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Solving transportation problem using object-oriented model (JAVA)

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Abstract

This paper is about solving transportation problem using Operation Research (OR) approach in analysis and design phases and we used Java programming language to model the problem. The results obtained from both solutions are compared in order to make analysis and prove the object-oriented model's correctness. We proved that results are identical when solving the problem using the five methods, namely, northwest corner method, minimum cost method, row minimum cost method, column minimum cost method, and Vogel's approximation method.

Keywords: linear Programming (LP), object-oriented programming (Java), operation research, transportation problem, vogel's approximation

INTRODUCTION

The main purpose of this paper is solving transportation problem using five methods of Linear Programming (LP). The second objective is solving transportation problem by object-oriented programming. Java programming language is used to get the solution. The results obtained from both LP and object-oriented programming solutions are compared.

The five methods explored for solving transportation problems are:

1. Northwest Corner method
2. Minimum cost method
3. Row Minimum Method
4. Column Minimum Method.
5. Vogel's approximation method

This paper introduces methods for solving transportation problem by Java programming language; We used flow chart, algorithms and consider the importance of defining a problem sufficiently and what assumptions we may consider during the solution. Solving transportation problem by computer involves series steps: defining the problem, analysis of the problem and formulationof a method to solve it, describing the solution in the form of an algorithm, drawing a flow chart of the algorithm, writing the computer program, compiling and running the program, testing the program and interpretation of results.

We design Object-Oriented Model as decision support tool to evaluate the solution for the five methods using Java language. After designing the five models (the five programs) we compare between each solution using Java programs and LP solution. Comparison between different solutions is done by choosing less value of the objective function so that the user will be able to make decision.

TRANSPORTATION MODEL

Transportation model is a special type of network problem for sending a commodity from source (e.g., factories) to destinations (e.g., warehouse).

Transportation model deals with the minimum-cost plan to transport a commodity from a number of sources (m) to number of destinations (n).

Let s_i is the number of supply units required at source i (i=1, 2, 3 …….. m), dj is the number of demand units required at destination (j=1, 2, 3…… n) and c_{ij} represent the unit transportation cost for transporting the units from sources i to destination j.

Using linear programming method to solve transportation problem, we determine the value of objective function which minimize the cost for transporting and also determine the number of units that can be transported from source i to destination j.

If x_{ij} is number of units sent from source i to destination j. the equivalent linear programming model will be as follows.

The objective function

$$\text{Minimize} \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$$

Subject to

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$$\sum_{j=1}^{n} x_{ij} = s_i \qquad \text{for } i=1,2,\ldots\ldots\ldots m$$

$$\sum_{i=1} x_{ij} = d_j \qquad \text{for } j=1,2,\ldots\ldots\ldots\ldots n.$$

And

$x_{ij} \geq 0$ for all i to j.

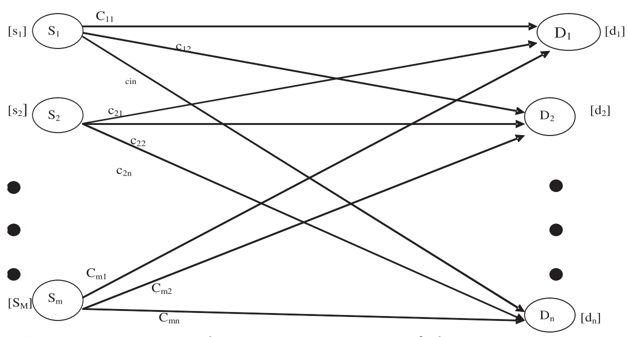

Figure 1. Network representation of the transportation problem

A transportation problem is said to be balanced if the total supply from all sources equals the total demand in all destinations

$$\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} dj.$$

otherwise it is called unbalanced.

METHODS FOR SOLVING TRANSPORTATION PROBLEM

There are five methods to determine the solution for balanced transportation problem:

1. Northwest Corner method
2. Minimum cost method
3. Row Minimum Method
4. Column Minimum Method.
5. Vogel's approximation method

The five methods differ in the "quality" of the starting basic solution they produce and better starting solution yields a smaller objective value.

We present the five methods and an illustrative example is solved by these five methods.

1. North West-Corner Method

The method starts at the northwest-corner cell (route) of the tableau (variable x_{11})

i) Allocate as much as possible to the selected cell and adjust the associated amounts of supply and demand by subtracting the allocated amount.

ii) Cross out the row or Column with zero supply or demand to indicate that no further assignments can be made in that row or column. If both a row and a column net to zero simultaneously, cross out one only and leave a zero supply (demand in the uncrossed-out row (column)).

iii) if exactly one row or column is left uncrossed out, stop; otherwise, move to the cell to the right if a column has just been crossed out or below if a row has been crossed out. Go to step (i).

2. Minimum – Cost Method

The minimum – cost method finds a better starting solution by concentrating on the cheapest routes. The method starts by assigning as much as possible to the cell with the smallest unit cost. Next, the satisfied row or column is crossed out and the amounts of supply and demand are adjusted accordingly. If both a row and a column are satisfied simultaneously, only one is crossed out, the same as in the northwest-corner method. Next look for the uncrossed-out cell with the smallest unit cost and repeat the process until exactly one row or column is left uncrossed out.

3) Row Minimum Method

Row minimum method starts with first row and chooses the lowest cost cell of first row so that either the capacity of the first supply is exhausted or the demand at jth distribution center is satisfied or both. Three cases arise:

i) If the capacity of the first supply is completely exhausted, cross off the first row and proceed to the second row.

ii) If the demand at jth distribution center is satisfied, cross off the jth column and reconsider the first row with the remaining capacity.

iii) If the capacities of the first supply as well as the demand at *j*th distribution center are completely satisfied, make a zero allocation in the second lowest cost cell of the first row; cross off the row as well as the *j*th column and move down to the second row.

Continue the process for the resulting reduced transportation table unit all the rim conditions (supply and demand condition) are satisfied.

4. Column Minimum Method

Column minimum method starts with first column and chooses the lowest cost cell of first column so that either the demand of the first distribution center is satisfied or the capacity of the *i*th supply is exhausted or both these cases arise:

i) if the demand of the first distribution center is satisfied, cross of the first column and move right to the second column.

ii) If the capacity of *i*th supply is satisfied, cross off *i*th row and reconsider the first column with the remaining demand.

iii) If the demands of the first distribution center as well as the capacity of the *i*th supply are completely satisfied, make a zero allocation in the second lowest cost cell of the first column. Cross of the column as well as the *i*th row and move right to the second column.

Continue the process for the resulting reduced transportation table until all the rim conditions are satisfied.

5. Vogel's Approximations Method (VAM)

Vogel's Approximation Method is an improved version of the minimum-cost method that generally produces better starting solutions.

i) For each row (column) determine a penalty measure by subtracting the smallest unit cost element in the row (column) from the next smallest unit cost element in the same row (column).

ii) Identify the row or column with the largest penalty. Break ties arbitrarily. Allocate as much as possible to the variable with the least unit cost in the selected row or column. Adjust the supply and demand and cross out the satisfied row or column. If a row and column are satisfied simultaneously, one of the two is crossed out, and the remaining row (column) is assigned zero supply (demand).

iii) a) If exactly one row or column with zero supply or demand remains uncrossed out, stop.

b) If one row (column) with positive supply (demand) remains uncrossed out, determine the basic variables in the row (column) by the least - cost method. Stop

c) If all the uncrossed out rows and columns have (remaining) zero supply and demand, determine the zero basic variables by the least-cost method. Stop.

d) Otherwise, go to step (i).

ILLUSTRATIVE EXAMPLE

Siva Ram Transportation Company ships truckloads of grain from three silos to four mills [2]. The supply (in truck loads) and the demand (also in truck loads) together with the unit transportation costs per truck load on the different routes are summarized in the transportation model in table. 1.

Table 1. Transportation Model of example

Depot / Unit	B1	B2	B3	B4	Supply
A1	2	3	5	1	8
A2	7	3	4	6	10
A3	4	1	7	2	20
Demand	6	8	9	15	38

The model seeks the minimum-cost shipping schedule between the silos and the mills. This is equivalent to determining the quantity x_{ij} shipped from silo i to mill j (i=1, 2, 3; j = 1, 2, 3, 4)

1. **Northwest-Corner method**

The application of the procedure to the model of the example results in the starting of basic solution given in table.2.

Table 2. The starting solution using Northwest – corner method

6 2	2 3	 5	 1	8 / 2 / 0
 7	6 3	4 4	 6	10 / 4 / 0
 4	 1	5 7	15 2	20 / 15 / 0
6 / 0	8 / 6 /0	9 / 5 / 0	15 /0	

The starting basic solution is given as

$X_{11}=6, X_{12}=2, X_{22}=6, X_{23}=4, X_{33}=5, X_{34}=15$

The objective function is

$Z= 6 \times 2 + 2 \times 3 + 6 \times 3 + 4 \times 4 + 5 \times 7 + 15 \times 2$

$= 12 + 6 + 18 + 16 + 35 + 30$

$= \$ 117$

2. Minimum Cost Method

The minimum –cost method is applied to the above example (Sivaram Transportation) in the following manner;

1. Cell (1,4) has the least unit cost in the tableau (=\$1). the most that can be shipped through (1,4) is X_{14}= min (15,8)=8 which happens to satisfy both row 1 cross out row 1 and adjust the supply in row 1 to 0.

2. Cell (3, 2) has the smallest uncrossed-out unit cost (=\$1). Assign X_{32}=8, cross out column 2 because it is satisfied and adjust the demand of row 3 to 20-8=12 truck loads.

3. continuing in the same manner.

Table 3. The Staring Solution using Minimum – Cost Method

 2	 3	 5	8 1	8/0
1 7	 3	9 4	 6	10/ 1/0
5 4	8 1	 7	7 2	20 /12/5/ 0
6 / 1 / 0	8 / 0	9 / 0	15 / 7/0	

The resulting starting solution is summarized in this table.3.

The starting basic solution is given as

X_{14}=8, X_{21}=1, X_{23}=9, X_{31}=5, X_{32}=8,X_{33}=7

The objection function is

Z = 8 x 1 + 1 x 7 + 9 x 4 + 5 x 4 + 8 x 1 + 7 x 2

= 8 + 7 + 36 + 20 + 8 + 14

= $ 93.

The quality of the least cost starting solution is better than that of the northwest- corner method because it yields a smaller value of Z ($ 93 versus $ 117).

3. Row minimum method

Row minimum method is applied to the example (Sivaram Transportation) as shown intable 4.

Table 4. The staring solution using row minimum method

2	3	5	8 1	8/0
7	8 3	2 4	6	10/2/0
6 4	1	7 7	7 2	20/13/7/0
6/0	8/0	9/7/0	15/7/0	

The starting basic solution is given as

X_{14} = 8, X_{22} = 8, X_{23} = 2, X_{31} =6, X_{33} =7, X_{34}=7

The objective function is

Z = 8 x 1 + 8 x 3 + 2 x 4 + 6 x 4 + 7 x 7 + 7 x 2

= 8 + 24 + 8 + 24 + 49 + 14

= $ 127

4. Column Minimum Method

Column Minimum method is applied to example (Sivaram Transportation) as shown in table 5

Table 5. The starting solution using column minimum method.

6 2	3	5	2 1	8/2/0
7	3	9 4	1 6	10/1/0
4	8 1	7	12 2	20/12/0
6 /0	8/0	9/0	15/13/ 1/0	

The Staring basic solution is given as

X_{11} = 6, X_{14} = 2, X_{23} = 4, X_{24} = 1, X_{32} = 8, X_{34} = 12,

The objective function is

Z = 6 x 2 + 2 x 1 + 9 x 4 + 1 x 6 + 8 x 1 + 12 x 2

= 12 + 2 + 3 6 + 6 + 8 + 24

= $ 88.

5. Vogel's Approximation Method (VAM)

VAM is applied to the example (Sivaram Transportation) in the following manner :-

Table 6. Step 1 to determine be starting solution using VAM

					Row penalty
2	3	5	1	8	2 – 1 = 1
7	3	4	6	10	4-3=1
4	1	7	2	20	2-1=1
6	8	9	15		

Column Penalty

4-2=2 3-1=2 5-4=1 2-1=1

Vogel's Approximation method

1. We compute that column 1 &2 have the largest penalty, column 1 (1,1) has the smallest unit cost 2. In the column the amount 6 is assigned to X_{11}. Column 1 is now satisfied and must be crossed out. Table 7 shows the next step.

Table 7. Step 1 to determine the starting solution using (VAM)

6 2	3	5	1	8
7	3	4	6	10
4	1	7	2	20
6	8	9	15	

2. Table 7 shows that row 1 has the highest penalty (=2). Hence, we assign the maximum amount possible to cell (1,4), which yields x_{14} = 2.

3. Continuing in the same manner, Column 4 will produce the highest penalty (=4) and we assign x_{34}=13, which crosses out column 4 and leaves 13 units in row 4. Only column 4 is left. Identity the maximum penalties. In this case it is at row three. Now allocate the maximum possible units to the minimum cost position. Here it is at (3,2) position and allocate maximum possible units i.e. 7 to this position. Now in order to complete sum

6 2	3	5	2 1	8
7	1 3	9 4	6	10
4	7 1	7	13 2	20
6	8	9	15	

(2,2) position will take 1 unit and (2,3) position will be allocated 9 units.

The starting basic solution is given as

$X_{11} = 6, X_{14} = 2, X_{22}=1, X_{23} = 9, X_{32} = 7, X_{34} = 13$

The objective function is

Z = 6 x 2 + 2 x 1 + 1 x 3 + 9 x 4 + 7 x 1 + 13 x 2

= 12 + 2 + 3 + 3 6 + 7 + 26

= $ 86 VAM produces a better starting solution.

COMPARISON BETWEEN THE FIVE METHODS

North-west corner method is used when the purpose of completing demand No. 1 and then the next and is used when the purpose is completing the warehouse No. 1 and then the next. Advantage of northwest corner method is quick solution because computations take short time; but it yields a bad solution because it is very far from optimal solution.

Vogel's approximation method and Minimum-cost method are used to obtain the less cost

Advantage of Vogel's approximation method and Minimum-cost method, which yield the best starting basic solution because it gives the initial solution that were very near to optimal solution; but the solution of Vogel's approximation method is slow because computations take long time. The cost of transportation with Vogel's approximation method and Minimum – cost method is less than north-west corner method.

Row – minimum method is used when the purpose of completing the warehouse No.1 and then the next. Row minimum cost is useful in small number of supply and when the cost of transportation on supply is small. Hence, the cost of transportation is less than North-west corner method.

Column minimum method is used when the purpose of completing the warehouse No.1 and then the next. Row minimum cost is useful in small number of supply and when the cost of transportation on supply is low.

The cost of transportation is less than North-west corner method.

OBJECT – ORIENTED PROGRAMMING

Object – Oriented Programming (OOP) is a method of implementation in which programs are organized as cooperative collections of objects and each object is an instance of some classes, Classes are related to one another *via* inheritance relationship.

In Object – Oriented programming, the data and functions are integrated. An object is like a box containing in data and its functions which can operate on the data.

Object-Oriented programming languages Provides great flexibility, clarity and reusability through inheritance, It leads to faster software development, increased quality, easier maintenance, and flexible modifiability.

Objects are the basic elements for executing object oriented programs while classes are the basic elements for defining object-oriented programs. If any of these elements is missing, it is not an object-oriented program. Object-oriented programming languages such as java are useful.

SOLVING TRANSPORTATION PROBLEM USING JAVA LANGUAGE

We need to describe the five methods (mentioned above) of transportation model in LP using the five algorithms and we draw a flow chart for each algorithm. After designing algorithms for the five methods we develop Java program for each one. We used Java language to facilitate getting the result and the complex problems which take long time using LP solution. After running these programs we compared between each solution using Java program and LP solution which show that they have the same result and also compared the difference between different solutions for choosing less value of the objective function. The main ideas for designing five Java programs are to save time, money and effort.

In the example Sivaram Transportation we use the five Java programs to minimize the cost of transportation and determine the number of units transported from source i to destination j.

The results are shown as follows.

The result of northwest-corner method program by Java language is the cost of transportation =$117

The number of units transported from source i to destination j.

We transport

Supply [0] to demand [0] = 6

Supply [0] to demand [1] = 2

Supply [1] to demand [1] = 6

Supply [1] to demand [2] = 4

Supply [2] to demand [2] = 5

Supply [2] to demand [3] = 15

Press any key to continue

The result of minimum –cost method program by Java language is the cost of transportation = $93

The number of units transported from source i to destination j

We transport

Supply [0] to demand [3] = 8

Supply [1] to demand [0] = 1

Supply [1] to demand [2] = 9

Supply [2] to demand [0] = 5

Supply [2] to demand [1] = 8

Supply [2] to demand [3] = 7

Press any key to continue

The result of row minimum method program by Java language is the cost of transportation =$127

The number of units transported from source i to destination j

We transport

Transport supply [0] to demand [3] =8

Transport supply [1] to demand [1] = 8

Transport supply [1] to demand [2] = 2

Transport supply [2] to demand [0] = 6

Transport supply [2] to demand [0] = 7

Transport supply [2] to demand [3] = 7

Press any key to continue

The result of column minimum method program by Java language is

The cost of transportation =$88

The number of units transported from source i to destination j

We transport

Supply [0] to demand [1] = 6

Supply [0] to demand [3] = 2

Supply [1] to demand [2 = 9

Supply [1] to demand [3] = 1

Supply [2] demand [1] = 8

Supply [2] demand [3] = 12

Press any key to continue

The result of vogel approximation method program by Java language is the cost of transportation = $86

The number of units transported from source i to destination j

We transport

Supply [0] to demand [0] = 6

Supply [0] to demand [3] = 2

Supply [1] to demand [1] = 1

Supply [1] to demand [2] = 9

Supply [2] to demand [1] = 7

Supply [2] to demand [3] = 13

Press any key to continue

Minimum-cost method, Vogel's approximation method and column minimum methods are having the less value from other methods. We choose less result in vogal approximation method.

We transport

Supply [0] to demand [0] = 6

Supply [0] to demand [3] = 2

Supply [1] to demand [1] = 1

Supply [1] to demand [2] = 9

Supply [2] to demand [1] = 7

Supply [2] to demand [3] = 13

The results of the five programs using Java language are equal to LP solution but the solution using Java language will be faster and easier than LP solution.

CONCLUSION

Running the five Java programs for solving transportation problem show that the results of the five Java programs is equal to the result of the LP solution. But the result the five program are different. The decision maker may choose the optimal result of the running of the five program (minimum) and determined the number of units transported from source i to destination j.

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