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Solving Transshipment Problems: A Comparative Study of Multiple Approaches

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Abstract: *Transportation problem could be extended to transshipment problem using the addition of additional transient node(s). This makes the transportation of goods easier between sources to destinations. We study the transshipment problem containing transient nodes between sources and destination nodes. We solve the problem using two existing methods: Vogel's Approximation Method (VAM) and using a mathematical model. The VAM method is used to find the solution by converting the transshipment problem to a transportation problem. The method is applied in two-steps. While converting the transshipment problem to a transportation problem, we consider some costs as zero or M depending on some goods transport criterion in the specific test example. The problem is then solved using the mathematical model of network flow. The optimal solution found this way is used to compare the solution found using VAM. The paper concludes that VAM, which is applied through multiple stage process is an efficient one on transshipment problem having transient nodes.*

Key Words: *Transportation problem, Transshipment problem, Vogel's Approximation Method (VAM), Network flow model.*

I. INTRODUCTION

The operations research models can deal with various day-to-day problems. It also contains the solution to various problems arising from logistics. Transportation models with suitable constraints fit best for such problems. A transportation model contains some sources and some destination points. These sources and destinations contain a definite number of goods. Goods are to be transferred from sources to destinations at minimum possible cost, given the cost of transportation per unit on each path of transportation.

Transshipment problem is an extension of above defined transportation problem[1]. It contains some additional nodes as transient node(s), which work as the mediator node(s) between sources and destinations. Sometimes, a subset of sources or destination node(s) may work as transient nodes[2].

There are many literatures, which describe transshipment problems. A paper describing the variants of transshipment problem is[3]. This paper discusses balanced and unbalanced transshipment problems and about the unbalanced capacitated transshipment problems. Some models describing the different types of transshipment problem are there in[1]. This paper discusses the general model along with some other models like impaired flow model, enhanced flow model, bi-criteria multi-stage transshipment model etc. The paper[2] gives an analysis of variants of transshipment models in terms of use of transshipment nodes. Also, it gives the solution of a transshipment model using a minimum spanning tree approach. Recently, a new method, called Assigned Mini-max Method (ASM method) has evolved for solving transportation problem[4]. A paper[5] solves the transshipment problem using this method. The same is solved by conversion of transshipment problem to a transportation problem. The paper[5] also gives a comparison of the solution obtained from the optimal solution. The ASM method is found effective on transshipment problem also. However, the problem under consideration here consists of transshipment nodes as a subset of sources and/or destinations. A paper applying ASM method on transportation problem and comparing it with the performance of North-West Corner Rule (NWCR) is given in[9]. Some more papers describing some variants of transshipment problem are[6,7]. These papers describe variants like dynamic transshipment, multilocation transshipments etc.

Applications of transshipment problem also have many literatures. The transshipment problem in supply chain management is discussed in[8]. The paper gives a review of the work done in this field. A rubber transshipment problem from Tripura to Bangladesh is discussed in[11]. The paper gives a Vogel's Approximation Method (VAM) approach to solve the problem under study. A modified Vogel's Approximation Method (VAM) for transportation problem is given in[10]. The same could be extended for the transshipment problem also.

In the present paper, we consider only a version of transshipment problem in which the transient nodes are distinct nodes. Also, the goods availability at sources and the demand at destinations are same.

II.METHODOLOGY

This VAM method can be used to solve transportation problems[12]. We solve a transshipment problem consisting of transient nodes using VAM. We convert the transshipment problem to a transportation problem, then VAM method is applied in two steps to solve it. The assumption when solving the network formed by sources to transient nodes is that the transient nodes have sufficient amount of space to accommodate the goods transported from the source nodes.

We solve the same problem using a network flow model. A network flow model is a mathematical model, which minimizes the total transshipment cost subject to the constraints arising from source, transient and demand nodes.

The network flow model for solving the transshipment problem can be given as follows[1]:

Minimize $z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$ (1)

Subject to $\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = a_i$ (constraints for the source node i)

$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = 0$ (constraints for transient node)

$\sum_{arcin} x_{ij} - \sum_{arcout} x_{ij} = b_j$ (constraints for the destination node j)

Here, c_{ij} is the unit cost of shipping from node i to node j. x_{ij} is amount shipped from node i to node j. a_i is the goods availability at source node i and b_j is the demand at destination node j.

III.PROBLEM UNDER CONSIDERATION

We consider a random problem consisting of 3 sources, 3 transient nodes and 2 destinations. Note that a transient node is one which gives a temporary stay of goods which are to be sent from sources to destinations.
The following matrices represent a random problem under the study.

From\To	A	B	C	X	Y	Supply
S_1	90	75	40	-----	-----	1100
S_2	65	110	35	-----	-----	600
S_3	45	95	75	-----	-----	1300
A	0	160	-----	210	175	
B	-----	0	135	240	150	
C	-----	-----	0	190	220	
Demand				1800	1200	

Table no 1: The transshipment problem under consideration

The above problem consists of three sources S_1, S_2 and S_3. The three transient nodes are A, B and C. The two destination nodes are X and Y. The transient nodes have communication among themselves. Here, we have allowed communication from A to B and from B to C only. The supply from sources and demand at destinations are given in the table. We assumed here that there are no space constraints at transient nodes and therefore, any number of units could be stored at a transient node. The network representation corresponding to this problem is given below in Figure 1.

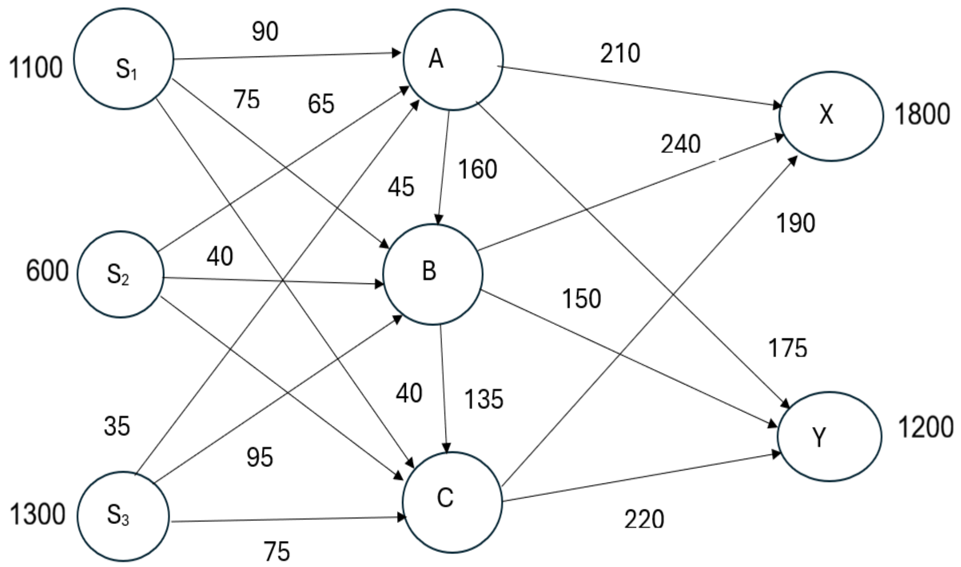

Figure 1: The network representation of the problem under study

IV.VAM METHOD FOR SOLUTION

We convert the problem to a transportation problem and apply the VAM method for solving the same. The same is suggested in[11]. For converting the problem to a transportation problem, the transshipment nodes were given the additional value, which is 3000 here. Also, the big M is used at some places to ensure that the transshipment of goods is not possible on that route. The steps of VAM method could be found in[12]. We apply the method in two steps and show directly the final solution found. A two-step VAM solves the sources-transient matrix in step 1, then it solves the transient-destination matrix as step 2, using the solution found from step 1. For the problem under consideration, when we go through step 1, we get the solution 1300 and 1700 units as the transferred goods at A and C respectively, which are further used as goods availability for step 2. The remaining costs are applied to balance the total supply and demand. The final solution is represented in table no 2.

From\To	A	B	C	X	Y	Supply
S_1	90	75	40 **1100**	M	M	1100
S_2	65	110	35 **600**	M	M	600
S_3	45 **1300**	95	75	M	M	1300
A	0 **1700**	160	M	210 **100**	175 **1200**	3000
B	M	0 **3000**	135	240	150	3000
C	M	M	0 **1300**	190 **1700**	220	3000
Demand	3000	3000	3000	1800	1200	12000

Table no 2: The solution to the problem using VAM method (applied in two steps)

The VAM method solution gives the cost as follows:

Total cost = 40×1100+35×600+45×1300+210×100+175×1200+190×1700 = 677500.

Boxes with zero costs are omitted. If we consider the unit cost in Rupees, the total cost is Rs. 677500 only.

V.NETWORK FLOW METHOD

The solution to a transshipment problem could be done using the network flow model. Here, we are considering S_1 as node 1, S_2 as node 2, S_3 as node 3. Similarly, the transient nodes A, B, C as 4, 5 and 6 respectively and the destination nodes X, Y as 7 and 8 respectively. Therefore, the network model of the problem under consideration could be expressed as follows

Minimize

$90x_{14}+75x_{15}+40x_{16}+65x_{24}+110x_{25}+35x_{26}+45x_{34}+95x_{35}+75x_{36}+160x_{45}+135x_{56}+210x_{47}+175x_{48}+240x_{57}+150x_{58}+190x_{67}+220x_{68}$

subject to

$x_{14}+x_{15}+x_{16}=1100$

$x_{24}+x_{25}+x_{26}=600$

$x_{34}+x_{35}+x_{36}=1300$

$x_{14}+x_{24}+x_{34}-x_{45}-x_{47}-x_{48}=0$

$x_{15}+x_{25}+x_{35}+x_{45}-x_{56}-x_{57}-x_{58}=0$

$x_{16}+x_{26}+x_{36}-x_{67}-x_{68}=0$

$x_{47}+x_{57}+x_{67}=1800$

$x_{48}+x_{58}+x_{68}=1200$

The solution of this LPP has been obtained from LINDO and given as follows

$x_{16} = 1100$, $x_{26} = 600$, $x_{34} = 1300$, $x_{47} = 100$, $x_{48} = 1200$, $x_{67} = 1700$, and the corresponding objective function is given by 677500. In terms of rupees, Its Rs. 677500.

VI.CONCLUSION

The present research gives an idea to formulate the transshipment model using a network flow model using an example. The same is used to obtain an optimal solution. Based on the results obtained from the two methods in the given example, it can be concluded that VAM, which is applied in two-steps provides an optimal or close to optimal result for transshipment problems involving three transshipment/transient nodes. The network flow method always guarantees an optimal solution. The same is also seen in this paper. The paper gives an idea to integrate the concept of transportation problem to transshipment problem. The same is solved using two methods and both produce the same optimal value for the problem under consideration.

VII.FUTURE SCOPE

The future scope includes the application of these ideas on a larger scale. The same could be applied in logistic problems. Along with that, the solution of transshipment problems using some similar algorithm could be done.

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