

Modelling and Analytics for Supply Chain Management
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Lecture 59

Designing the Global Supply Chain : Transshipment

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Hello, welcome to Modelling and Analytics for Supply Chain Management and we are in the final week of this program and as you know we had started off with designing and managing the global supply chain, basically designing the supply chain network.

Now, in this designing this global supply chain network, we first dealt with the taxation in supply chain and we said that taxation determines which countries you will pass through for your finish product movement. Same applies to your raw material movement also. If a country has a zero tax, you will pass through that, you will try to build a hub there; if a country has a higher taxation structure, you will bypass that particular country. So, this is the first lesson in designing the global supply chain.

Global supply chain, if you can see, can be broken up into 3, 4, 5 parts. First part as we mentioned is you will have to look into the taxation aspect. The second part that you have to be careful about is the risks for passing through a particular country.

Now, we have already covered this in the module of risk analytics. Just for a recap, every country has a risk in its profile that can be measured and the countries which have a higher degree of risk, which is again a weighted some of the economic, social, political and the other legal dimensions of risks, a country that has a higher risk, you do not want to go into that country.

For example, you might not want to, at this present moment you might not want to have your supply lines built through Afghanistan, because you do not know what will happen to your supply line because there is a lot of internal problems plaguing that country.

So, one was taxation that determines your design; second thing is risks that determine your design. Then today we will take up two more dimensions for the supply chain design. With these dimensions we will then link up and design a full blown global supply chain. Both a single period one and a multi period one.

Now, so let us take the third dimension today. So, just a recap, first dimension was taxation in supply chain, second was risks which we have covered earlier, and the third dimension we take up today that is transshipment.

Now, you remember that when we were doing transportation network design, we were basically looking at the products moving from one place to another, but the products will not move from one place to another at one go. Big trucks will come and then at some point they will be broken down into small, small vehicles, the total product will be, the total production will be, the total movement will be broken down into small, small, small consignments and then they will go to small towns.

For example, your product is coming from let us say Himachal Pradesh the factory, and the product has to come to central India. Now, in central India there is very little demand. Let us draw this then you will understand.

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The image consists of two screenshots from a video lecture. The top screenshot displays the title "Modeling the Global Supply Chain Phase 2: Transshipment" in a white font against a light blue background. The background features a stylized tree-like diagram with various icons (gears, a hard hat, a molecular structure, and a circuit board) scattered around it. At the bottom of the screenshot, there is a black bar with the NPTEL logo and the text "NPTEL Online Certification Course IIT Kharagpur".

The bottom screenshot shows a hand-drawn diagram on a white background. The diagram illustrates the concept of transshipment. A central node is connected to several arrows. One arrow points from the left towards the center, labeled "HP" (Himachal Pradesh). Another arrow points from the center towards the right, labeled "Big Trucks". A third arrow points from the center towards the right, labeled "Smaller Trucks". There are also two stick figure icons on the right side of the diagram. The text "Concept of transshipment" is written in the top left corner of the diagram area. A small video inset of the lecturer is visible in the bottom right corner of the screenshot. At the bottom of the screenshot, there is a black bar with the NPTEL logo and the text "NPTEL Online Certification Course IIT Kharagpur".

Modelling the global supply chain phase 2 that is transshipment, concept of transshipment. Let us see. What is happening? You are manufacturing in, you are manufacturing in let us say Himachal Pradesh. Now, Himachal Pradesh there is no demand, very little. So, this product has to be brought to central India and from central India the products will now be distributed among all these states.

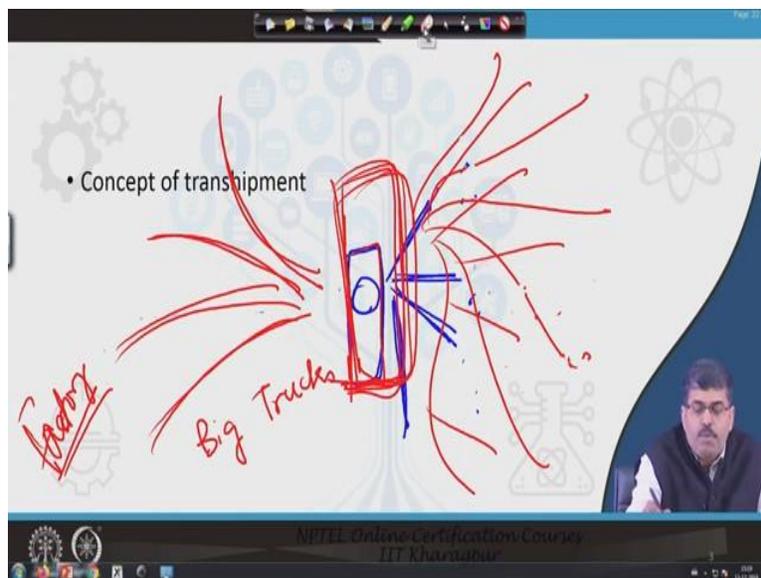
Similarly, so what will happen? A big vehicle will come with lots of tonnage of weight and then from here, these smaller vehicles will take over, those are also 10 metric ton

weight, but then smaller compared to this one, it is smaller in size. The smaller vehicles have to come here, the smaller vehicles will take it over to the destination point. The smaller vehicles will take it over to the destination points.

So, what is this point? What is this location? This location is basically my transshipment point, this location is basically my transshipment point. This location is basically my transshipment point. What is happening? From the big trucks it is going to smaller trucks. This is the transshipment point.

Now, if you look at it, the warehouse is also a transshipment point. Why? Products are coming in from the different directions, storage and then moving out in some other directions.

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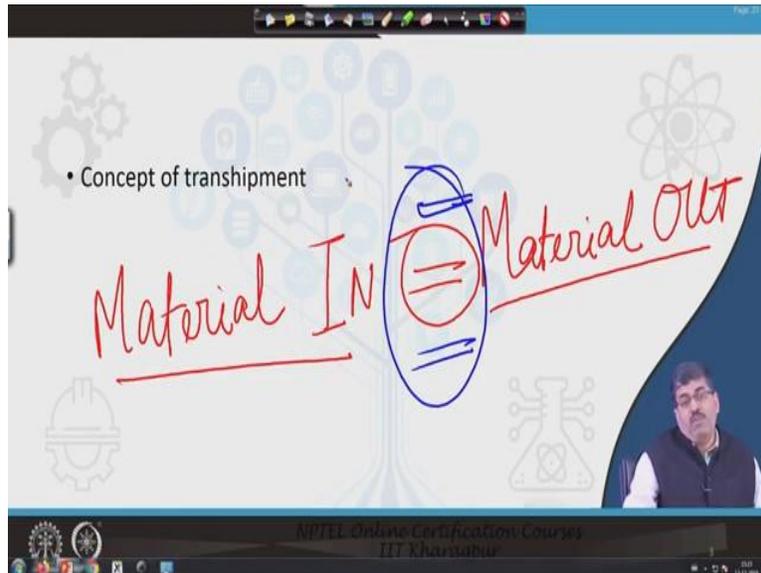


So, now if you see at the warehouse, at the warehouse, the products are coming in and the products are going out. So, if you see very carefully the products have been transshipped. So, warehouse is also a transshipment centre. Similarly, any such location which is a hub is a transshipment centre. Is factory a transshipment centre? Is factory a transshipment centre? Normally, no.

What is the difference let us see. So, in warehouse what is happening? It is a transshipment centre. So, what are we saying? What are we saying in a warehouse?

Material is coming in and material is going out. So, what is the basic principle of warehousing of this transshipment centre, what is the basic modus operandi of this transshipment centre? What is the basic modus operandi of this transshipment centre?

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Basic modus operandi of this transshipment is be very careful and this is very, very important. Basic modus operandi of the transshipment centre or the warehouse, whatever you may say, is material in is equal to material out. Now, storage. That is the basic principle of a transshipment centre.

Now you will say, but warehouse stores, warehouse stores, material in is not equal to material out. Yes, material in is equal to material out, but the gap is 7 days or 10 days or 1 month. But whatever comes in has to go out in a same form. What is happening in factory? Material in is material out, okay, but then one production cycle, the form of the material is changing. If 20 kgs of raw material are coming in, what is going out? 2 kgs of raw material, 2 kgs of finish product are going out.

So, the product form is changing, everything is changing, but your warehouse and transshipment centre what are they doing? Their objective is that general products in the same form, same pattern, same price everything, same form, material in is equal to material out.

So, what is the function of this warehouse? What is the function of this place? The function of this place is to facilitate the break bulking. The function of this place is to facilitate making into smalls the bulk orders. That is the function of this place. So, transshipment is basically a transit point, a temporary point with no storage.

Warehouse in that sense, in the real sense of the term is a transshipment point, nothing else. The storage time maybe 1 day, maybe 2 days, maybe 1 month, maybe few months, maybe one full season to take care of the rains or the winter. But again, if you look at it very carefully, the product form is not changing. So, warehouse is a transshipment centre. Similarly, there are other transshipment nodes available.

Like in the previous class, we were mentioning the flowers in Amsterdam, you remember? Flowers are going from India, all are being brought together in Amsterdam, put them together and from there again it is going to Canada et cetera, et cetera, et cetera, USA, et cetera. So, product coming in, product going out, what is Amsterdam serving as? Amsterdam is serving as the assembling point and a reorganizing and redistribution point, so transshipment centre.

So, what is the basic principle of working of the transshipment centre? I repeat basic principle of working in a transshipment centre, material in is equal to material out. This is a transshipment. So, let us try to solve a problem with transshipment, material in and material out.

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- The following is the cost of movement of goods from Factory to Warehouse and Warehouse to Retail Outlets.
- The warehouse serves as transshipment centres. Decide on which transshipment centre should handle how much quantity.

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The following is the cost of movement of goods from factory to warehouse and warehouse to retail outlets. The warehouse serves as a transshipment centre, decide on which transshipment centre should handle how much quantity.

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Plant \rightarrow W/House

Plant	Warehouse/TRNSHC		Capacity
Gurgaon	2	3	600
Mumbai	3	1	400

Material IN = Material OUT

Warehouse/TRNSHC	Retail Outlets			
	Delhi	Pune	Mangalore	Arunachal
HP	2	6	3	6
MP	4	4	6	5
Demand	200	150	350	300

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Let us see what has happened. There are at two plant, one at Gurgaon, one at Mumbai. There are two warehouses, Himachal and Madhya Pradesh. These are the transportation costs of Gurgaon, Mumbai, et cetera, et cetera, et cetera. Transportation costs from

Gurgaon to Himachal Pradesh, this we have already studied, per unit transportation cost. And the capacity of the Gurgaon plant and the Mumbai plants are given. Next stage what is happening, so what is happening here? From the plant the products are going to your warehouse, from the plant the products are going to your warehouse.

In the second phase what is happening you see? From the transshipment centres of Himachal and Madhya Pradesh, which you see these are your warehouses, from the transshipment centres of Himachal and Madhya Pradesh, it is going to four retail outlets of Delhi, Pune and Bangalore and Arunachal Pradesh. So, Delhi, Pune, Bangalore.

So, what is happening here again if you see? The transshipment centres, so here is your transshipment centre. What are your transshipment centres? Himachal Pradesh and Madhya Pradesh. So, materials coming in from Gurgaon and Mumbai can go into any of these places and from these transshipment centres, products will move to Delhi, Pune, Mangalore, Arunachal, Delhi, Pune, Mangalore, Arunachal.

So, these are, so now you go back, so now you go back and see what is happening? My material in the transshipment centre, material that comes in the transshipment centre is equal to material that goes out, material that goes out. So, my basic tenant that we have mentioned was at the transshipment centre, material in is equal to material out, material in is equal to material out. Understood? So, this is the model for transshipment.

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Warehouse/TRNSHC				Capacity	
Plant	HP	MP			
Gurgaon	2	3	x_1	x_2	600
Mumbai	3	1	x_3	x_4	400

Warehouse/ TRNSHC	Retail Outlets				Demand			
	Delhi	Pune	Mangalore	Arunachal				
HP	2	6	3	6	x_5	x_6	x_7	x_8
MP	4	4	6	5	x_9	x_{10}	x_{11}	x_{12}
	200	150	350	300				

MIN C
 $2x_1 + 3x_2 + 3x_3 + 1x_4 + 2x_5 + 6x_6 + \dots + 6x_{11}$

$x_1 + x_2 \leq 600$
 $x_3 + x_4 \leq 400$
 $x_5 + x_9 = 200$
 $x_6 + x_{10} = 150$
 $x_7 + x_{11} = 350$
 $x_8 + x_{12} = 300$

So, how will I frame the problem now? A problem framing becomes very easy. What is my objective? Minimize total cost, so I do minimize cost. How many units are we transporting from Gurgaon to Himachal and MP? This is x_1 , x_2 , we have done this earlier so I am not going into the details, x_4 , how many units? This. x_5 , x_6 , x_7 , x_8 , 9, 10, 11, 12.

So, minimize cost $2x_1$ plus $3x_2$ plus $3x_3$ plus $1x_4$ $2x_5$ $6x_6$ et cetera, et cetera. So, $2x_1$ plus $3x_2$ plus $3x_3$ plus $1x_4$ $2x_5$ $6x_6$ dot dot dot dot dot $6x_{11}$. That is your objective function, minimize C. Subject to what? What is the capacity of Gurgaon? 600, so x_1 plus x_2 lesser than equal to 600 because as we have early mentioned it can never be equal because my factory's capacities, this is the maximum capacity and production will happen in any case at a bit lesser, than the maximum.

So my x_1 , x_2 less than equal to 600 x_3 plus x_4 lesser than equal to 400. What is the demand? x_5 , x_9 , x_5 , x_9 , x_5 , x_9 is the demand, x_5 , x_9 equal to 200, 6, 10, x_6 plus x_{10} is equal to 150, x_7 , x_{11} is equal to 350, x_8 , x_{12} is equal to 300. So, these was my minimization objective. These are my demand supply objectives.

Now, what are the other constraints? What are my transshipment centres? Himachal Pradesh and Madhya Pradesh, my transshipment centres are Himachal Pradesh and

Madhya Pradesh. So, I will do something now. My transshipment centres are Himachal and Madhya Pradesh.

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		Warehouse/TRNSHC		
Plant		HP	MP	Capacity
Gurgaon	2	X_1	X_2	600
Mumbai	3	X_3	X_4	400

		Retail Outlets			
Warehouse/TRNSHC		Delhi	Pune	Mangalore	Arunachal
HP	2	X_5	X_6	X_7	X_8
MP	4	X_9	X_{10}	X_{11}	X_{12}
Demand		200	150	350	300

Handwritten equations and constraints:

$$X_1 + X_3 = X_5 + X_6 + X_7 + X_8$$

$$X_2 + X_4 = X_9 + X_{10} + X_{11} + X_{12}$$

$$X_1 + X_2 \leq 600$$

$$X_3 + X_4 \leq 400$$

$$X_5 + X_6 + X_7 + X_8 = 200$$

$$X_9 + X_{10} + X_{11} + X_{12} = 150$$

$$X_7 + X_{11} = 350$$

$$X_8 + X_{12} = 300$$

What is the other constraint that is remaining? The other constraint that is remaining is at these transshipment centres of Himachal and Madhya Pradesh, Himachal and Madhya Pradesh, what will happen? Material in should equal to material out.

So, what is material in at Himachal Pradesh? What is transshipment centre? Material in is equal to material out. What are my, what is the material in at Himachal? X_1 . What is the material in at Himachal? X_1 , X_3 . So, X_1 plus X_3 is material in at Himachal, that is equal to material out.

What is the material out from Himachal? Here, X_5 plus X_6 plus X_7 plus X_8 . From Himachal, four lines are going to four markets, X_5 , X_6 , X_7 , X_8 . So, X_1 plus X_3 is equal to X_5 , X_6 , X_7 , X_8 , just see whether you are understanding this or not. Material in is equal to X_1 plus X_3 , material out is from Himachal Pradesh, from Himachal X_5 , X_6 , X_7 , X_8 .

Now, let us take Madhya Pradesh, what is the material in? X_2 , X_4 , X_2 plus X_4 is equal to X_9 , X_{10} , X_{11} , X_{12} . So, material in is equal to material out, X_9 , X_{10} , X_{11} , X_{12} . So, this is the material in material out equation. What does it mean? My stock at this warehouse

or transshipment centre is 0. So, if you notice, this is the transshipment modelling for every warehouse.

Now, whether the warehouse, I already have transshipment centres, will I have warehouse now? Answer lies in the warehousing borders that we did. Those are 0-1 integer programming models, so that will tell you whether I should have a transshipment centre at that location. But the material flow is material in is equal to material out. So, that is the transshipment problem.

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Plant	Warehouse/TRNSHC		Capacity
	HP	MP	
Gurgaon	2	3	600
Mumbai	3	1	400

1. Tax ✓
2. Risks ✓
3. Transshipment ✓

Warehouse/ TRNSHC	Retail Outlets			
	Delhi	Pune	Mangalore	Arunachal
HP	2	6	3	6
MP	4	4	6	5
Demand	200	150	350	300

So, up till now what have we done in designing the supply chain network? Up till now what we have done in designing the supply chain network? We first took the tax, then we took the risks, third we have taken the transshipment model. We have first taken taxation then the risks then the transshipment. Now, if you see all these three are adding to your supply chain design.

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Plant	Warehouse/TRNSHC		Capacity
	HP	MP	
Gurgaon	2	3	600
Mumbai	3	1	400

Warehouse/ TRNSHC	Retail Outlets			
	Delhi	Pune	Mangalore	Arunachal
HP	2	6	3	6
MP	4	4	6	5
Demand	200	150	350	300

This is the place that I left for the modelling which I have shown you there.

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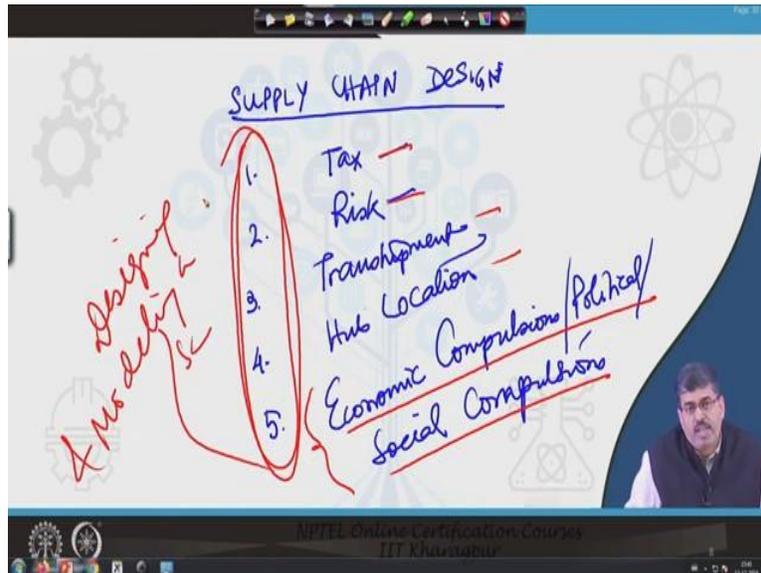
• Hub Location Decisions \approx Warehousing Location Decisions

MLP

The next part is your hub location decisions. Hub location decisions, this is similar to, hub location decisions is similar to your warehouse location decisions. And here what will you use? You will use the, sorry, sorry, sorry, here you will use the mixed integer linear programming problem. Here you will use the mixed integer linear programming

problem. That is your hub location decisions. So, what have we done? Let us again go, let us step by step. Your hub location decisions, sorry, sorry, sorry, sorry, your hub location decisions is this.

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So, what have you done for supply chain design? First, we calculated the tax, then you calculate the risk, then you model transshipment, then you model hub location. Four things we have covered. The fifth thing, the hub location as we measure is similar to warehouse location decisions. The fifth thing that we will look at in the global supply chain location decisions is economic political and social compulsions.

Let us say you do not want a, logically you do not want a supply chain to be built through today's Myanmar, that is Burma. The Myanmar has a historical relation with India. Originally, Myanmar, the ruler, named Burma, when the British has annexed Burma, the erstwhile rulers of Burma were exiled to India and their descendants are still in India. They lived a pretty free life, they used to get some privy purse from the British government but none of them were allowed to stay in Burma, where all were sent to India, the mainland India. That is India's relation with Burma. Recent past won.

The next major relation that we had with Burma is when our great, great son of India, Netaji Subhash Chandra Bose with his Indian National Army, the Azad Hind Fauj,

marched through Southeast Asia and entered Burma and from there came into India up to but, right through Manipur and came up to Imphal.

Very recently, whether you are aware or not, the soldiers of the Azad Hind Fauj took that memorable journey route, the elderly soldiers took that memorable journey route through Burma to commemorate the movement of the Azad Hind Fauj. And in this way the live events of the last era of the Second World War under Netaji Subhash Chandra Bose, we can remember.

And so we see, today if you will see, if you are building up, sometimes hub location just maintain the trade relationships. Many nations ask us to have business centres or the Government of India will also like to have business centres. So, sometimes this, suppose we economic, presently we do not have that much of political as well as economic relationships with Burma, today's Myanmar. With the India's supported democratic movement in Myanmar and that is there. So, right now again we are building up some sort of relationships.

What we want to say is supply chain, for example, we are giving the name of Burma, for example, suppose we want to have a hub in Burma, it may be economically viable, it may not be economically viable also. But if India wants to develop a very, very much cordial relations economic as well as trade relations with Burma, might be, there will be thought processes to set up trade hubs in that country, trade hubs in Myanmar.

So, and actually it is economic compulsions that drive, economic as well as political compulsions, should put it both together, economic as well as political compulsions that drive your business relations, international business relations. So, when economic compulsions, political compulsions, we might be, we might be designing a business hub in Myanmar and already some Indian companies are doing very good business in Myanmar. So, the days may not be far away when we might have a business hub in Myanmar.

So, apart from the tax, risk, transshipment, hub location, we will also have to look into, apart from the political, apart from the, sorry the taxation, the risk, the transshipment,

apart from all these purely managerial aspects, what I want to say is apart from all the purely managerial aspects of supply chain design, there will be something called economic and political and social compulsions that will also prompt you to take these into consideration when you are designing and modelling a supply chain.

So, we have looked into, so in a nutshell we have looked into five aspects of supply chain design and in the next class we will take a fully drawn mathematical problem and we will solve this problem. With all numbers we will solve, we will model the supply chain design. We will model the supply chain design. Thank you for today. We will carry on in the subsequent session. Thank you.