Urban Landuse and Transportation Planning

Prof. Debapratim Pandit
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Lecture - 54
Last Mile Logistics 1

This lecture deals with the first part of last mile logistic.

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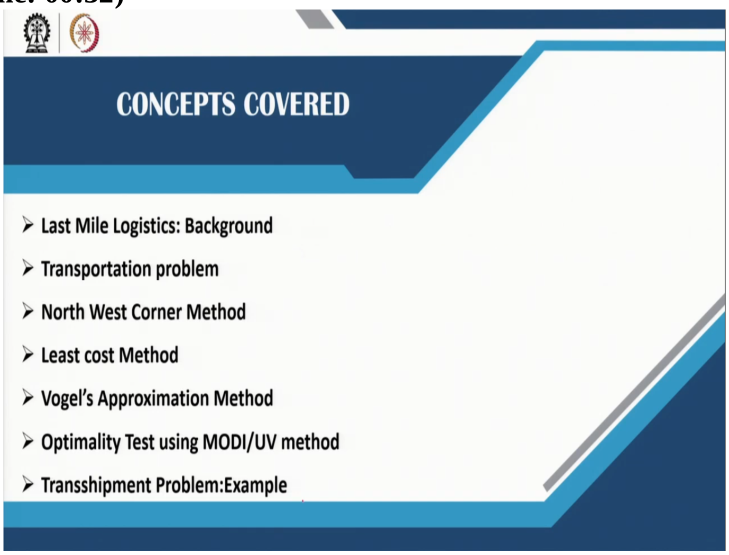

This lecture deals with last mile logistics, transportation problem and the transhipment problem. The initial solution of the transportation problem is obtained using three methods – the North West corner method, the Least cost method and the Vogel's approximation method. The initial solution so obtained, is checked for optimality using the MODI or UV method. The transhipment problem is solved by converting it into a transportation problem.

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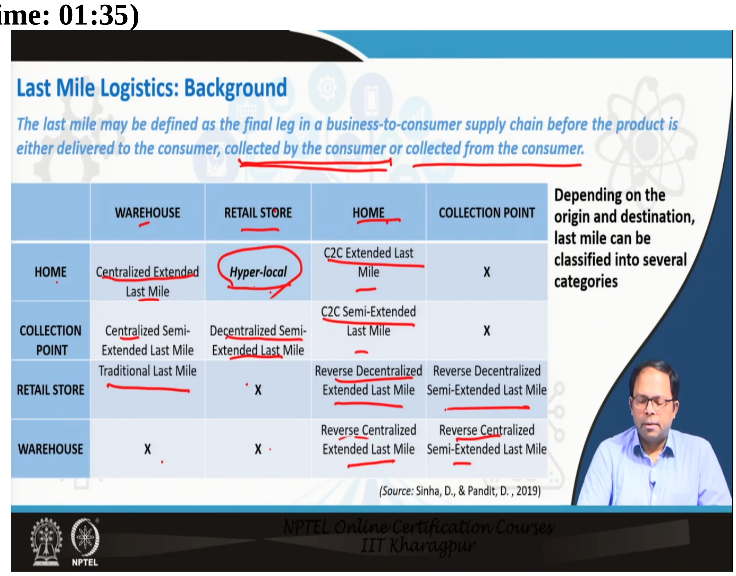

Last mile logistics (LML)

The last mile may be defined as the final leg in a business-to-consumer supply chain before the product is either delivered to the consumer, collected by the consumer or collected from the consumer.

The classification of LML can be done based on the origin and destination. Warehouse, Retail store, home, and collection point serve as either origin or destination. The classification so obtained can be referred to from the slide. Goods can be delivered to a retail store, a collection point or directly to a consumer's house. In case of delivery to a collection point, the delivery cost is reduced, but the consumer has to expend effort in the collection of the goods. Deliveries can originate at warehouses and retail stores. But in case of returns, a now common feature of e-commerce, it may also originate at the customer's home. All cases of return trips are marked by the word *reverse*, for example Reverse Decentralized Extended Last Mile. Another case of the delivery originating at the home is C2C e-commerce, for example as in OLX. The delivery from the warehouse to the retail store, constitute the traditional last mile. Many such trips are getting replaced by home deliveries.

Hyper-local delivery, originating at a retail store and culminating at the home, is getting increasingly popular for delivering groceries and cooked food. In this case companies save on warehouses and inventory, and are also able to conduct faster deliveries. Prominent examples include Swiggy, Zomato and Grofers.

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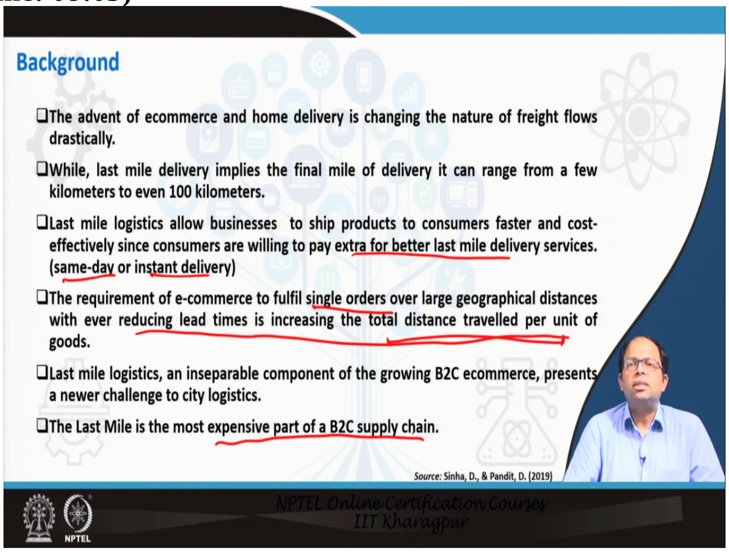

Last mile logistics is the most expensive part of a B2C supply chain. And with the growth of home delivery and e-commerce presents a newer challenge to city logistics. E-commerce requires the fulfilment of single orders over large geographical distances with reduced lead times. This is drastically increasing the total distance travelled per unit of goods. Consumers are willing to pay for such services, but this is resulting in the generation of large vehicle-kilometres. This leads to negative externalities like congestion, emissions, accidents, etc.

Also, the change from the traditional last mile presents the problem of modelling such services. Crowd sourced deliveries on motorbikes can be a part of both passenger or freight trips. Constructing a trip chain for such activities is also an added problem. So it is necessary to model such freight flows exclusively.

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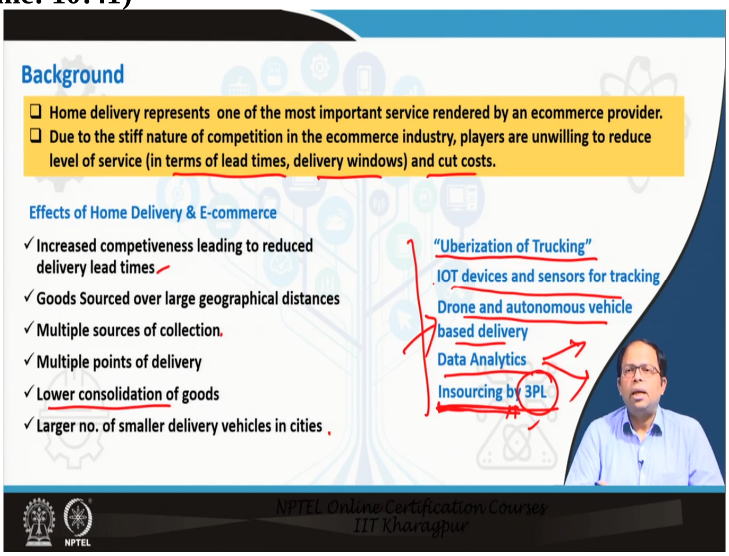

Home delivery represents one of the most important services rendered by an e-commerce provider. And due to stiff nature of competition in the e-commerce industry players are unwilling to reduce level of service in terms of lead time, delivery windows and cut cost. This is leading to reduced delivery lead times, goods sourced over large geographical distances, multiple source of collection, multiple points of delivery, and lower consolidation of goods. This results in larger number of smaller delivery vehicles in cities.

The Uberization of trucking is another important issue. Logistic companies, called third party logistics (3PL), are consolidating goods from different senders and completing the last mile to the ultimate customers. That means, they are not only doing the delivery till the warehouse, but also extending their supply chain and delivering to individual customers.

The increasing penetration of drones and autonomous vehicles for delivery, and IoT devices for tracking delivery vehicles is creating vast amounts of data. Thus, an increasing need is also being felt for exploring these data to optimize the delivery for the future.

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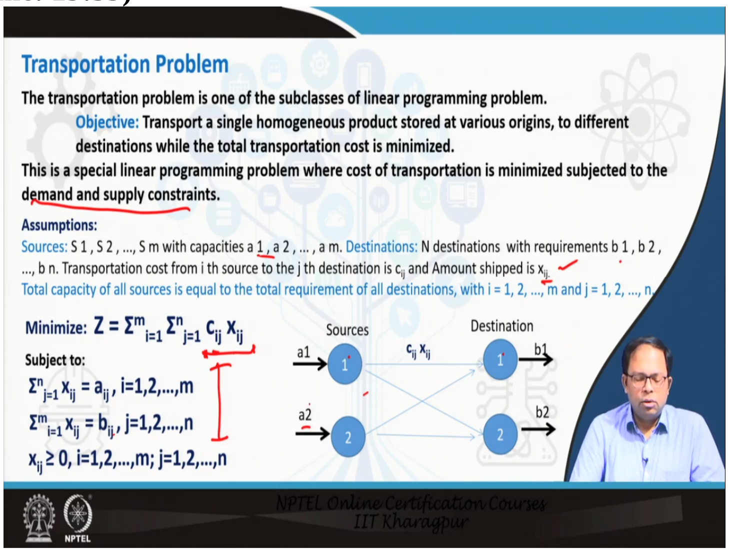

Transportation Problem

The transportation problem is one of the subclasses of linear programming problem with the objective of transporting a single homogeneous product stored at various origins, to different destinations while keeping the total transportation cost to a minimum.

There is a need to understand how to locate different transhipment centres or how to determine freight flows between the supply points and the delivery points through transhipment centres or without transhipment centres. The transportation problem helps us to determine this freight flows from the point of supply to the point of demand without any transhipment.

Consider the following linear programming formulation of the transportation problem.

There are m sources S1 , S2 , ..., Sm having capacities a1 , a2 , ... , am. N destinations have requirements b1 , b2 , ..., bn. The transportation cost from the source i to the destination j is c_{ij} and the amount shipped is x_{ij}.

Total capacity of all sources is equal to the total requirement of all destinations. This means that the problem is balanced.

The objective is to minimize: $\mathbf{Z = \Sigma^m_{i=1} \Sigma^n_{j=1} c_{ij} x_{ij}}$

Subject to:

$\Sigma^n_{j=1} x_{ij} = a_{ij}$, i=1,2,…,m

$\Sigma^m_{i=1} x_{ij} = b_{ij}$, j=1,2,…,n

$x_{ij} \geq 0$, i=1,2,…,m; j=1,2,…,n

The first two constraints ensure that supply never exceeds demand and the problem remains balanced. The third constraint makes sure that cost is always positive.

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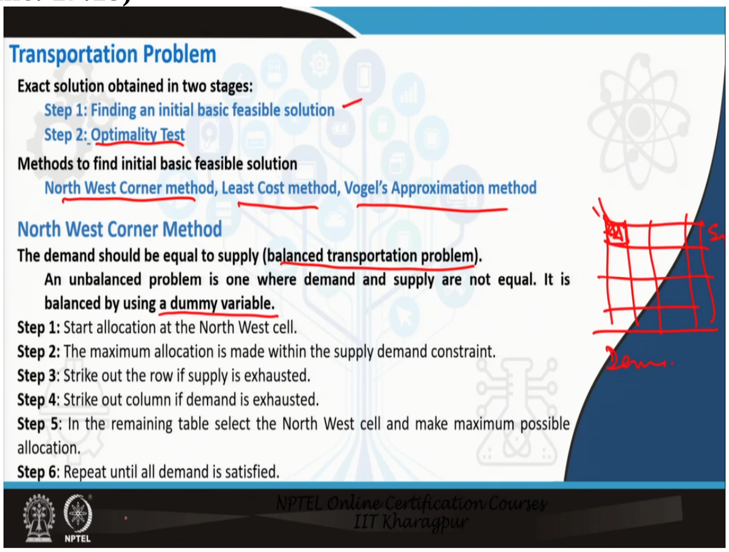

North West Corner Method

This method is used to obtain an initial basic feasible solution.

The transportation problem can be solved in two stages. The first step is to find an initial basic feasible solution. And then step 2 is to modify this solution using optimality tests to find the final optimum solution. There are three common methods to find the initial basic solutions- North West corner method, least cost method and Vogels approximation method. The optimality test is carried out by using the UV method.

In case the problem is unbalanced, a dummy variable is used for balancing the excess supply or demand. A matrix of supply and demand is created. The next steps are as follows.

Step 1: Allocation is made at the North West cell.

Step 2: The maximum allocation is made within the supply demand constraint.

Step 3: If supply is exhausted, the row is struck out.

Step 4: : If demand is exhausted, the column is struck out.

Step 5: In the remaining table the North West cell is selected and maximum possible allocation is made.

Step 6: The steps are repeated until all demand is satisfied.

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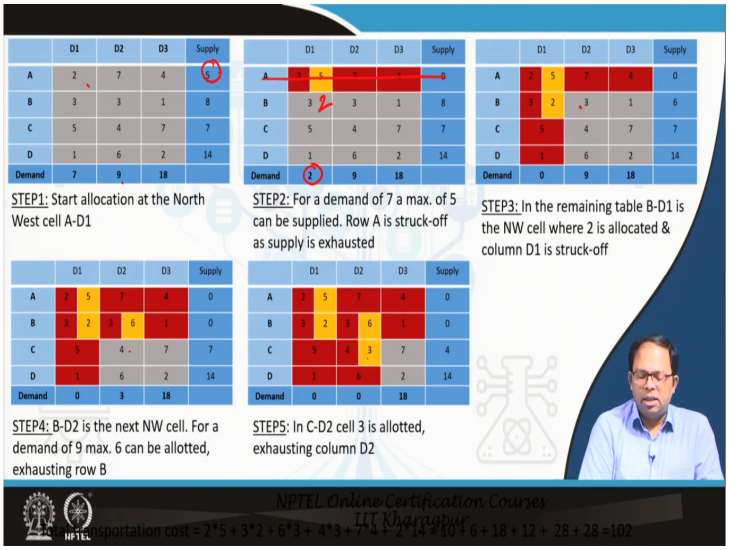

This is explained by the following example as referred to in the above slide.

Step 1: Start allocation at the North West cell A-D1.

Step 2: For a demand of 7 a maximum of 5 can be supplied. Row A is struck-off as supply is exhausted.

Step 3: In the remaining table B-D1 is the NW cell where 2 is allocated & column D1 is struck-off.

Step 4: B-D2 is the next NW cell. For a demand of 9, a maximum of 6 can be allotted, exhausting row B.

Step: In C-D2 cell 3 is allotted, exhausting column D2

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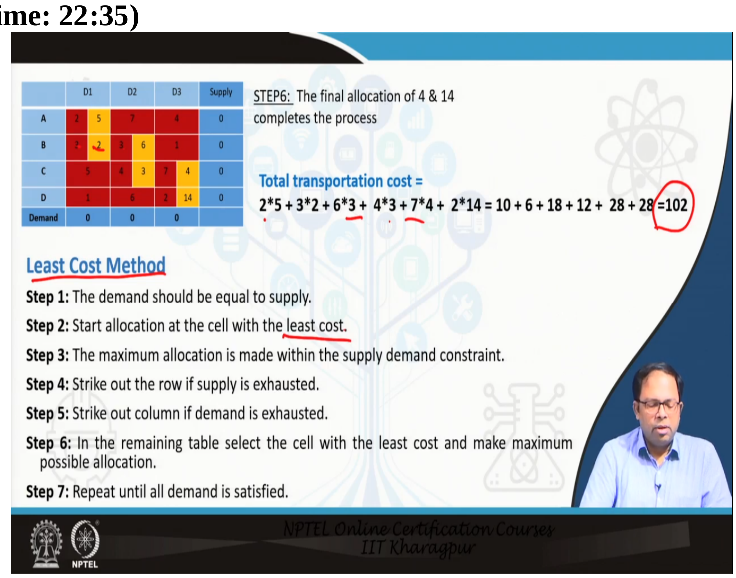

Step 6: The final allocation of 4 & 14 completes the process.

The Total transportation cost = 2*5 + 3*2 + 6*3 + 4*3 + 7*4 + 2*14 = 10 + 6 + 18 + 12 + 28 + 28 =102

Least Cost Method

The steps are given as follows.

Step 1: The demand should be equal to supply.

Step 2: Start allocation at the cell with the least cost.

Step 3: The maximum allocation is made within the supply demand constraint.

Step 4: Strike out the row if supply is exhausted.

Step 5: Strike out column if demand is exhausted.

Step 6: In the remaining table select the cell with the least cost and make maximum possible allocation.

Step 7: Repeat until all demand is satisfied.

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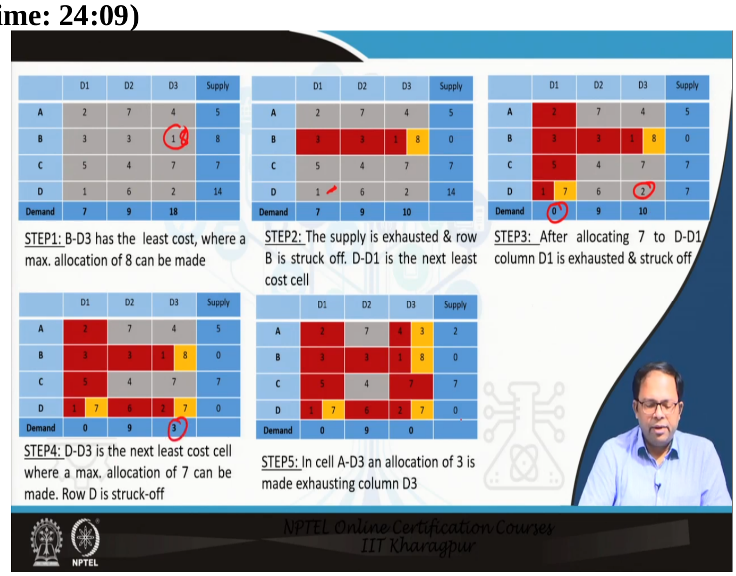

This is explained by the following example as referred to in the above slide.

Step 1: B-D3 has the least cost, where a maximum allocation of 8 can be made.

Step 2: The supply is exhausted & row B is struck off. D-D1 is the next least cost cell.

Step 3: After allocating 7 to D-D1, column D1 is exhausted & struck off.

Step 4: D-D3 is the next least cost cell, where a maximum allocation of 7 can be made. Row D is then struck-off.

Step 5: In cell A-D3 an allocation of 3 is made exhausting column D3.

Step 6: The final allocation of 2 & 7 in A-D2 & C-D2 respectively, completes the process.

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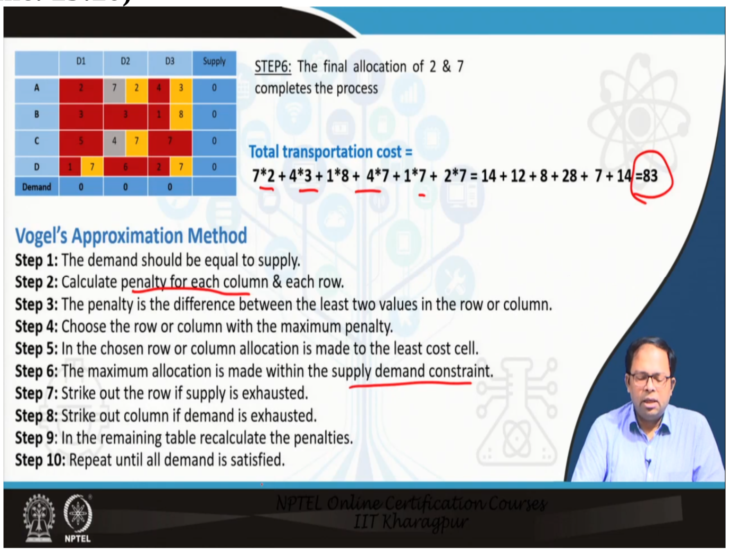

The total transportation cost = 7*2 + 4*3 + 1*8 + 4*7 + 1*7 + 2*7 = 14 + 12 + 8 + 28 + 7 + 14 =83

Vogel's Approximation Method

The steps are as follows.

Step 1: The demand should be equal to supply.

Step 2: Calculate penalty for each column & each row.

Step 3: The penalty is the difference between the least two values in the row or column.

Step 4: Choose the row or column with the maximum penalty.

Step 5: In the chosen row or column allocation is made to the least cost cell.

Step 6: The maximum allocation is made within the supply demand constraint.

Step 7: Strike out the row if supply is exhausted.

Step 8: Strike out column if demand is exhausted.

Step 9: In the remaining table recalculate the penalties.

Step 10: Repeat until all demand is satisfied.

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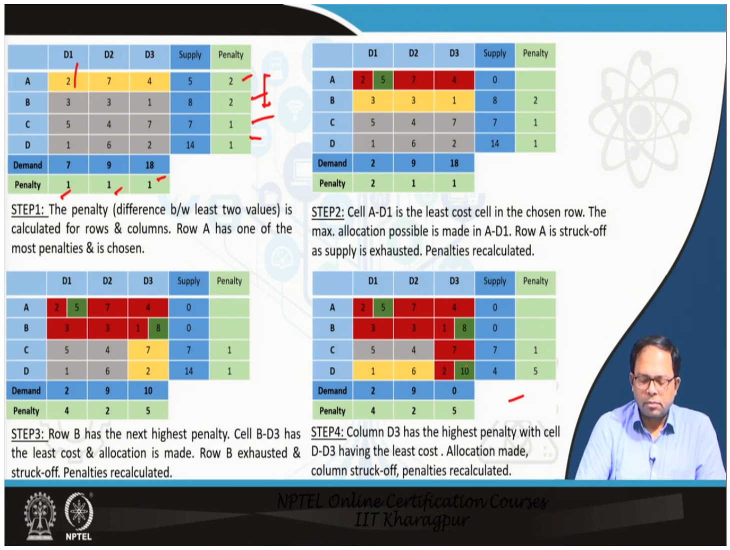

The method is explained by the following example as referred to in the above slide.

Step 1: The penalty (difference b/w least two values) is calculated for rows & columns. Row A has one of the most penalties & is chosen.

Step 2: Cell A-D1 is the least cost cell in the chosen row. The maximum allocation possible is made in A-D1. Row A is struck-off as supply is exhausted. Penalties recalculated.

Step 3: Row B has the next highest penalty. Cell B-D3 has the least cost & allocation is made. Row B exhausted & struck-off. Penalties recalculated.

Step 4: Column D3 has the highest penalty with cell D-D3 having the least cost. Allocation made, column struck-off, penalties recalculated.

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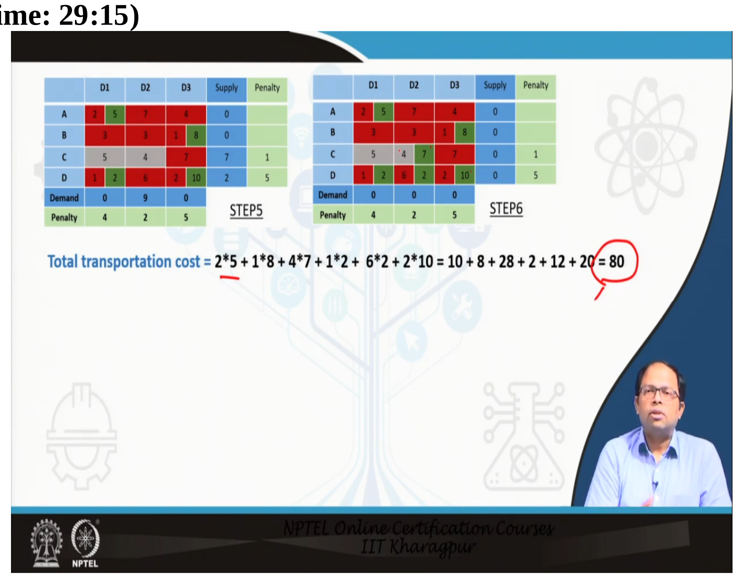

The total transportation cost = 2*5 + 1*8 + 4*7 + 1*2 + 6*2 + 2*10 = 10 + 8 + 28 + 2 + 12 + 20 = 80

This is the least value obtained from amongst the three methods. But this may not always be the case.

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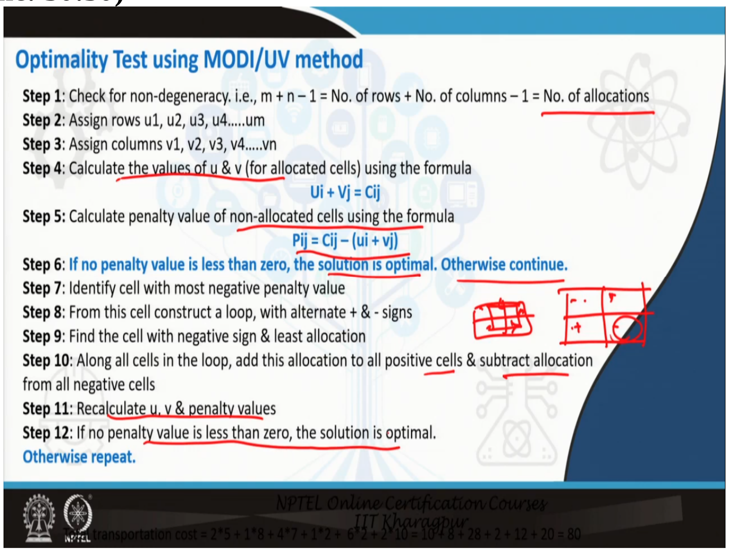

<u>Optimality Test using MODI/UV method</u>

The next step involves the optimality test using UV method. The steps to be followed are as follows.

Step 1: Check for non-degeneracy. i.e., No. of rows + No. of columns – 1 = No. of allocations

Step 2: Assign rows u1, u2, u3, u4…..um

Step 3: Assign columns v1, v2, v3, v4…..vn

Step 4: Calculate the values of u & v (for allocated cells) using the formula Ui + Vj = Cij

Step 5: Calculate penalty value of non-allocated cells using the formula Pij = Cij – (ui + vj)

Step 6: If no penalty value is less than zero, the solution is optimal. Otherwise continue.

Step 7: Identify cell with most negative penalty value

Step 8: From this cell construct a loop, with alternate + & - signs

Step 9: Find the cell with negative sign & least allocation

Step 10: Along all cells in the loop, add this allocation to all positive cells & subtract allocation from all negative cells

Step 11: Recalculate u, v & penalty values

Step 12: If no penalty value is less than zero, the solution is optimal.

Otherwise repeat.

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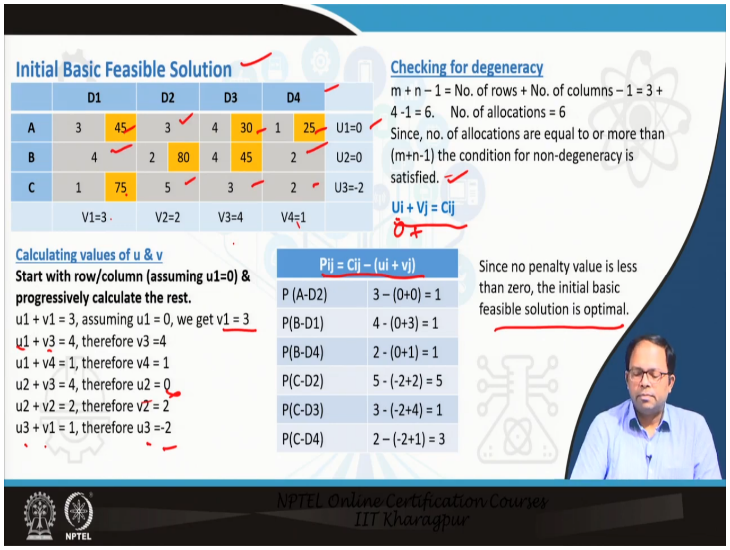

This is explained with an example.

So, let us assume this is an initial feasible solution. A, B, and C are the three supply points and then D1, D2, D3, and D4 are the delivery locations. The cost is given in the grey cells. The allocation is given in the yellow cells.

Checking for degeneracy

No. of rows + No. of columns – 1 = 3 + 4 -1 = 6.   No. of allocations = 6

Since, no. of allocations is equal to (m+n-1) the condition for non-degeneracy is satisfied.

Using the formula Ui + Vj = Cij, the u and v values are calculated. A start is made with the assumption that Ui = 0. The start can be made with any one of the rows or columns.

If u1 + v1 = 3, assuming u1 = 0, v1 = 3. Similarly,

u1 + v3 = 4, therefore v3 =4

u1 + v4 = 1, therefore v4 = 1

u2 + v3 = 4, therefore u2 = 0

u2 + v2 = 2, therefore v2 = 2

u3 + v1 = 1, therefore u3 =-2

Using the u and v values, the penalty values are calculated.

P (A-D2)	**3 – (0+0) = 1**
P(B-D1)	4 - (0+3) = 1
P(B-D4)	2 - (0+1) = 1

P(C-D2)	5 - (-2+2) = 5
P(C-D3)	3 - (-2+4) = 1
P(C-D4)	2 – (-2+1) = 3

Since no penalty value is less than zero, the initial basic feasible solution is optimal.

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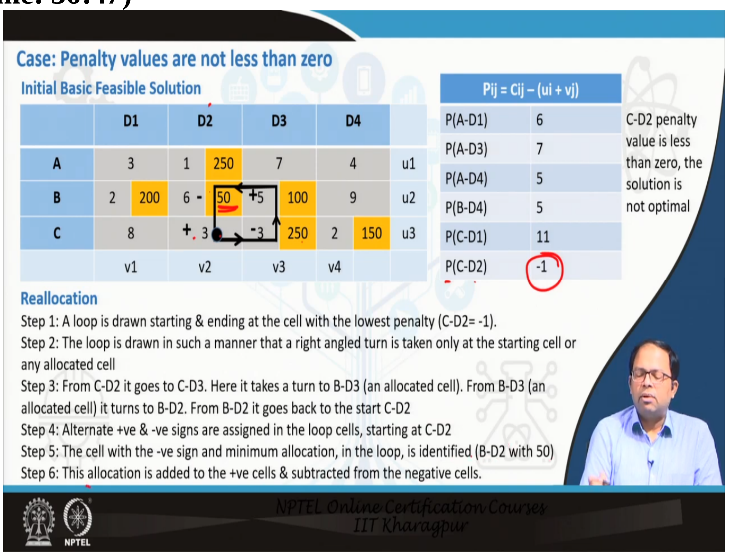

<u>Case: Penalty values are not less than zero</u>

The above slide shows a case with a penalty value less than zero. In this case reallocation is carried out as follows.

Step 1: A loop is drawn starting & ending at the cell with the lowest penalty (C-D2= -1).

Step 2: The loop is drawn in such a manner that a right angled turn is taken only at the starting cell or any allocated cell

Step 3: From C-D2 it goes to C-D3. Here it takes a turn to B-D3 (an allocated cell). From B-D3 (an allocated cell) it turns to B-D2. From B-D2 it goes back to the start C-D2

Step 4: Alternate +ve & -ve signs are assigned in the loop cells, starting at C-D2

Step 5: The cell with the -ve sign and minimum allocation, in the loop, is identified (B-D2 with 50)

Step 6: This allocation is added to the +ve cells & subtracted from the negative cells.

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1. 50 is allocated C-D2
2. 50 is subtracted from C-D3
3. 50 is added to B-D3
4. 50 is subtracted from B-D2

The u and v values are recalculated followed by the penalty values. Since no penalty value is less than zero, the solution is optimal.

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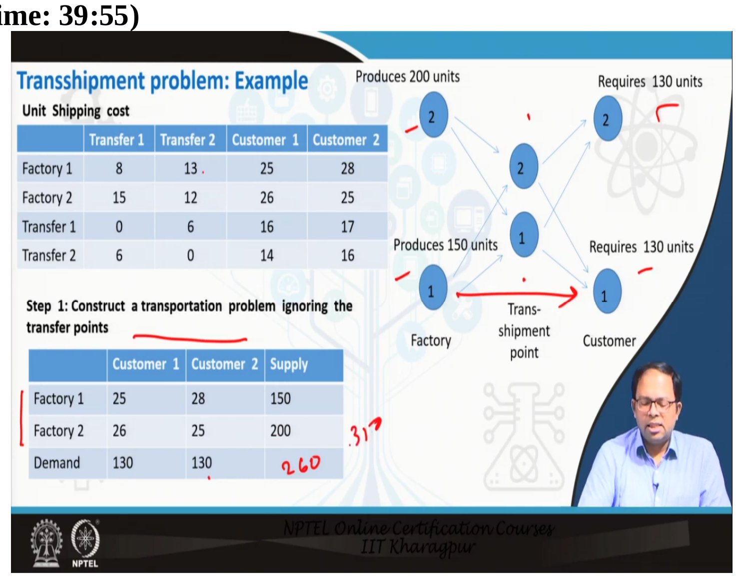

Transshipment problem

A transhipment problem is solved by converting it into a transportation problem. Following is an example. Factory 1 produces 200 units while Factory 2 produces 150 units. There are two transhipment centres. Both customers require 130 units of goods. The shipping costs is given in the table (refer to the slide).

Step 1: This involves constructing a transportation problem by ignoring the transfer points.

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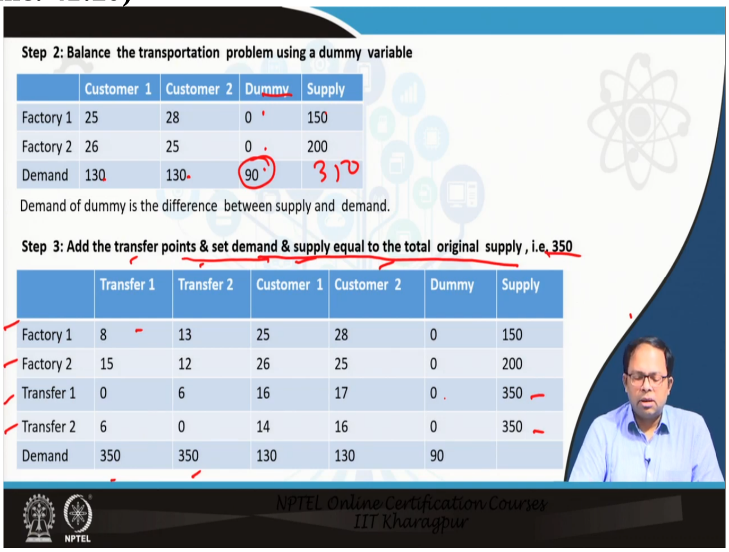

Step 2: The problem is balanced using a dummy variable. Demand of the dummy variable is the difference between supply and demand. A dummy demand of 90 is added.

Step 3: The transfer points are added and their demand & supply is set equal to the total original supply, i.e. 350

The cost of transfer to and from the dummy variable is zero, since no actual transfer takes place.

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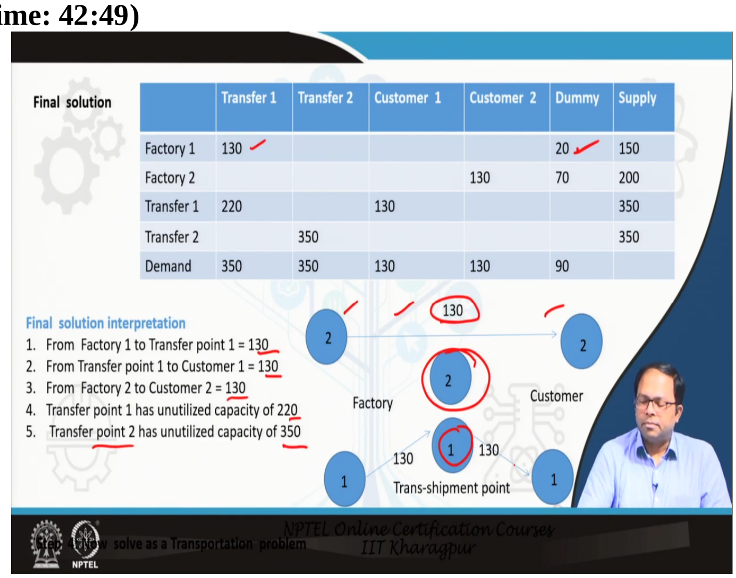

After solving the above transportation problem, the solution as shown in the slide is obtained.

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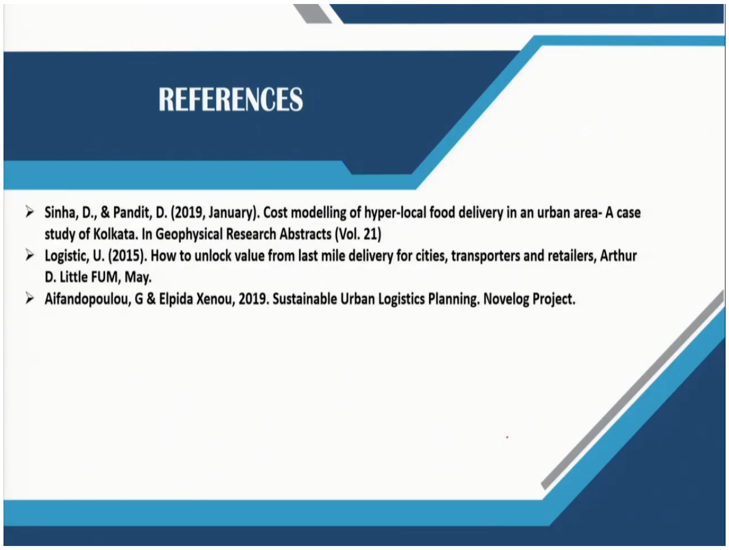

The above slide gives some references.

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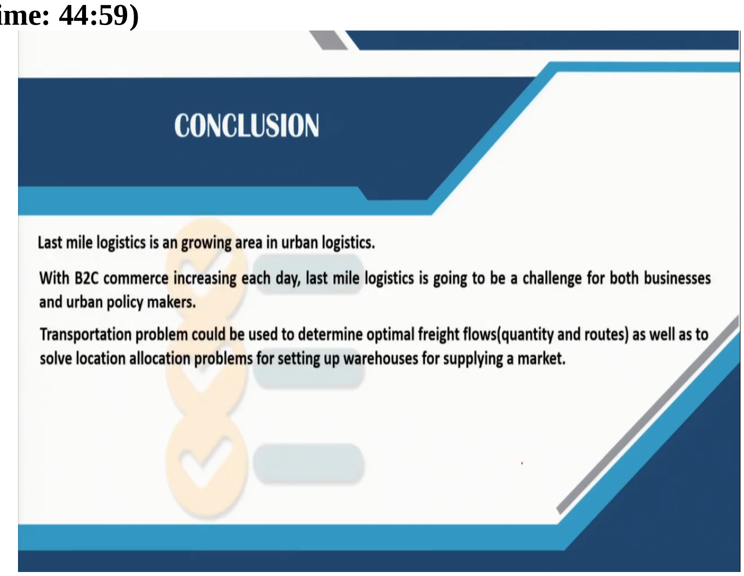

<u>Conclusion</u>

Last mile logistics is a growing area in urban logistics. And with B2C commerce increasing each day last mile logistics is going to be a challenge for both business and urban policy makers. Transportation problem could be used to determine optimal freight flows in terms of both quantity and routes. It can be used for solving the location allocation problems for determining both warehouse size and location.