what are the shipped to the second set. So, only the major concern here is, this I will put them in a circle, these are to be equal to this, this is what the connection is.

This connection is taken at the warehouses and the cost that we have obtained is the minimum cost. Sometimes, the case might occur that all the variables are taken only from one center that is, only from one warehouse.

Now, an important point here is, warehouses do not have a storage limitations that we have not put as any of the constraints here. That could be also one of the constraints that the warehouses Kanpur whatever their storage that is there, should be less than equal to the storage capacity. So, if storage capacity is limited, it could be something like that everything is just moved to only one store, one warehouse and for the other warehouse, all the cost might be 0, 0 or so.

In that case two kinds of store constraints would come into play, one is that is the number of units available in Kanpur that should be less than it could let me say, the storage capacity is 1000 and maybe for Lucknow, that should be less than equal to I would say maybe 800. And, if I wish to say that both of the stores should be selected at least, I will put this constraint that Kanpur allotment should be greater than equal to 1 and Lucknow allotment should be greater than equal to 1 that means, it cannot be 0, it would not be 1, it would be more than or equal to 1 that means, it would not remain 0.

So, some allotments in Kanpur would come, some would come in Lucknow. So, these kinds of constraints are sometime to be put to finally get the solution and to have a capacity utilization for all the various is in stores. So, with this the Excel demonstration on transportation models and its variations is completed.

Only assignment model demonstration would be discussed whenever we will try to solve the assignment model in the next lecture. We will try to see different methods of solving the assignment model and we will try to also have an Excel demonstration on how to solve the assignment model using the solver program again. Thank you.