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OPERATION MANAGEMENT ON TRANSPORTATION AND DISTRIBUTION PROBLEM

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Abstract

Operational management on the transportation and distribution problem of automobile tyres was considered with selected destinations in the states of Sabah and Sarawak in East Malaysia. With Sibu in Sarawak as the origin, Kuching, Sarikei, Bintulu, Miri, Saratok and Kota Kinabalu were chosen as selected destinations. The objectives of this research were to minimize the total transportation cost, and to optimize the distribution of available resources. Data were obtained and formulated into Operational Research (OR) models using the simplex method of linear programming. Five transportation algorithms, viz. Vogel's Approximation Method, North-West Corner Method, Least Cost Method, Column-Minimum Method and Row-Minimum Method were utilised and iterated in order to get the initial basic feasible solution. Optimal solutions were obtained using Maple17. The transportation algorithms were compared for 2 types of automobile tyres, based on the least percentage difference and number of iterations. The Vogel's Approximation method (VAM) was found to be an effective method at 26 iterations for optimal distribution solution with percentage difference of 4.8873%, while the Column-Minimum method (CMM) at 26 iterations with percentage difference of 0.9541% performed better at minimal cost. The modelling procedures on the transportation and distribution problem would be useful in making better decisions for companies such as the automobile-tyre companies in making optimal distribution of their tyre commodities by various designated transporters, transporting from origin site to the different destinations at minimal transportation cost.

Keywords: Operational research (OR) models, transportation, minimal cost.

Introduction

Many companies in the world nowadays provide transactions globally instead of only locally. Transportation does not only involve the movement of people but also the transport of goods and products (Rodrigue *et al.*, 2013). The transaction will involve transportation of items or products from an origin to a destination. Hence, transportation problems play a very important role in transportation. Some of the companies transport their own products by

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themselves. However, some of the companies did not, but instead request transportation services in order to save costs. This is because transporting items will need transportation facilities like lorries, trucks, ships, airplanes or helicopters. Owning those transportation facilities will need a substantial amount of budget which includes fuels, tires, registration fees, depreciation, maintenance and repairs, and it will add costs for a company. Thus, there are many transportation companies already existed in the market. Each of them might have different ways, costs, and capacities to transport an item to different destinations. Companies are used to ship their items or products in bulk within a short term period. Hence, they are needed to decide and distribute these transportation jobs to transportation services companies so that items can reach the destinations on time. The focus of this study is to schedule shipments from sources to destinations so that the total shipping cost for the company is minimized. In addition, the available resources and alternative costs will be checked for optimality.

Past Research on Transportation Problem

Ajibade & Babarinde (2013) had presented on the use of transportation technique to determine the cost of transporting commodity. Their paper focused on an effective and appropriate method of calculating the lowest cost of transporting goods from several supply centers to several demand centers. The data on the supply center capacity per year and the unit cost of transporting newspaper from three sources to twelve destinations was analyzed in this research paper.

Loch *et al.* (2014) had presented the computational study of degeneracy in initial basic feasible solution for the transportation problem. The initial feasible solution obtained might not be basic and it needed to be completed with degenerated variables. In order to analyze the existence of degenerated variable, the selected least cost method used to study transportation problem of different sizes, costs ranges, supply ranges and demand ranges. Loch & Silva (2014) had alsopresented a computational study on the number of iterations to solve the transportation problem. It showed that least cost method and Vogel's approximation method were the most suitable methods to solve larger problems. Meanwhile, Kumaraguru *et al.* (2014) had presented the comparative study of various methods for solving transportation problem. In overall of their paper, zero suffix method could reach optimum in the numerical example. Nevertheless, user could not just admit to one particular method as the best optimum method because sometimes it did not perform when came to different transportation problem.A computer oriented method was presented by Afroz & Hassan (2015) for solving transportation problems. They found out that it would be hard and time consuming to compute manually using the simplex method if the number of variables were becoming large. Therefore, using a mathematical software could save a lot of time.

Methodology

Transportation and Distribution Problem

Transportation Problem is a subclass of Linear Programming which was presented by Rao & Mishra (2005). The main objective of this transportation and distribution problem is to determine the transportation schedule that minimize the total cost of transporting products from one origin to other different destinations by different transporters. Before solving, the transportation problem must be balanced, which means that the total demand is equal to total supply. If not, it is known as an unbalanced transportation problem (Taylor, 2013; Panneerselvam, 2006). In this case, a dummy column or dummy row must be introduced to balance the transportation problem.

In a transportation and distribution problem, there are m transporters and n destinations, where m transporters, $O_1, \dots, O_i$, that help the Tyre Company ship their products, and n destinations, $D_1, \dots, D_j$, to which the products must be transported, with m=1,2,…, *i* and n=1, 2, …, *j*. It is a minimization problem that considers the total cost of transportation from one origin to the different destinations by different transporters. The main aim for the transportation problem is to minimize the total transportation cost and meet the demand from destinations and supply from the transporters. Therefore, let c_{ij} stands for the cost of transporting the commodity to destination D_j by transporters O_i, and let x_{ij} be the quantity of the commodity to be shipped by transporters to destinations. The total cost function is assumed as linear, hence, the total cost of this transportation is given by $x_{ij}c_{ij}$, as shown in Table 1 below (Gupta & Hira, 2005).

Table 1. Basic Transportation & Distribution Tableau

Destinations / Transporters	D_1	D_2	D_j	D_n	Supply from Transporters
O_1	c_{11}	c_{12}	…	c_{1n}	a_1
	x_{11}	x_{12}		x_{1n}	
O_2	c_{21}	c_{22}	…	c_{2n}	a_2
	x_{21}	x_{22}		x_{2n}	
O_i	…	…	c_{ij}	…	a_i
			x_{ij}		
O_m	c_{m1}	c_{m2}	…	c_{mn}	a_n
	x_{m1}	x_{m2}		x_{mn}	
Demand from Destinations	b_1	b_2	b_j	b_m	$\sum a_i$
					$\sum b_j$

Mathematical Statement of Transportation and Distribution Problem

The objective function is given by: $\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}c_{ij}$ …………………………………… (1)

According to Gupta & Hira (2005), the assumptions for the transportation problem are: i) origin O_i has acquired an amount a_i of the commodity and ii) destination D_j must receive the amount b_j of the commodity. The demand constraint is given by:-

$$\sum_{j=1}^{n} x_{ij} \le a_{ij},\ i = 1,2,\dots,m \quad \text{(2)}$$

while, the supply constraint is given by:-

$$\sum_{i=1}^{m} x_{ij} \ge b_{ij},\ j = 1,2,\dots,n \quad \text{(3)}$$

The non-negativityconstraints are: $x_{ij} \ge 0,\quad for\, i = 1,\dots,m;\ j = 1,\dots,n.$ …………………… (4)

Degeneracy: Degeneracy will only occur when the number of filled cells is less than number of rows plus the number of columns minus one (m+n-1) (Rao & Mishra, 2005). Degeneracy may exist during the initial allocation when the first entry satisfies both row and column requirements and/or when the added and subtracted values are equal.

Transportation Algorithms

Below are the transportation algorithms that are used to find out the initial basic feasible solution and optimal solution in this study.

i) Vogel Approximation Method (VAM)

VAM is computed by using the concept of penalty cost. The detailed steps of performing VAM are shown below.

Step 1: Select the lowest costc_{ij} and the next lowest cost c_{ik} for each row. Then, compute the penalty cost by compute the difference between$c_{ik} - c_{ij}$. Then, display them alongside the transportation tableau. After that, continue to compute the differences for each column.

Step 2: Identify the largest penalty cost which is the largest difference among the row or column. If there is a tie, use any one of it randomly. Let the largest penalty cost be the i^{th} row and let c_{ij} be the smallest cost in the i^{th} row. Then, allocate $x_{ij} = \min(a_i,\ b_j)$ and either the i^{th} row or the j^{th} column will cross out or be deleted.

Step 3: Compute the new penalty cost for each row and column of the reduced matrix, and repeat the step 1 and 2 till all the demand and supply are satisfied.

ii) Least Cost Method (LCM)

Least cost method is a method that is concerned at the least cost of the whole transportation tableau. The order of the allocation is to start from the lowest cost to the last (Taha, 2007; Srinivasan, 2010).

Step 1: Choose the cell that has least cost cell, c_{ij} and then allocate maximum quantity to the cell by taking $x_{ij} = \min(a_i, b_j)$.

Step 2: If$x_{ij} = a_i$, i^{th} row must be deleted and go for reduced matrix. In contrast, if$x_{ij} = b_j$, then j^{th} column must be cross out and proceed with reduced matrix.

Step 3: Repeat steps I and 2 with reduced matrix until all the demand and supply are allocated.

iii) North-West Corner Method (NWCM)

Following steps are involved in this method:

Step 1: Allocate the first cell at the upper-left hand cell which is the rule for north-west corner. Assign the first cell, $x_{11} = min(a_1, b_1)$ (Taha, 2007; Panneerselvam, 2006).

Step 2: If $x_{11} = a_1$ which mean row 1 was satisfied, then row 1 can be deleted and replaced b_1 by $b_1 - a_1$. If $x_{11} = b_1$then it means column 1 satisfied, then column 1 can be cross out and changed $a_1$to $(a_1 - b_1)$.

Step 3: If$a_1 = b_1$, then $x_{11} = a_1 = b_1$and both row 1 and column 1 will be deleted altogether. This gives an indication that a degenerate initial basic feasible solution will be obtained which mean at least one of the basic variable is zero. Thus, less m+ n- 1 positive basic variable will be there in the basic feasible solution.

Step 4: Repeat steps 1 to 3 till all demand and supply are exhausted. This is possible if it is a balanced problem.

iv) Column Minimum Method (CMM)

Column minimum method is a method that deals with the column of the transportation problem (Rao & Mishra, 2005; Ali & Mustafa, 2013). It must be started from the lowest cost cell, c_{ij} of the first column and allocate $x_{i1} = min(a_i, b_1)$. Column minimum method did not have much step but it does have some cases arise. Three cases are discussed below.

Case 1: If the demand of the destination satisfied $x_{i1} = b_1$. Then the first column was cross out and change a_i to $(a_i - b_1)$.

Case 2: If the supply from the origin is exhausted $x_{i1} = a_i$, then the i^{th} row is deleted and the demand b_1 for the first column needed to be changed to $b_1 - a_i$.

Case 3: If both the demands from destinations and supplies from origins are completely satisfied which mean $x_{i1} = a_i = b_1$, then both i^{th} row and first column are deleted.

v) Row Minimum Method (RMM)

Row minimum method is a method that starts from the smallest cost cell, c_{ij} of the first row of the transportation problem (Rao & Mishra, 2005; Gupta & Hira, 2005). It allocates $x_{1j} = min(a_1, b_j)$. Row minimum method does not involve much step but it does have three cases. Those three cases are shown below.

Case 1: If the demand of the destination satisfied $x_{1j} = b_j$. Then the first column was cross out and change a_1 to $a_1 - b_j$.

Case 2: If the supply from the origin is exhausted $x_{1j} = a_1$, then the first row is deleted and the demand b_j for the j^{th} column needed to be changed to $b_j - a_1$.

Case 3: If both the demands from destinations and supplies from origins are completely satisfied which mean $x_{1j} = a_1 = b_j$, then both first row and j^{th} column are deleted.

In applying the MODI method, we begin with an initial solution obtained by using any transportation algorithm rules(Rao & Mishra, 2005; Liu &Trung, 2013).

vi) Modified Distribution Method (MODI)

The MODI method then requires seven steps:

Step 1: To compute the values for each row and column, set those occupied squares or so called basic variable as equations like $U_i + V_j = C_{ij}$. For example, if the basic variable at the intersection of row 1 and column 2 is occupied, then it was set as $U_1 + V_2 = C_{12}$.

Step 2: After all the occupied squares have been written as equations, set $U_1 = 0$.

Step 3: After U_1 was set as 0, then other U_i and V_j values can be solved.

Step 4: Compute the unoccupied squares or so called non-basic variables by using the formula improvement index $I_{ij} = U_i + V_j - C_{ij}$.

Step 5: Select the most positive values from I_{ij} and proceed to solve the problem using stepping stone method.

Step 6: A closed loop is drawn on the unoccupied selected cell. The positive and negative signs are assigned on the corner points of the closed loop for the unoccupied cell.

Step 7: The unit to be transported to the entering cell is the smallest value having a minus position on the closed loop. It has to be added to all cells located on the corner point of the closed loop which containing a positive sign and negative cells which was subtracted. Hence, an unoccupied cell will be occupied.

All the outputs of the above transportation algorithms were then compared for its efficiency by the percentage of difference, given as:-

Percentage of Difference = Initial Basic Feasible Solution (IBFS) - Optimal Solution (OS)

$$= \frac{IBFS - OS}{OS} x100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Results and Discussion

The collected data would include: a list of Transportation Companies (m=20), destinations (n=6), annual amount of demand from different destinations, capacity of supply from different transporters and transportation costs for different transporters. Firstly, some of the hot sale tyres were selected, namely, 295 X 80 R 22.5 and 1000 X 20 types. Both sizes of tyres were mostly used by trailers and lorries. Then, lists of transporters that have ever shipped Tyre Company's goods to different destinations were selected. Since the scope of study is within East Malaysia, therefore Sibu was selected as the origin and the other destinations were selected based on the states in Sabah and Sarawak. Therefore, Kuching, Sarikei, Bintulu, Miri, Saratok and Kota Kinabalu were selected as destinations. Besides, the prices for transporting an item to different destinations were needed. Different transporter had different ways or routes to ship the goods to the destinations. Therefore, the prices will be different for different transporters. The demand for the product is referring to the in-stock for the year of 2014. The supply is referring to the supply limit of the Transportation Companies because every transporter might have other products from other companies that were needed to be transported at the same time. Hence, the supply limit might not be the same as any other day. The supply will be set according to the number of trailers provided. Different company might provide different types of trailers, such as a 21-ton cargo and a 15-ton cargo. In addition, there was a capacity for the cargo to fit the product. For example, the 1000 X 20 tyre could only fit for 120 units for a 21-ton cargo and 70 units for a 15-ton cargo. Table 2 and Table 3 below showed the optimal solutions for the transportation and distribution of the two types of tyres 1000 X 20 and 295 X 80 R 22.5 respectively.

Table 2: Optimal Solution for Tyre 1000 X 20

Product type : Tyre 1000 X 20								
No	Transportation Companies	1	2	3	4	5	6	Supply
		SIB – KCH	SIB – BTU	SIB – MIRI	SIB – KK	SIB – SRK	SIB – SRTK	
1	Transporter 1	10	7.8	10.5	18	5	8	240
2	Transporter 2	11	9	11	19.5	5.5	8.8	240
3	Transporter 3	11	8	11	19	6	8	480
4	Transporter 4	12	9.5	12	25	5.5	9	480
5	Transporter 5	10.5	9.5	11	22	4	9.5	360
6	Transporter 6	9	8	9	22	5.8	8.5	120
7	Transporter 7	12	8.5	9.5	21	4.5	8.5	360
8	Transporter 8	9.5	8	10	20	6	8	70
9	Transporter 9	11	9	11.5	25	4.8	8.5	360
10	Transporter 10	9	7.8	8.8	20	5	7.5	70
11	Transporter 11	12	10	12	20.5	5	8	70
12	Transporter 12	13	10.5	12	23.5	4	9	120
13	Transporter 13	10.5	8.5	10.5	24	5.4	8	240
14	Transporter 14	9.5	7.8	10	22	4	8	240
15	Transporter 15	11.5	8	10.5	20	4.4	8.4	70
16	Transporter 16	8.5	7.8	8.5	21.5	5	8.5	70
17	Transporter 17	9.5	7.8	10	19	4	7.5	120
18	Transporter 18	12	10	11.5	21	5.5	9.5	120
19	Transporter 19	11.5	9.5	11.5	18.5	5	9.5	120
20	Transporter 20	11	9	11	22	4.5	9	70
	Demand	530	1630	490	660	330	290	4020

Table 3: Optimal solution for Tyre 295 X 80 R 22.5

Product type : Tyre 295 X 80 R 22.5								
No	Transportation Companies	1	2	3	4	5	6	Supply
		SIB – KCH	SIB – BTU	SIB – MIRI	SIB – KK	SIB – SRK	SIB – SRTK	
1	Transporter 1	11	10	11	23	6	9	900
2	Transporter 2	9	7.8	9	20	5	7.5	900
3	Transporter 3	13.5	9.5	12.5	21.5	7	9	1800
4	Transporter 4	12	10	12	22	6	9	1200
5	Transporter 5	10	8	10.5	25	6	9	1100
6	Transporter 6	12	8.8	12	22.5	5	8	400
7	Transporter 7	9.5	7.8	10.5	21.5	6.5	8	1000
8	Transporter 8	10	8	10	25	4.5	8.4	400
9	Transporter 9	13.2	9	12	19	4.5	9.2	1800
10	Transporter 10	10	8	10.5	19.5	6	8.8	300
11	Transporter 11	12	8	12.5	19	6.5	8	400
12	Transporter 12	11.2	7.8	11	26	4	7	900
13	Transporter 13	10	8.8	10	23	5	8	1000
14	Transporter 14	9.8	8	10	19.5	5.5	8	900
15	Transporter 15	11	9	11	21.5	7	9	300
16	Transporter 16	12.5	8.5	12	20	6	8.5	400
17	Transporter 17	11	9	10	22.5	6	9	300
18	Transporter 18	10	8	11	30	4	8.5	300
19	Transporter 19	10	7.8	10	20	4.5	7.5	700
20	Transporter 20	9.5	8	10	19	4.5	8	1000
	Demand	3110	5160	2130	4230	570	610	16,000

Since the transportation and distribution problems had variables which were too large, therefore Maple 17 was used to find the optimal solution. The MODI method was found to take a longer computational time than the other methods. Usingthe mathematical software Maple 17, the optimal solutionsobtained for minimal cost were RM39,879 for Tyre1000 X 20, and RM185,721 for Tyre 295 X 80 R 22.5 respectively. The transportation algorithms were then compared for its efficiency as shown in the following Table 4 and Table 5.

Table 4. Comparisons between the transportation algorithms for Tyre 1000 X 20

Product Tyre: Tyre 1000 x 20					
Methods	IBFS (RM)	Optimal solution (RM)	Difference	Percentage of Difference	Number of Iterations
Northwest- corner (NWCM)	44,448	39,879	4569	11.4572	26
Least cost (LCM)	43,983	39,879	4104	10.2911	26
Vogel approximation (VAM)	41,828	39,879	1949	4.8873	26
Row minimum (RMM)	42,889	39,879	3010	7.5478	26
Column minimum (CMM)	42,224	39,879	2345	5.8803	26

Table 5. Comparisons between the transportation algorithms for Tyre 295 X 80 R 22.5

Product Tyre: Tyre295 X 80 R 22.5					
Method	IBFS (RM)	Optimal solution (RM)	Difference	Percentage of Difference	Number of Iterations
Northwest- corner (NWCM)	208,895	185,721	23174	12.478	26
Least cost (LCM)	189,179	185,721	3458	1.8619	26
Vogel approximation (VAM)	192,761	185,721	7040	3.7906	26
Row minimum (RMM)	200,542	185,721	14821	7.9802	26
Column minimum (CMM)	187,493	185,721	1772	0.9541	26

From Table 4 and Table 5, different algorithms will give different costs on the initial basic feasible solutions. These algorithms werethen compared so as to find the best method in obtaining the optimal minimum cost. The criterion to select the best transportation algorithm is referred as to the percentage of difference. If the percentage of difference is low, it means that the initial solution is very near to the optimal solution. In the transportation and distribution problem for tyre 1000 X 20, Vogel's approximation method (VAM) is the most efficient method which gives the lowest percentage of difference (4.8873%). On the other hand, the column minimum method (CMM) is excellent in the transportation and distribution for tyre 295 X 80 R 22.5 giving a percentage difference of 0.9541% which is less than 1% from the optimal solution.

Conclusion

Transportation and distribution problem can be solved either by the simplex method and/or different transportation algorithms. However, in large transportation problem, thesimplex method might not be efficient because it might take a longer time to obtain the initial solution. Therefore, transportation algorithms will be much more efficient in solving a larger transportation and distribution problem. From this study, it is shown that the Vogel Approximation Method obtain an initial solution that is as near to the optimal solution in the transportation and distribution for tyre 1000 X 20. In the transportation and distribution for tyre 295 X 80 R 22.5, however, the column minimum method performs excellently. In conclusion, users should not fix to one particular method as the best optimum method since different sizes of the transportation and distribution problem will exhibit different characteristics and goals, and hence, demand different approaches in solving the problems. Kumaraguru *et al.* (2014) mentioned that users for the transportation algorithms cannot fix to one particular method as best optimum method. This is because the reliability condition for transportation problems might differ.This study thus has made use of mathematical techniques and some management knowledge to solve operation management problems, and thus optimize the time in decision making.

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