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TRANSPORTATION MODELS: A TOOL FOR INVESTIGATING MARKET PERFORMANCE AND EFFICIENCY DECISIONS

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An efficient marketing system is the one which is capable of moving goods from producer to consumer at the lowest cost consistent with the provision of the services that consumers demand. Fish marketing in India is characterized by uncertainties in supply, assembling fish from too many landing centres, different types/ varieties and demand patterns, numerous marketing channels, intermediaries and price fluctuations. The fishers are unaware of where to sell their fish with minimum transportation cost, what quantity to be supplied, what is the demand of a particular market, etc. Transportation models are one of the technique which analyses all these and thereby investigating the structure and performance of fish markets. Transportation models enable to understand the price variations and uncertainties in the fishery marketing systems. It helps to make aware of where to supply more fish, how much quantity to be supplied with least transportation cost and moreover it point outs the most demanding species in each markets.

Definition

Transportation models have got very wide role in all the arenas of day to day life. In fisheries, spatial market efficiency can be assessed by examining trade volumes, prices or both. Transportation theory and modeling examines the optimal transportation of commodities in markets. The transportation problem is a special type of linear programming problem where the objective is to transport various quantities of a single homogeneous commodity to different destinations in such a way that the total transportation cost is minimum. Since there is only one commodity, a destination can receive its demand from more than one source. The major objective of the model is to determine how much should be shipped from each source to each destination so as to minimize the total transportation cost. The origin of a transportation problem is the location from which shipments are dispatched and the destination of a transportation problem is the location to which shipments are transported.

Theoretical background

Transportation model has been considered as one of the important applications of Linear Programming Problem (LPP). The objective of transportation model is to determine the schedule for transportation of goods from source to destination in such a way that minimizes the shipping cost and satisfies all the demand and supply constraints. The numerous research works has been done to obtain the optimal cost of shipment in a minimum number of iterations. There are also some methods and techniques that developed in the past few years for finding the lowest cost plan in distributing goods from source to destination.

In transportation model we have to make following two assumptions.

- The requirement assumption-Each source has a fixed supply of units, where this entire supply must be distributed to the destinations. Similarly, each destination has a fixed demand for units, where this entire demand must be received from the sources.
- The cost assumptions- the cost of distributing units from any particular source to any particular destination is directly proportional to the number of units distributed. Therefore, the cost is just the unit

cost of distribution times the number of units distributed.

A general transportation model with m sources and n destinations has m+n constraint equations, one for each source and each destination. However, because the transportation model is always balanced (sum of the supply=sum of the demand), one of these equations is redundant. Thus, the model has m+n-1 independent constraint equations, which mean that the starting solution basic solution consists of m+n- 1 independent equations, which means that the starting basic solution consists of m+n-1 basic variables.

Terminology used in transportation problem :-

- Feasible solution: Non negative values of Xij where i=1,2,3……….m ; j = 1,2,3,……….n which satisfy the constraints of supply and demand
- Basic feasible solution: If the numbers of positive allocations are m+n-1
- Balanced transportation problem: A transportation problem in which the total supply from all the sources is equal to the total demand in all destinations.
- Matrix terminology: In the transportation matrix, squares are called cells and forms columns vertically and rows horizontally.

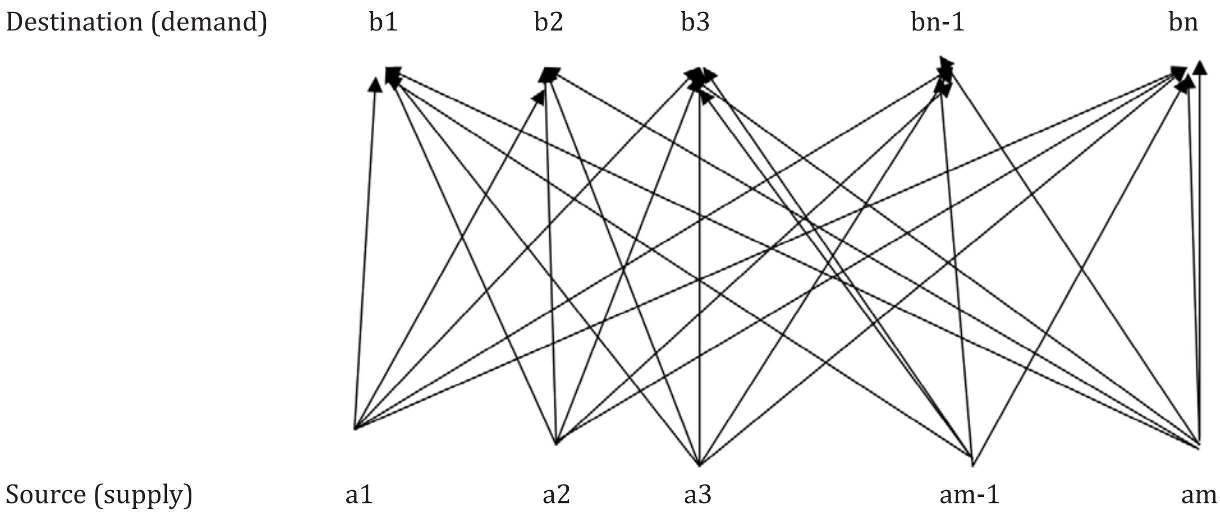
Data requirement

The data of the transportation model include

1. The level of supply at each source and the amount of demand at each destination.
2. The unit transportation cost of the commodity from each source to each destination.
3. Data on market prices, transportation costs and quantities transported.

Computation Techniques

The following figure represents a transportation model with m sources and n destinations. Each source or destination is represented by a node. The route between a source and destination is represented by an arc joining the two nodes. The amount of supply available at source i is ai , and the demand required at destination j is bj.



The costs of transporting one unit between source i and destination j is cij.

Let xij denote the quantity transported from source i to destination j.

The cost associated with this movement is cost× quantity = cij xij.

The cost of transporting the commodity from source i to all destinations is given by

$$\sum_{j=i}^{n} c_{ij}\ x_{ij} = c_{i1}\ x_{i1}\ + c_{i2}\, x_{i2}\ + \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots..\, c_{in}\, x_{in}$$

Thus, the total cost of transporting the commodity from all the sources to all the destinations is

Total Cost = $\sum_{i=i}^{m} \sum_{j=i}^{n} c_{ij}\ x_{ij}$

In order to minimize the transportation costs, the following problem must be solved:

Minimize z = $\sum_{i=i}^{m} \sum_{j=i}^{n} c_{ij}\ x_{ij}$

subject to $\sum_{j=1}^{n} x_{ij}$ ≤ ai for i = 1. . . m

and $\sum_{i=1}^{m} x_{ij}$ ≥ bj for j = 1. . . n where xij ≥ 0 for all i and j.

The first constraint says that the sum of all shipments from a source cannot exceed the available supply. The second constraint specifies that the sum of all shipments to a destination must be at least as large as the demand. The above implies that the total supply.

Methods to solve the transportation problems are given below;

1. North West Corner Method (NWCM)

Step 1. Start with the cell at the upper left (north-west) corner of the transportation matrix and allocate commodity equal to the minimum of rim values for the first row and first column.

Step 2. (a) If allocation made in step 1 is equal to the supply available at the first source (first row) then move vertically down to the cell (second row and first column). Apply step 1 again, for the next allocation (b) If allocation made in step 1 is equal to the demand of the first destination (first column) then move horizontally to the cell (first row and second column). Apply step 1 again for next allocation.

3. Continue the procedure step by step till an allocation is made in the south east corner cell of the transportation matrix

2. Least Cost Method (LCM)

Step 1. Select the cell with the lowest unit cost in the entire transportation table and allocate as much as possible to this cell. Then eliminate that row or column in which either the supply or demand is satisfied. If, a row and a column are both satisfied, simultaneously then crossed off either row or a column.

Step 2. After adjusting the supply and demand for all uncrossed rows and columns repeat the procedure to select a cell with the next lowest unit cost among the remaining rows and columns.

Step 3. Repeat the procedure until the available supply at various sources and demand at various destinations is satisfied.

3. Vogel Approximation Method (VAM)

Step 1. Calculate the penalties for each row (column) by taking the difference between the smallest and the next smallest unit transportation cost in the same row (Column).

Step 2. Select the row or column with the largest penalty and allocate as much as possible in the cell that has the least cost in the selected row or column and satisfies the rim conditions.

Step 3. Adjust the supply and demand and cross out the satisfied row or column.

Step 4. Repeat step 1 to 3 until the available supply at various sources and demands at various destinations is satisfied.

4. Method using Excel Solver for solving transportation problem.

Step 1. First 'Set Target Cell' for the total transportation cost which is to be minimized.

Step 2. Click on the text box 'By Changing Cells' and then select cells by clicking and dragging.

Step 3. By using the solver option, put the minimum number of iterations by hit and trial to get the optimal solution.

Step 4. To checks further for optimal solution, the result is same on increasing the number of iterations.

Worked out example

Formulating a balanced transportation problem

Suppose there are three landing centres L1,L2,L3 that supplies the needs to four fish markets M1,M2,M3,M4. Each landing centre can supply the following quantity of fish: L1, 6 tones; L2, 8 tonnes; L3, 16.The demands of the markets is as follows: M1, 4 tones; M2, 7 tones; M3, 6 tonnes; M4, 13 tones. The cost of sending 1 ton of fish from landing centre to market is as given in the table below. To minimize the cost of meeting each markets peak demand, formulate a balanced transportation problem in a transportation tableau and represent the problem as a LP model.

	M1	M2	M3	M4
L1	14	25	45	5
L2	65	25	35	55
L3	35	3	65	15

Representation of the problem as a LP model

Xij: number of (tones) fish at landing centre i and sent to market j.

Min z = 14X11 +25 X12 + 45 X13 + 5 X14 + 65 X21 + 25 X22 + 35 X23 + 55 X24 + 35 X31 + 3 X32 + 65 X33 + 15 X34

subject to :

$$\left.\begin{array}{l} X11 + X12 + X13 + X14 \le 6 \\ X21 + X22 + X23 + X24 \le 8 \\ X31 + X32 + X33 + X34 \le 16 \end{array}\right\} \text{Supply constraints}$$

$$\left.\begin{array}{l} X11 + X21 + X31 \ge 4 \\ X12 + X22 + X32 \ge 7 \\ X13 + X23 + X33 \ge 6 \\ X14 + X24 + X34 \ge 13 \end{array}\right\} \text{Demand Constraints}$$

Xij ≥ 0, (i= 1, 2, 3; j= 1, 2, 3, 4)

Solving Transportation problem using Spreadsheet Modeling and Excel Solver

A mathematical model implemented in a spreadsheet is called a spreadsheet model. Major spreadsheet packages come with a built-in optimization tool called Solver. Now we demonstrate how to use Excel spreadsheet modeling and Solver to find the optimal solution of optimization problems. If the model has two variables, the graphical method can be used to solve the model. Very few real world problems involve only two variables. For problems with more than two variables, we need to use complex techniques and tedious calculations to find the optimal solution. The spreadsheet and solver approach makes solving optimization problems a fairly simple task and it is more useful for students who do not have strong mathematics background.

Step 1 : Open the spread sheet and construct the transportation matrix with landings (L1, L2, L3, L4), markets (M1, M2, M3), supply and demand as shown below.

	M1	M2	M3	M4	Supply
L1	14	25	45	5	6
L2	65	25	35	55	8
L3	35	3	65	15	16
Demand	4	7	6	13	30

Total supply & total demand both equal 30 hence "balanced transportation problem".

Step 2: Construct a duplicate of the transportation matrix as shown.

	M1	M2	M3	M4	Supply reference	supply
L1					0	6
L2		Changing variables			0	8
L3					0	16
Demand reference	0	0	0	0		
demand	4	7	6	13		
Total cost						

Step 3: Click on solver: Set the objective which is here the row of total cost indicated in green colour. Click on To (min). Then Set the changing variables here it is the cells indicated in yellow colour. (i.e. insert the corresponding rows and columns)Then add the constraints in sub to constraints box .Click on add. Give the cell reference (supply reference) and the operation <=.Then give the cell constraint (supply). Repeat the same for demand constraint also. Select the linear solving method on solver. Click on solve.

The output of the problem is as shown below.

	M1	M2	M3	M4		Supply
L1	4	0	0	2	6	6
L2	0	2	6	0	8	8
L3	0	5	0	11	16	16
	4	7	6	13		
Demand	4	7	6	13		
Total cost	**506**					

The minimum cost obtained is Rs. 506

Interpretation of results

The solver results interpret that the minimum cost required to meet each markets peak demand is Rs. 506. The result also indicate that how much fish should be shipped from each landing centre to each market so as to minimize the transportation cost.

Suggested readings

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