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

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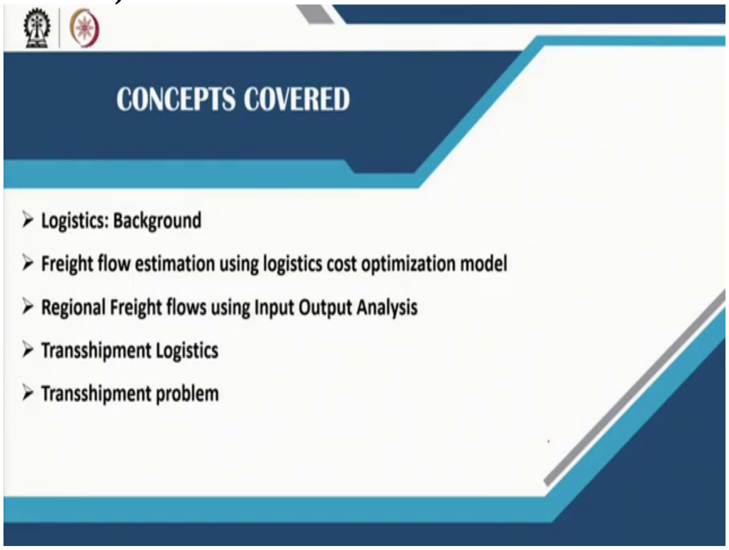

Lecture 53 deals with logistics. The connection is established between urban freight planning and management with logistics. In this regard freight flows are estimated using the logistic cost optimization model. Regional freight flows are predicted using input output analysis and finally, the transshipment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

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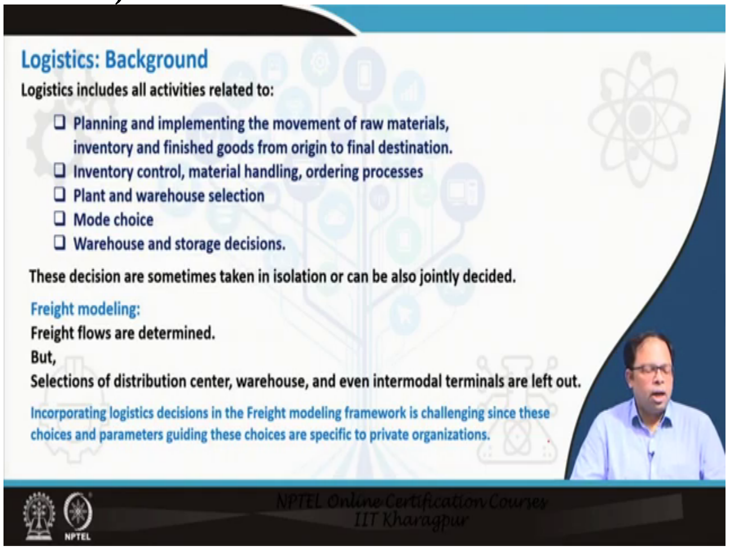

Logistics include different kinds of activities, for example, the entire supply chain is actually controlled through logistics. Planning and implementation of the movement of the raw materials, inventory, and the movement of finished goods from origin to destination are controlled through logistics operation. 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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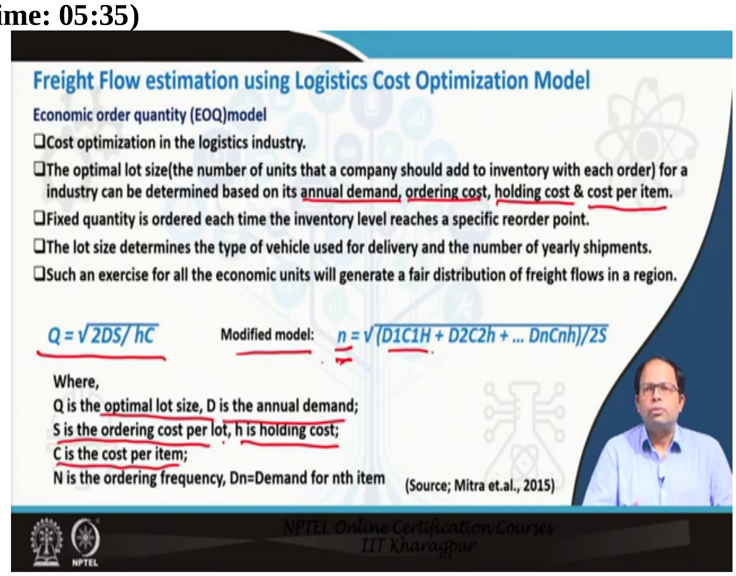

Logistics Cost Optimization Model

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

$$N = \sqrt{(D_1 C_1 h + D_2 C_2 h + \cdots D_n C_n h)/2S}$$

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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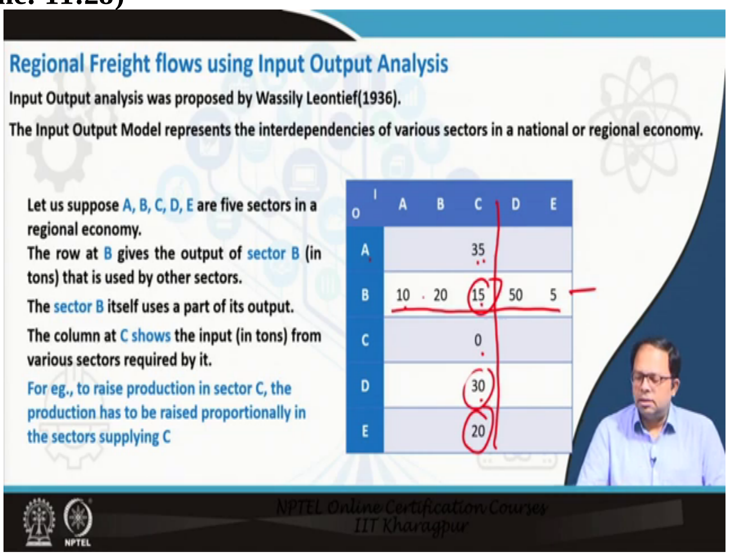

Input Output Analysis

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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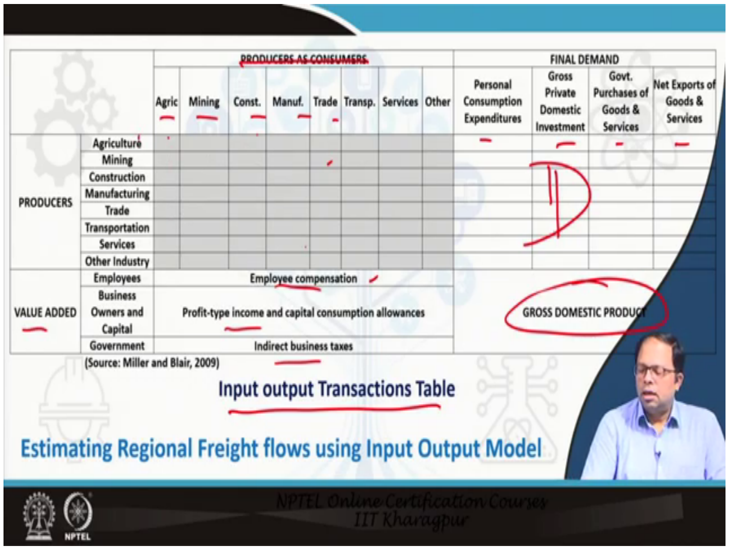

The above slide shows the input output transaction table. This is one variant of the table. It shows the relationship between the various sectors like agriculture, mining, construction, manufacturing, trade, etc. it also shows how much of the output goes into personal consumption, gross private domestic 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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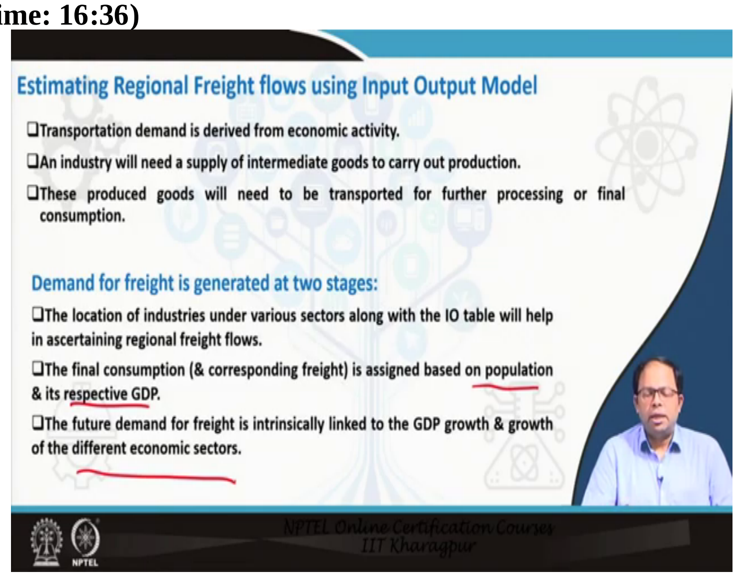

Transportation demand is derived from economic activity. Each industry will need a supply of intermediate goods to carry out production and this produce will need to be transported for further processing or for final consumption. So, that means, whenever there is a requirement for goods, there is also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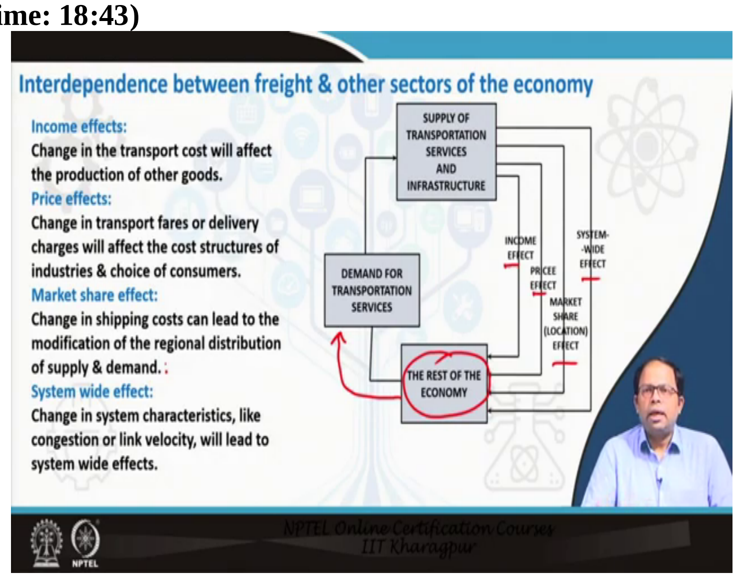

<u>Interdependence between freight & other sectors of the economy</u>

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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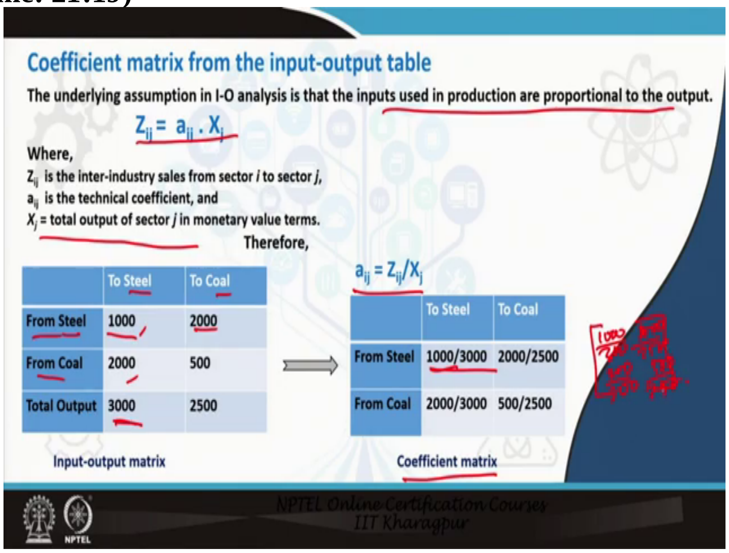

Technical Coefficient matrix

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.

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

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

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

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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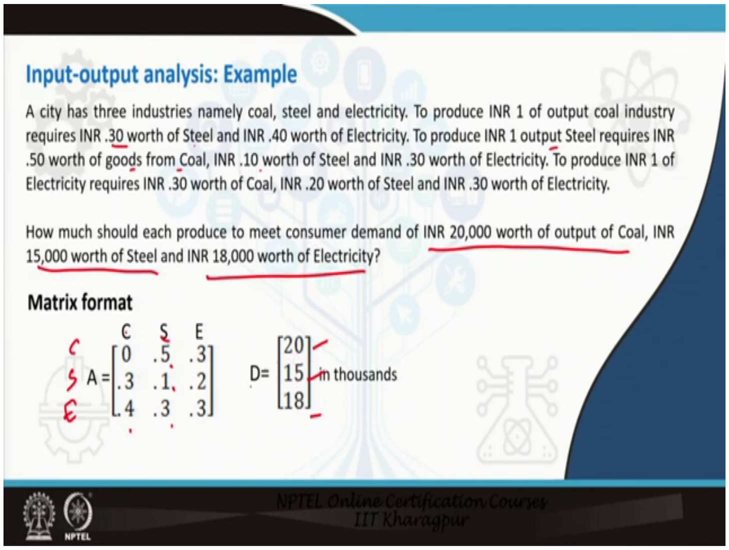

In the above example, a city has got 3 industries namely coal, steel and electricity. To produce INR 1 output of coal industry INR .30 worth of steel and INR 0.40 worth of electricity is required. To produce INR 1 output Steel requires INR .50 worth of goods from Coal, INR .10 worth of Steel and INR .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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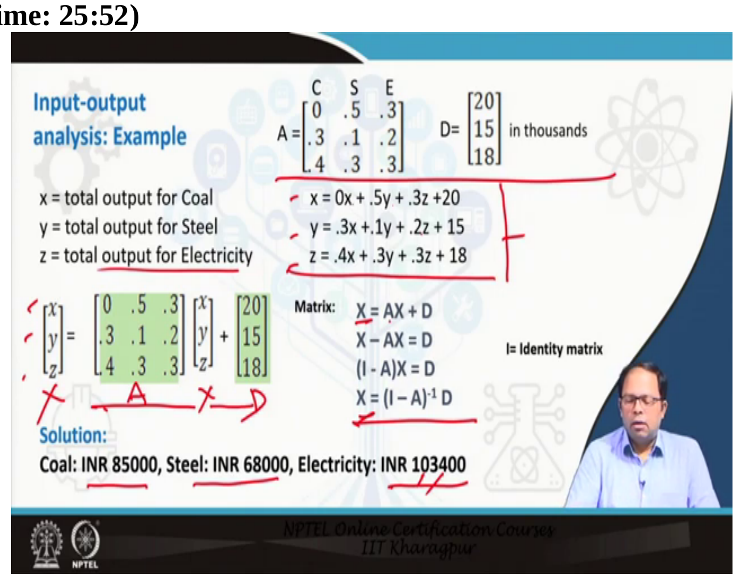

Let x be the total output for Coal, y be the total output for Steel, and z be the total output for Electricity. To produce 1 INR of coal, 0.5 INR worth of steel and 0.3 INR worth of electricity is required. Therefore, the total output of coal should not only satisfy the final demand for 20000 INR, but also the intermediate demand for the other sectors. This is represented by the equation

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

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

This equation can be re-written as

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

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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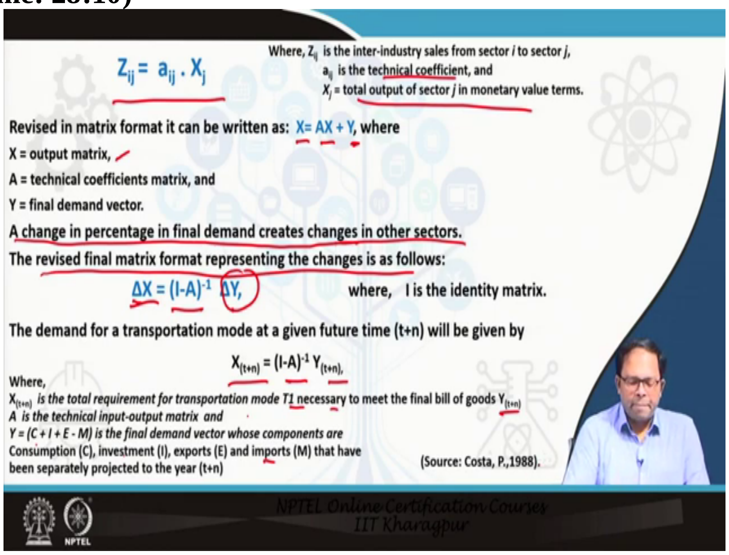

The equation **X = AX + D, can also be written as X = AX + Y.** Y represents the final demand vector, consisting of consumption C, investment I, Exports E and imports M.

$$Y = (C + I + E - M)$$

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

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

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

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

$$X_{(t+n)} = (I-A)^{-1} Y_{(t+n)},$$

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

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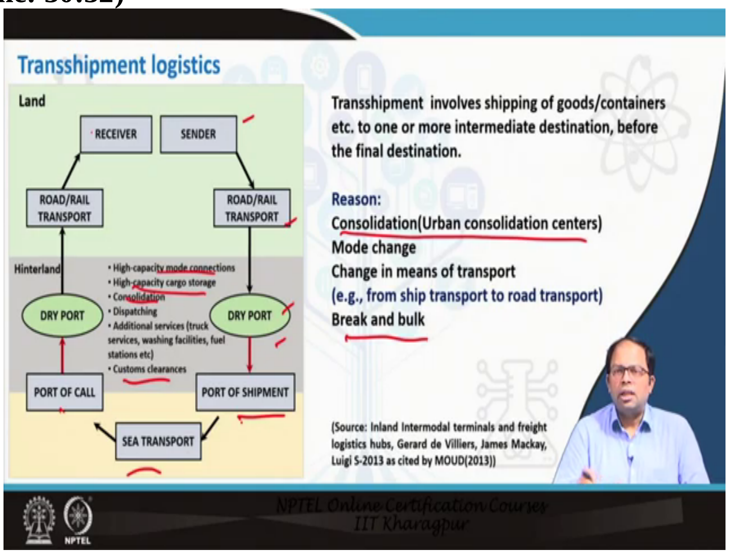

Transshipment logistics

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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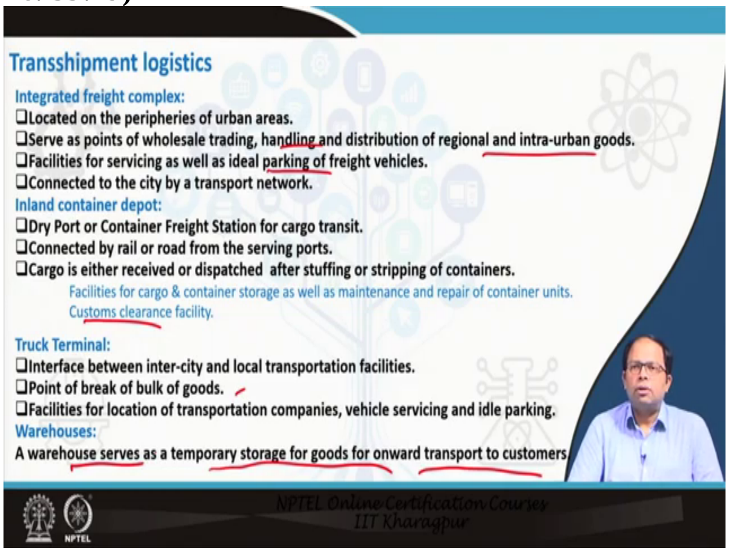

The different forms of transshipment centers are discussed below.

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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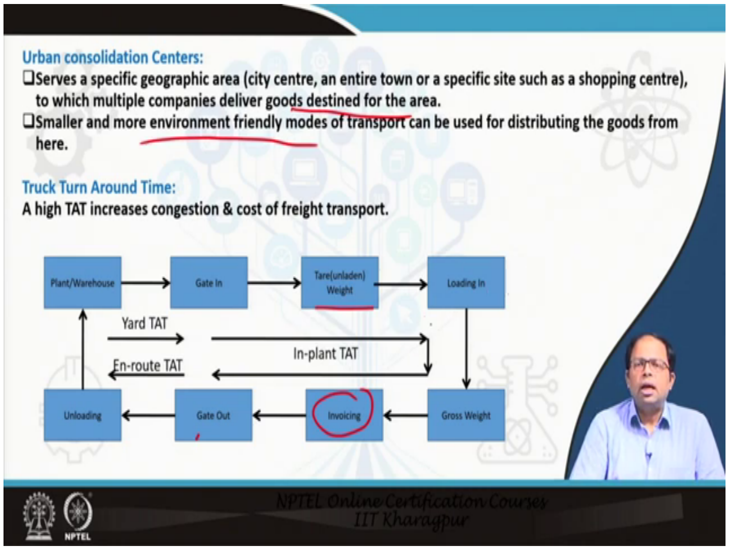

Urban consolidation Centres

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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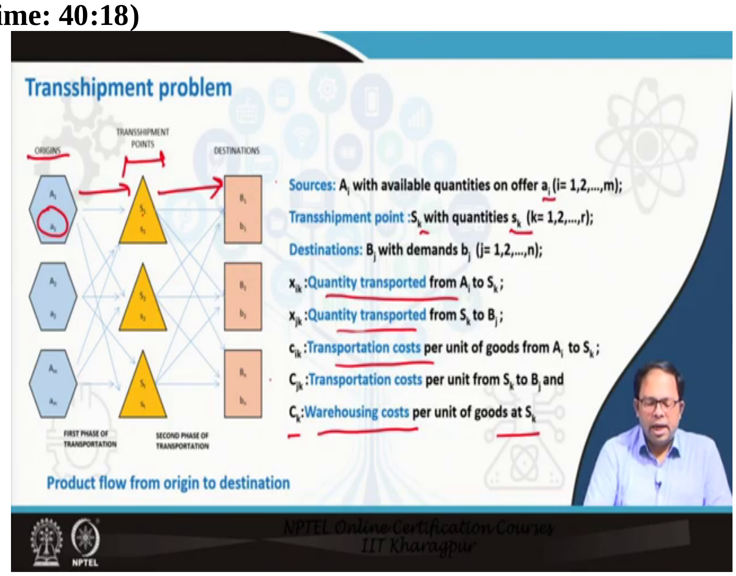

Transshipment problem

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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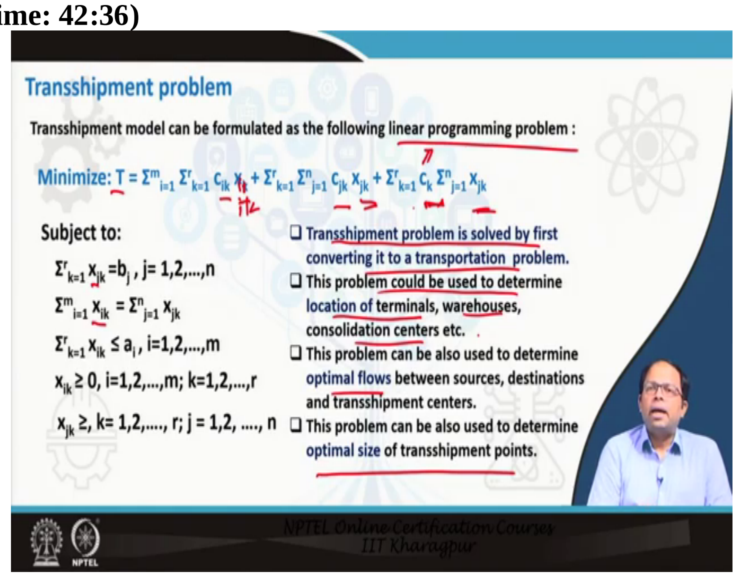

The problem is formulated as a linear programming problem, where the objective is to minimize T. T is the total cost of transportation and warehousing. The transportation cost includes the cost of transporting the goods from the origin to the transshipment center and the cost of transporting the goods 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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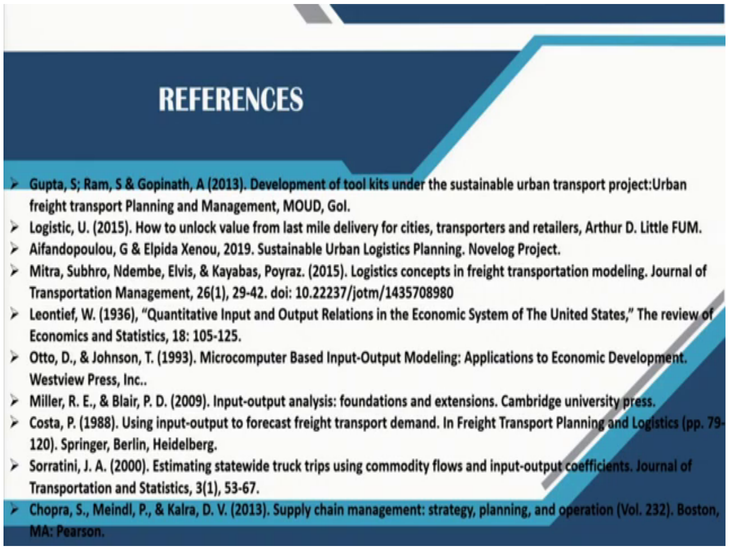

The above slide refers to some of the references.

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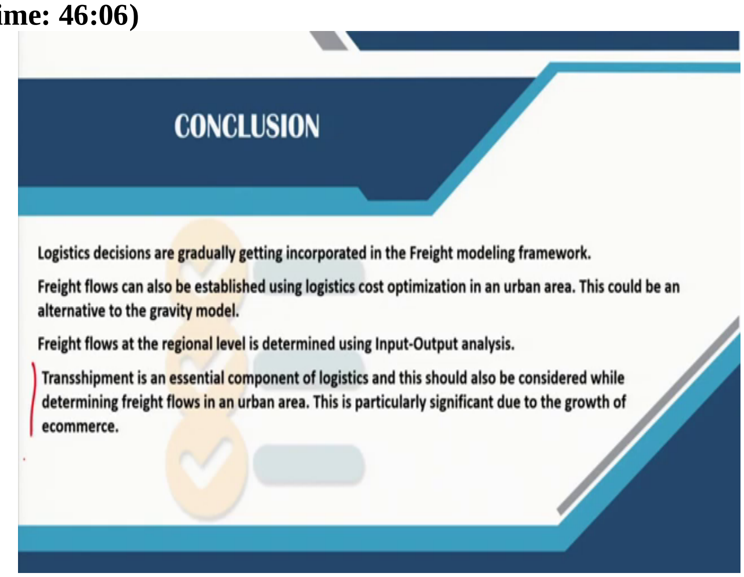

Conclusion

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.