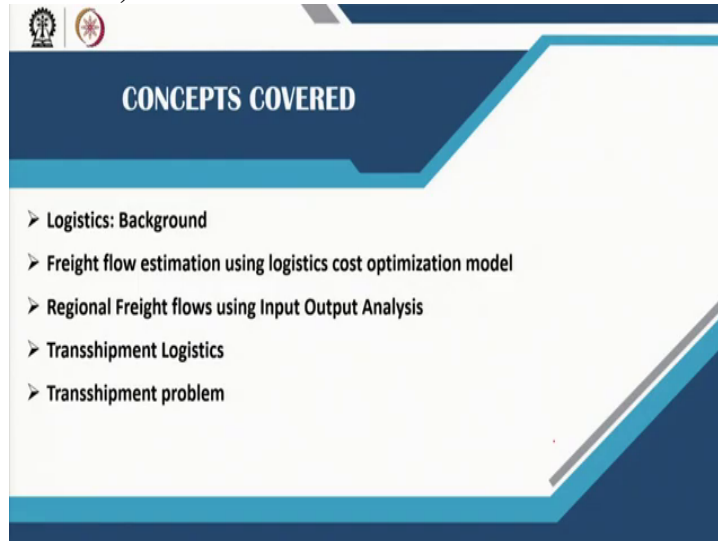


Urban Landuse and Transportation Planning
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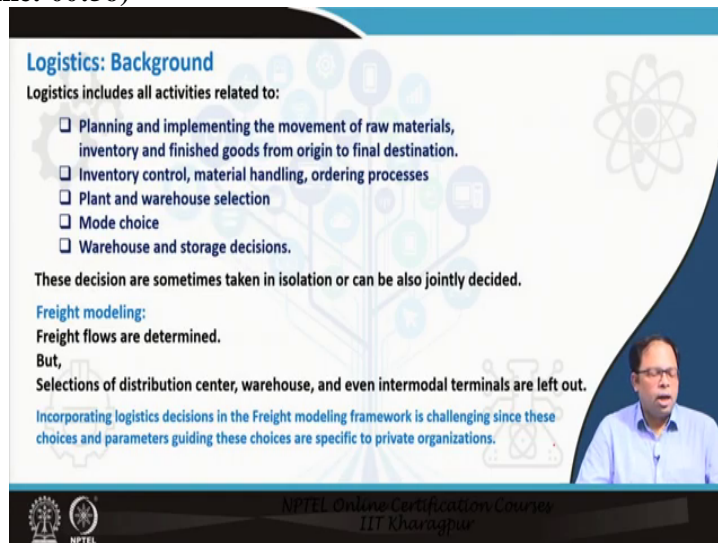
Lecture - 53
Urban Freight Planning : Logistics

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Lecture 53 deals with logistics. The connection is established between urban freight planning and management with logistics. In this regard freight flows are estimated using the logistic cost optimization model. Regional freight flows are predicted using input output analysis and finally, the transshipment logistic as well as the transshipment problem is studied.

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Logistics include different kinds of activities, for example, the entire supply chain is actually controlled through logistics. Planning and implementation of the movement of the raw

materials, inventory, and the movement of finished goods from origin to destination are controlled through logistics operation. Logistics also include inventory control, material handling and the ordering processes. Therefore, it may involve ideally locating a plant or warehouse, sourcing goods from a gamut of plants or warehouses, deciding on the amount of inventory, and selecting the type and size of vehicle for the process. Whereas freight modeling concerns determining freight flows only, leaving out the aspect of locating distribution centers, warehouses, and intermodal terminals. But there is a need to incorporate logistics decision in the freight planning process, which becomes challenging as these decisions are specific to private organizations, and as discussed earlier, private players are apprehensive about sharing data.

This data gap can be overcome by means of municipal licensing requirements, obligating the sharing of some amount of data. Surveys can also be resorted to, to overcome this challenge.

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Freight Flow estimation using Logistics Cost Optimization Model

Economic order quantity (EOQ) model

- Cost optimization in the logistics industry.
- The optimal lot size (the number of units that a company should add to inventory with each order) for an industry can be determined based on its annual demand, ordering cost, holding cost & cost per item.
- Fixed quantity is ordered each time the inventory level reaches a specific reorder point.
- The lot size determines the type of vehicle used for delivery and the number of yearly shipments.
- Such an exercise for all the economic units will generate a fair distribution of freight flows in a region.

$Q = \sqrt{2DS/hC}$ Modified model: $n = \sqrt{(D1C1H + D2C2h + \dots DnCnh)/2S}$

Where,
Q is the optimal lot size, D is the annual demand;
S is the ordering cost per lot, h is holding cost;
C is the cost per item;
 N is the ordering frequency, Dn=Demand for nth item (Source: Mitra et.al., 2015)

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Logistics Cost Optimization Model

Logistics Cost Optimization Model is used for estimating the optimal lot size for a firm. The optimal lot size is the number of units that a company should add to its inventory with each reorder. This is determined based on its annual demand, ordering cost, holding cost & cost per item. This lot size will determine the type of vehicle used for delivery and the number of yearly shipments. Such estimation for all the economic units in an urban area will generate a distribution of the freight flows in the region. The optimal lot size Q for a firm, with annual demand D , ordering cost/lot S , holding cost h , and cost per item C is given by

$$Q = \sqrt{2DS/hC}$$

The ordering frequency N , with D_n being the demand for the n th item is given by

$$N = \sqrt{(D_1 C_1 h + D_2 C_2 h + \dots + D_n C_n h) / 25}$$

Both these formulas could be used to determine the total number as well as the quantity of order that has to be served. And from that one can determine what kind of freight flows will be generated. Besides the four stage modeling process, this is another approach to determine freight flows.

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Regional Freight flows using Input Output Analysis
 Input Output analysis was proposed by Wassily Leontief(1936).
 The Input Output Model represents the interdependencies of various sectors in a national or regional economy.

Let us suppose A, B, C, D, E are five sectors in a regional economy.
 The row at B gives the output of sector B (in tons) that is used by other sectors.
 The sector B itself uses a part of its output.
 The column at C shows the input (in tons) from various sectors required by it.
 For eg., to raise production in sector C, the production has to be raised proportionally in the sectors supplying C

	I	A	B	C	D	E
A				35		
B	10	20	15	50	5	
C				0		
D				30		
E				20		

Input Output Analysis

The input output analysis is used for estimating freight flows at the regional level, because of the lack detailed data at the regional level. The analysis was first proposed by Wassily Leontief and he got a Nobel Prize for it. The input output model represents the interdependencies of various sectors in a national or regional economy. There are multiple sectors in an economy. Each sector depends on the other sectors. So, to increase production in one of the sector, production has to be increased in all the other sectors which contribute to this particular sector. In other words, the production of one sector is not only consumed by the end consumers but also by the other sectors.

The table in the above slide refers to an economy with five sectors A, B, C, D, and E. Of the total output of B, 10 ton is consumed by A; 15 ton is consumed by C; 50 ton is consumed by D; and 5 ton is consumed by E. It is also to be noted, that B itself consumes 20 ton of its total output. Thus, there is a proportional relationship between the various sectors of an economy.

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		PRODUCERS AS CONSUMERS							FINAL DEMAND				
		Agric.	Mining	Const.	Manuf.	Trade	Transp.	Services	Other	Personal Consumption Expenditures	Gross Private Domestic Investment	Govt. Purchases of Goods & Services	Net Exports of Goods & Services
PRODUCERS	Agriculture												
	Mining												
	Construction												
	Manufacturing												
	Trade												
	Transportation												
	Services												
	Other Industry												
VALUE ADDED	Employees	Employee compensation											
	Business Owners and Capital	Profit-type income and capital consumption allowances											
	Government	Indirect business taxes											
										GROSS DOMESTIC PRODUCT			

(Source: Miller and Blair, 2009)

Input output Transactions Table

Estimating Regional Freight flows using Input Output Model

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The above slide shows the input output transaction table. This is one variant of the table. It shows the relationship between the various sectors like agriculture, mining, construction, manufacturing, trade, etc. it also shows how much of the output goes into personal consumption, gross private domestic investment, or is exported. The table also shows value added services like employee compensation, profit on capital, and taxes. The addition of the value added services gives the total amount of monetary value that is produced by each of these sectors. Leontief's transaction table included around 500 odd sectors of the economy.

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Estimating Regional Freight flows using Input Output Model

- Transportation demand is derived from economic activity.
- An industry will need a supply of intermediate goods to carry out production.
- These produced goods will need to be transported for further processing or final consumption.

Demand for freight is generated at two stages:

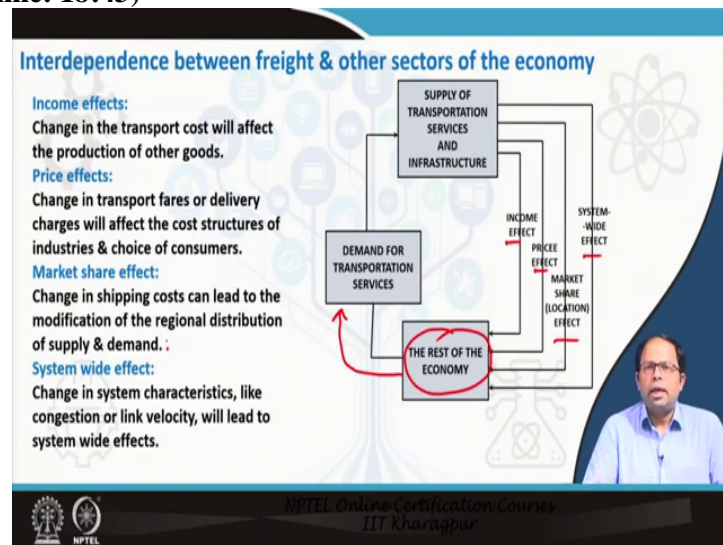
- The location of industries under various sectors along with the IO table will help in ascertaining regional freight flows.
- The final consumption (& corresponding freight) is assigned based on population & its respective GDP.
- The future demand for freight is intrinsically linked to the GDP growth & growth of the different economic sectors.

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Transportation demand is derived from economic activity. Each industry will need a supply of intermediate goods to carry out production and this produce will need to be transported for further processing or for final consumption. So, that means, whenever there is a requirement for goods, there is also a requirement for freight transport.

The demand for freight is basically generated in two stages. The location of industries under various sectors along with the input output table will help in ascertaining regional freight flows. And the final consumption and cost and corresponding freight is assigned based on population and its respective GDP. The GDP of that particular area and the future demand for freight is intrinsically linked to GDP growth and growth of different economic sectors. Therefore, an estimate of GDP growth can be translated into the growth of individual sectors, which will give the growth in freight traffic as well. Thus, a macroeconomic perspective is used for estimating the freight flows.

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Interdependence between freight & other sectors of the economy

Economic growth leads to an increase in demand for freight. As freight is an integral part of the economy, an increased freight demand boosts the economy. Thus, there is interdependence between freight and other sectors of the economy. This interdependence can be studied under the following heads.

Income effects: An increase or decrease in freight costs will respectively increase or decrease the price of other goods.

Price effects: The change in the price of goods due to the change in the price of freight will alter consumer choices.

Market share effect: A change in shipping costs can lead to the modification of the regional distribution of supply & demand.

System wide effect: Similarly, a change in system characteristics, like congestion or link velocity, will lead to system wide effects. This will include location choices for warehouses, transshipment points, etc.

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Coefficient matrix from the input-output table

The underlying assumption in I-O analysis is that the inputs used in production are proportional to the output.

$$Z_{ij} = a_{ij} \cdot X_j$$

Where,
 Z_{ij} is the inter-industry sales from sector i to sector j ,
 a_{ij} is the technical coefficient, and
 X_j = total output of sector j in monetary value terms.

Therefore,

$$a_{ij} = Z_{ij}/X_j$$

	To Steel	To Coal
From Steel	1000	2000
From Coal	2000	500
Total Output	3000	2500

Input-output matrix

	To Steel	To Coal
From Steel	1000/3000	2000/2500
From Coal	2000/3000	500/2500

Coefficient matrix

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Technical Coefficient matrix

In the input output table as discussed earlier, the underlying assumption is that the inputs used in production are proportional to the output. The relation between Z_{ij} , the inter-industry sales from sector i to sector j , and X_j , the total output of sector j in monetary value terms, is given by the following equation.

$$Z_{ij} = a_{ij} X_j, \text{ where } a_{ij} \text{ is the technical coefficient.}$$

The value of the technical coefficient a_{ij} can thus be obtained by dividing Z_{ij} by X_j .

$$a_{ij} = Z_{ij}/X_j$$

From the above example it can be said that if 1000 dollars of steel, go into the making of 3000 dollars of steel itself, the technical coefficient is 1000/3000. Similarly, if 2000 dollars of steel is required for making 2500 dollars of coal, the coefficient is 2000/2500.

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Input-output analysis: Example

A city has three industries namely coal, steel and electricity. To produce INR 1 of output coal industry requires INR .30 worth of Steel and INR .40 worth of Electricity. To produce INR 1 output Steel requires INR .50 worth of goods from Coal, INR .10 worth of Steel and INR .30 worth of Electricity. To produce INR 1 of Electricity requires INR .30 worth of Coal, INR .20 worth of Steel and INR .30 worth of Electricity.

How much should each produce to meet consumer demand of INR 20,000 worth of output of Coal, INR 15,000 worth of Steel and INR 18,000 worth of Electricity?

Matrix format

	C	S	E
C	0	.5	.3
S	.3	.1	.2
E	.4	.3	.3

$$D = \begin{bmatrix} 20 \\ 15 \\ 18 \end{bmatrix} \text{ in thousands}$$

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In the above example, a city has got 3 industries namely coal, steel and electricity. To produce INR 1 output of coal industry INR .30 worth of steel and INR 0.40 worth of electricity is required. To produce INR 1 output Steel requires INR .50 worth of goods from Coal, INR .10 worth of Steel and INR .30 worth of Electricity. To produce INR 1 of Electricity requires INR .30 worth of Coal, INR .20 worth of Steel and INR .30 worth of Electricity. This data is tabulated in the matrix format. The task is to find how much each sector should produce to meet a consumer demand of INR 20,000 worth of coal, INR 15,000 worth of steel and INR 18,000 worth of electricity. The matrix D represents this final demand.

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Input-output analysis: Example

	C	S	E
C	0	.5	.3
S	.3	.1	.2
E	.4	.3	.3

$$D = \begin{bmatrix} 20 \\ 15 \\ 18 \end{bmatrix} \text{ in thousands}$$

x = total output for Coal
 y = total output for Steel
 z = total output for Electricity

$$\begin{aligned}
 x &= 0x + .5y + .3z + 20 \\
 y &= .3x + .1y + .2z + 15 \\
 z &= .4x + .3y + .3z + 18
 \end{aligned}$$

Matrix: $X = AX + D$
 $X - AX = D$
 $(I - A)X = D$
 $X = (I - A)^{-1}D$

I = Identity matrix

Solution:
 Coal: INR 85000, Steel: INR 68000, Electricity: INR 103400

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Let x be the total output for Coal, y be the total output for Steel, and z be the total output for Electricity. To produce 1 INR of coal, 0.5 INR worth of steel and 0.3 INR worth of electricity

is required. Therefore, the total output of coal should not only satisfy the final demand for 20000 INR, but also the intermediate demand for the other sectors. This is represented by the equation

$$\mathbf{X} = \mathbf{AX} + \mathbf{D}, \text{ where}$$

$$\mathbf{X} = \begin{bmatrix} x \\ y \\ z \end{bmatrix}, \quad \mathbf{D} = \begin{bmatrix} 20000 \\ 15000 \\ 18000 \end{bmatrix}, \quad \mathbf{A} = \begin{bmatrix} 0 & .5 & .3 \\ .3 & .1 & .2 \\ .4 & .3 & .3 \end{bmatrix}$$

This equation can be re-written as

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{D}$$

Solving for X we get the values of total production required as follows:

Coal: INR 85000; Steel: INR 68000; and Electricity: INR 103400.

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The equation $\mathbf{X} = \mathbf{AX} + \mathbf{D}$, can also be written as $\mathbf{X} = \mathbf{AX} + \mathbf{Y}$. \mathbf{Y} represents the final demand vector, consisting of consumption C , investment I , Exports E and imports M .

$$\mathbf{Y} = (\mathbf{C} + \mathbf{I} + \mathbf{E} - \mathbf{M})$$

A change in percentage in final demand creates changes in other sectors. The revised final matrix format representing the changes is as follows:

$$\Delta \mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \Delta \mathbf{Y}, \quad \text{where,}$$

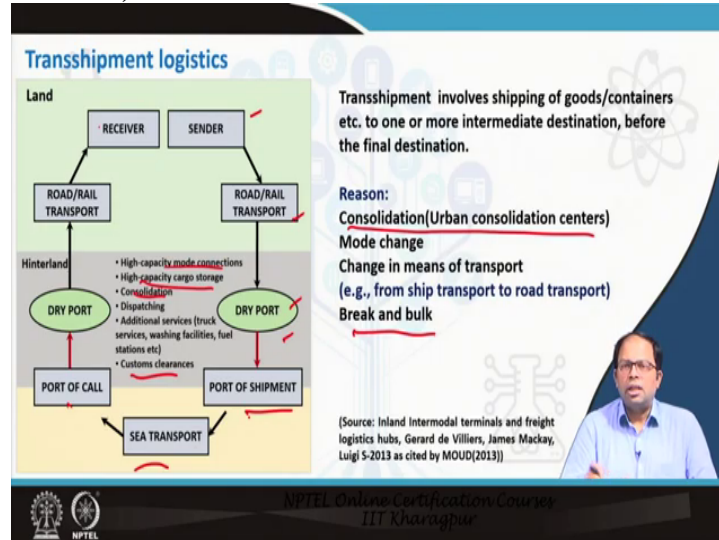
\mathbf{I} is the identity matrix, \mathbf{X} is the output matrix, \mathbf{A} is the technical coefficients matrix, and \mathbf{Y} is the final demand vector.

The demand for a transportation mode at a given future time $(t+n)$ will be given by

$$\mathbf{X}_{(t+n)} = (\mathbf{I}-\mathbf{A})^{-1} \mathbf{Y}_{(t+n)},$$

So, this is how the transportation requirement based on input output analysis is determined.

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Transshipment logistics

Transshipment involves shipping of goods/containers to one or more intermediate destination, before the final destination. There are different forms of transshipment centers. Like integrated freight complexes, located at the periphery of the urban areas, serve as a point of wholesale trading, handling and distribution of regional and interurban goods, and they provide facilities for servicing as well as for parking of freight vehicles. These centers remain well connected to a city by a road network. These centers reduce the cost of logistics by serving as points of consolidation for urban goods, as points for break of bulk, and as points of mode change. Urban consolidation centers serve to consolidate goods coming from different places and companies. From these centers smaller vehicles can carry out deliveries to specific locations within the city. Thus, large consignments can be broken down into smaller ones, resulting in what is referred to as the break of bulk.

The figure in the above slide gives an example of a transshipment centers. In this case a change of mode from road/rail to sea is seen. The dry ports act as the transshipment point, serving as points of consolidation, and dispatch.

In freight modeling, once the total amount of commodities that would be supplied one zone to another is known, it is necessary to understand whether it will go directly or it will go via a transshipment center. But, these decisions are taken by private entities and it is very difficult for urban policymakers to optimize such freight decisions.

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Transshipment logistics

Integrated freight complex:

- ❑ Located on the peripheries of urban areas.
- ❑ Serve as points of wholesale trading, handling and distribution of regional and intra-urban goods.
- ❑ Facilities for servicing as well as ideal parking of freight vehicles.
- ❑ Connected to the city by a transport network.

Inland container depot:

- ❑ Dry Port or Container Freight Station for cargo transit.
- ❑ Connected by rail or road from the serving ports.
- ❑ Cargo is either received or dispatched after stuffing or stripping of containers.

Facilities for cargo & container storage as well as maintenance and repair of container units.
Customs clearance facility.

Truck Terminal:

- ❑ Interface between inter-city and local transportation facilities.
- ❑ Point of break of bulk of goods.
- ❑ Facilities for location of transportation companies, vehicle servicing and idle parking.

Warehouses:

A warehouse serves as a temporary storage for goods for onward transport to customers

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The different forms of transshipment centers are discussed below.

Integrated freight complexes are located on the peripheries of urban areas. They serve as points of wholesale trading, handling and distribution of regional and intra-urban goods, as well as facilities for servicing as well as ideal parking of freight vehicles. They are well-connected to the city by a transport network.

An inland container port has facilities not only for receiving or dispatching cargo after stripping off of the containers, but also facilities for custom clearance, facilities for cargo storage and container repair.

Truck terminals serve as the interface between intercity and local transportation facilities. Bigger trucks come from the all over the country to this truck terminal, which is near a city, because the city will not allow larger vehicles to go in. From here smaller vehicles carry the goods inside a city. Thus, they serve as points of break of bulk. They also serve as facilities for location of transportation companies, vehicle servicing and idle parking.

A warehouse serves as a temporary storage for goods for onward transport to customers. So, this is a place where the supply and demand gets balanced, because production rate and demand rate may not be same. As production rate is dependent on the machineries and other investments, it is difficult to vary it with the variation in demand. An investment in warehousing is thus a cheaper alternative.

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Urban consolidation Centers:

- ❑ Serves a specific geographic area (city centre, an entire town or a specific site such as a shopping centre), to which multiple companies deliver goods destined for the area.
- ❑ Smaller and more environment friendly modes of transport can be used for distributing the goods from here.

Truck Turn Around Time:
A high TAT increases congestion & cost of freight transport.

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Urban consolidation Centres

Urban consolidation centers, serve a specific geographic area and to which multiple companies deliver. From here goods are dispatched to specific locations in the urban area using smaller vehicles.

Truck Turnaround Time (TAT):

Truck turnaround time is the time taken to complete a cycle of loading finished goods from the factory and unloading it at a warehouse. A high turnaround time increases congestion and cost of freight transport. Therefore, it is important to lower the turnaround time. The TAT consists of in-plant TAT, en-route TAT and yard TAT. In-plant TAT starts with the entry of the truck inside the factory, where its tare weight is taken, goods loaded, gross weight taken and invoicing completed.

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Transshipment problem

Sources: A_i with available quantities on offer a_i ($i=1,2,\dots,m$);
 Transshipment point: S_k with quantities s_k ($k=1,2,\dots,r$);
 Destinations: B_j with demands b_j ($j=1,2,\dots,n$);

x_{ik} : Quantity transported from A_i to S_k ;
 x_{jk} : Quantity transported from S_k to B_j ;
 c_{ik} : Transportation costs per unit of goods from A_i to S_k ;
 c_{jk} : Transportation costs per unit from S_k to B_j and
 C_k : Warehousing costs per unit of goods at S_k

Product flow from origin to destination

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Transshipment problem

Transshipment is delivery via another point. Mathematically it is similar to a transportation problem. So, a transshipment problem is solved by converting it into a transport problem. This is shown in the next lecture. The above slide shows a transshipment problem with origins A_1 to A_m , and destinations B_1 to B_n . The transshipment points are shown as S_1 to S_t . x_{ik} is the quantity transported from A_i to S_k ; x_{jk} is the quantity transported from S_k to B_j ; c_{ik} is the transportation cost per unit of goods from A_i to S_k ; C_{jk} is the transportation cost per unit from S_k to B_j ; and C_k is the warehousing cost per unit of goods at S_k .

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Transshipment problem

Transshipment model can be formulated as the following linear programming problem :

Minimize: $T = \sum_{i=1}^m \sum_{k=1}^r C_{ik} x_{ik} + \sum_{k=1}^r \sum_{j=1}^n C_{jk} x_{jk} + \sum_{k=1}^r C_k \sum_{j=1}^n x_{jk}$

Subject to:

- $\sum_{k=1}^r x_{ik} = b_j, j = 1, 2, \dots, n$
- $\sum_{i=1}^m x_{ik} = \sum_{j=1}^n x_{jk}$
- $\sum_{k=1}^r x_{ik} \leq a_i, i = 1, 2, \dots, m$
- $x_{ik} \geq 0, i = 1, 2, \dots, m; k = 1, 2, \dots, r$
- $x_{jk} \geq 0, k = 1, 2, \dots, r; j = 1, 2, \dots, n$

- Transshipment problem is solved by first converting it to a transportation problem.
- This problem could be used to determine location of terminals, warehouses, consolidation centers etc.
- This problem can be also used to determine optimal flows between sources, destinations and transshipment centers.
- This problem can be also used to determine optimal size of transshipment points.

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The problem is formulated as a linear programming problem, where the objective is to minimize T. T is the total cost of transportation and warehousing. The transportation cost includes the cost of transporting the goods from the origin to the transshipment center and the cost of transporting the goods from the transshipment center to the destination. The constraints include supply side constraints, demand side constraints and storage constraints. The problem can be solved to ideally locate transshipment centers, determine their size, or to determine optimal flows.

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The above slide refers to some of the references.

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CONCLUSION

Logistics decisions are gradually getting incorporated in the Freight modeling framework.

Freight flows can also be established using logistics cost optimization in an urban area. This could be an alternative to the gravity model.

Freight flows at the regional level is determined using Input-Output analysis.

Transshipment is an essential component of logistics and this should also be considered while determining freight flows in an urban area. This is particularly significant due to the growth of ecommerce.

Conclusion

Logistic divisions are gradually getting incorporated in the freight modeling framework. Freight flows can also be established using logistic cost optimization in an urban area. And this could be an alternative to the gravity model. Freight flows at the regional level is determined using input output analysis. And transshipment is an essential component of logistics and this could also be considered by determining freight flows in an urban area, which is particularly significant due to the growth of e-commerce.