

Application of Transportation Methods in Optimizing Transportation Cost for Fleet Product Distribution

Radhiah¹, Siti Rusdiana¹, Marzuki², T. Murdani Saputra¹, Uly Handayani Mukhra¹

¹ Department of Mathematics, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia.

² Department of Statistics, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia.

Corresponding email: radhiah@usk.ac.id

ARTICLE INFO	ABSTRACT
Article History Received : 20-03-2023 Revised : 10-04-2023 Accepted : 13-04-2023 Keyword MODI; Transportation; VAM; Cost.	Motor vehicle distribution companies which are the source of this research data are located in Banda Aceh and Medan. The vehicles will then be sent to several areas, namely Lhokseumawe, Panton Labu, Meulaboh, Takengon, Subulussalam, Kuta Binjei, Kutacane, Aceh Singkil, Rimo and North Aceh. The problem in the process of sending vehicles is that if the inventory of vehicles in one of the warehouses is empty, then the supply of vehicles is obtained from warehouses that are still available in the warehouse regardless of distance. This paper describes the optimization of transportation costs for Fleet product distribution. Products are distributed from two sources to ten destinations. The cost of sending the vehicle incurred by the company is Rp 152,994,625. By using the Vogel's Approximation Method (VAM) and Modified Distribution Method (MODI), the total cost generated is Rp 142.728.100. Solving transportation problems with the transportation method can minimize and optimize the cost of sending a vehicle of Rp 10.266.525 or 6.71% and it can increase company profits.

DOI: ...

©2023 TJoMA. All rights reserved.

1. INTRODUCTION

Linear programming is a general model consisting of a linear objective function and a system of linear constraints that can be used in solving problems of optimally allocating limited resources. One of the linear programming problems is the transportation problem which is a special model of the linear programming problem (Abdel-Basset et al., 2019). The solution can be carried out using the transportation method for the problem of product distribution from a number of sources to a number of destinations, namely minimizing the cost of transporting the product. Because basically companies that make the transportation process a strategic tool will have an advantage in seizing competition among companies with similar products (Zhang et al., 2022).

Motor vehicle distribution companies which are the source of this research data are located in Banda Aceh and Medan. The vehicles will then be sent to several areas, namely Lhokseumawe, Panton Labu, Meulaboh, Takengon, Subulussalam, Kuta Binjei, Kutacane, Aceh Singkil, Rimo and North Aceh. The problem in the process of sending vehicles is that if the inventory of vehicles in one of the warehouses is empty, then the supply of vehicles is obtained from warehouses that are still available in the warehouse regardless of distance. The delivery process also does not use special transportation because the vehicles distributed are large vehicles. This causes the delivery process to take a long time and costs a lot in the distribution process.

Based on the description above, the problem raised in this paper is optimizing transportation costs for vehicle distribution using transportation methods, namely the Vogel's Approximation Method (VAM) and the Modified Distribution Method (MODI).

2. METHODS

2.1.Linear Programming

According to (Dimiyati & Dimiyati, 1994) a linear program is planning activities to obtain an optimum result, namely a result that achieves the best objective among all feasible alternatives. According to (Hiller & Lieberman, 2010) linear programming problems in general can be written in the following general form:

Objective function:

$$\text{Maximum/minimum } Z(x_1, x_2, \dots, x_n) = \sum_{j=1}^n c_j x_j$$

Constraint function:

$$\sum_{j=1}^n a_{ij} x_j (\leq, =, \geq) b_i, \quad i = 1, 2, \dots, m \quad \text{dan} \quad x_j \geq 0, \quad j = 1, 2, 3, \dots, n$$

2.2.Transportation Method

The general model of a classic transportation problem is based on the following assumptions (Nasendi & Anwar, 1985): 1) That a product to be transported is available in a fixed and known amount. 2) That the product will be sent through the existing transportation network using certain transportation methods from the procurement center to the demand center. 3) That the number of requests at the request center is known in a certain and fixed amount. 4) That the cost of transportation per unit of product transported is known, so that the objective of minimizing the total cost of transportation can be achieved.

Transportation method completion procedure (Mosca et al., 2019).

1. Compile the transportation matrix and initial table

Table 1. Initial table of transportation problems

Sumber	Tujuan				Persediaan
	D_1	D_2	D_3	D_4	
O_1	$\begin{matrix} c_{11} \\ x_{11} \end{matrix}$	$\begin{matrix} c_{12} \\ x_{12} \end{matrix}$	$\begin{matrix} c_{13} \\ x_{13} \end{matrix}$	$\begin{matrix} c_{14} \\ x_{14} \end{matrix}$	s_1
O_2	$\begin{matrix} c_{21} \\ x_{21} \end{matrix}$	$\begin{matrix} c_{22} \\ x_{22} \end{matrix}$	$\begin{matrix} c_{23} \\ x_{23} \end{matrix}$	$\begin{matrix} c_{24} \\ x_{24} \end{matrix}$	s_2
O_3	$\begin{matrix} c_{31} \\ x_{31} \end{matrix}$	$\begin{matrix} c_{32} \\ x_{32} \end{matrix}$	$\begin{matrix} c_{33} \\ x_{33} \end{matrix}$	$\begin{matrix} c_{34} \\ x_{34} \end{matrix}$	s_3
Permintaan	d_1	d_2	d_3	d_4	$\sum s_i = \sum d_j$

c_{ij} is the shipping cost per 1 unit of goods from i origin to destination j . x_{ij} is the number of items to be sent from i origin to destination j . $\sum s_i = \sum d_j$ is the total supply capacity equal to the total demand capacity (Taylor III, 2001).

2. Balanced transport method

The general model of balanced transportation is as follows (Baloch et al., 2022):

$$\text{Minimum } \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \quad (1)$$

Constraint Function:

$$\sum_{j=1}^n x_{ij} = s_i, \quad i = 1, 2, \dots, m; \quad \sum_{i=1}^m x_{ij} = d_j, \quad j = 1, 2, \dots, n; \quad \text{and } x_{ij} \geq 0, \quad s_i \geq 0, \quad d_j \geq 0$$

Additional requirements that the total supply capacity equals the total demand capacity, with the equation:

$$\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$$

3. Unbalanced transportation method

a) First condition (Zhan et al., 2021):

If the number of inventories is greater than the amount of demand or $\sum_{i=1}^m s_i > \sum_{j=1}^n d_j$, then the situation will be balanced by adding an additional goal (*dummy*) at its limits. This is because shipments to *dummy* destinations are not carried out, so the distribution cost per unit is zero. Then the limit function becomes:

$$\sum_{j=1}^n x_{ij} = s_i \quad i = 1, 2, \dots, m; \quad \sum_{i=1}^m x_{ij} = d_j \quad j = 1, 2, \dots, n, n+1; \quad x_{ij} \geq 0 \quad \text{for all } i \text{ and } j$$

where $j = n + 1$ goal. *Dummy* demand:

$$d_{n+1} = \sum_{i=1}^m s_i - \sum_{j=1}^n d_j \quad (2)$$

The formulation in equation (2) explains that the demand for additional destination areas is the result of a reduction from the source i ($1, 2, \dots, m$) with goal j ($1, 2, \dots, n$) where $c_{i,n+1} = 0$, for all $i = 1, 2, \dots, m$. In equation (1), the formulation of the problem states that all objective requests can be fulfilled (Rivindran, 1987).

b) Second condition (Ma et al., 2021):

If the amount of supply is less than the number of requests or $\sum_{i=1}^m s_i < \sum_{j=1}^n d_j$, it can be balanced by adding an additional (*dummy*) source to the constraint function:

$$\sum_{j=1}^n x_{ij} = s_i, \quad i = 1, 2, \dots, m, m+1; \quad \sum_{i=1}^m x_{ij} = d_j, \quad j = 1, 2, \dots, n; \quad x_{ij} \geq 0 \quad \text{for all } i \text{ and } j$$

where $i = m + 1$ goal. *Dummy* demand:

$$s_{m+1} = \sum_{j=1}^n d_j - \sum_{i=1}^m s_i \quad (3)$$

The formulation in equation (3) explains that the demand for additional destination areas is the result of reducing the destination j ($1, 2, \dots, n$) by region of origin i ($1, 2, \dots, m$) where $c_{m+1,j} = 0$, for all $j = 1, 2, \dots, n$. In equation (1), the formulation of the problem states that all objective requests can be fulfilled (Rivindran, 1987).

3. RESULT AND DISCUSSION

3.1. Transportation distribution process

The process of distribution of vehicle transportation can be seen in the following table.

Table 2. Vehicle distribution process data

Sumber (unit)	Tujuan (unit)										S
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	
o_1	43	2	53	6	4	3	2	1	6	4	124
o_2	34	2	51	12	10	15	6	13	18	4	171
D	77	4	104	18	14	18	8	14	24	8	

Information:

o_1 = Banda Aceh	d_3 = Meulaboh	d_7 = Kutacane
o_2 = Medan	d_4 = Takengon	d_9 = Rimo
d_1 = Lhokseumawe	d_5 = Subulussalam	d_{10} = Aceh Utara
d_2 = Pantan Labu	d_6 = Kuta Binjei	
S = Persediaan	D = Permintaan	

Meanwhile, transportation costs can be seen in Table 3 as follows:

Table 3. Total cost of distribution of vehicle transportation

Sumber	Tujuan	Kendaraan (unit)	Biaya Pengiriman Per unit (Rp)	Total Biaya (Rp)
Banda Aceh	Lhokseumawe	43	499.500	21.478.500
	Panton Labu	2	520.100	1.040.200
	Meulaboh	53	484.050	25.654.650
	Takengon	6	514.950	3.089.700
	Subulussalam	4	612.800	2.451.200
	Kuta Binjei	3	612.800	1.838.400
	Kutacane	2	597.350	1.194.700
	Aceh Singkil	1	633.400	633.400
	Rimo	6	628.250	3.769.500
	Aceh Utara	4	509.800	2.039.200
Medan	Lhokseumawe	34	525.250	17.858.500
	Panton Labu	2	499.500	999.000
	Meulaboh	51	648.850	33.091.350
	Takengon	12	561.300	6.735.600
	Subulussalam	10	473.750	4.737.500
	Kuta Binjei	15	404.225	6.063.375
	Kutacane	6	473.750	2.842.500
	Aceh Singkil	13	494.350	6.426.550
	Rimo	18	499.500	8.991.000
	Aceh Utara	4	514.950	2.059.800
Total				152.994.625

Based on Table 3, the amount of transportation costs for delivery of vehicles with regular delivery processes carried out by the company or without using any method is IDR 152,994,625.

3.2. Settlement of transportation methods

The steps in completion will be explained as follows:

1. Compile the transportation matrix and initial table

From Table 2 it can be seen that the amount of supply is greater than the number of requests. Then the transportation method is said to be unbalanced and satisfies first condition namely ($\sum_{i=1}^m s_i > \sum_{j=1}^n d_j$). Therefore, it is necessary to add an additional source (dummy), which is an addition to the destination or request column. So that the initial matrix and table of transportation methods can be seen in Table 4 as follows:

Table 4. Matrix and initial table of transportation methods

Sumber	Tujuan											S
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	
o_1	499,5	520,1	484,05	514,95	612,8	612,8	597,35	633,4	628,25	509,8	0	124
o_2	525,25	499,5	648,85	561,3	473,75	404,225	473,75	494,35	499,5	514,95	0	171
D	77	4	104	18	14	18	8	14	24	8	6	295

2. Allocation of transportation methods

The completion steps using the Vogel approximation method are as follows:

- Calculate the penalty for each row and column by determining the difference between the smallest cost and the second smallest cost of each row and column.
- Select the row or column with the highest penalty cost, then allocate to the cell with the smallest cost in the selected row and column.

This step continues to be repeated (iteration) until an even distribution process is obtained for each cell. The process of calculating the final results of the transportation matrix using the VAM method can be seen in Table 5 as follows:

Table 5. The final results of the transportation matrix using the VAM method

Sumber	Tujuan											S	PB
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}		
o_1	499,5	520,1	484,05	514,95	612,8	612,8	597,35	633,4	628,25	509,8	0	124	10,3
	2	-	104	18	-	-	-	-	-	-	-		
o_2	525,25	499,5	648,85	561,3	473,75	404,225	473,75	494,35	499,5	514,95	0	171	15,45
	75	4	-	-	14	18	8	14	24	8	6		
D	77	4	104	18	14	18	8	14	24	8	6	295	
PK	25,75	20,6	164,8	46,35	139,05	208,575	123,6	139,05	128,75	5,15	0		

After obtaining the final results of the transportation method using the VAM method, the total transportation costs for the distribution of vehicles using the VAM method can be seen in Table 6 below:

Table 6. Total transportation costs for vehicle distribution using the VAM method

No	Description (Source-Destination)	Source-Destination	Amount (Item x Cost)	Total cost (IDR)
1	$o_1 - d_1$	Banda Aceh – Lhokseumawe	2x499.500	999.000
2	$o_1 - d_3$	Banda Aceh – Meulaboh	104x484.050	50.341.200
3	$o_1 - d_4$	Banda Aceh – Takengon	18x514.950	9.269.100

4	$o_2 - d_1$	Medan – Lhokseumawe	75x525.250	39.393.750
5	$o_2 - d_2$	Medan - Pantan Labu	4x499.500	1.998.000
6	$o_2 - d_5$	Medan - Subulussalam	14x473.750	6.632.500
7	$o_2 - d_6$	Medan - Kuta Binjei	18x404.225	7.276.050
8	$o_2 - d_7$	Medan - Kutacane	8x473.750	3.790.000
9	$o_2 - d_8$	Medan - Aceh Singkil	14x494.350	6.920.900
10	$o_2 - d_9$	Medan - Rimo	24x499.500	11.988.000
11	$o_2 - d_{10}$	Medan - Aceh Utara	8x514.950	4.119.600
12	$o_2 - d_{11}$	Medan - <i>Dummy</i>	6x0	0
			Total	142.728.100

From the calculation results in Table 6, the total cost of transportation for sending Motors vehicles using the Vogel's Approximation Method-VAM is IDR 142,728,100. Then a search for the optimal solution is carried out using the Modified Distribution Method (MODI). The steps for the solution are as follows:

- a) Calculate row values and column values with formulas $U_i + V_j = C_{ij}$, where U_i is row value, V_j is the column value and C_{ij} is the shipping fee. This calculation is performed on the basis variables or filled cells. The final result of the row value calculation U_i and column values V_j can be seen in Table 7 as follows:

Table 7. Transport matrix using the MODI method (stage 1)

Sumber	Tujuan											s	U_i
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}		
o_1	499,5	520,1	484,05	514,95	612,8	612,8	597,35	633,4	628,25	509,8	0	124	0
	2	-	104	18	-	-	-	-	-	-	-		
o_2	525,25	499,5	648,85	561,3	473,75	404,225	473,75	494,35	499,5	514,95	0	171	25,75
	75	4	-	-	14	18	8	14	24	8	6		
D	77	4	104	18	14	18	8	14	24	8	6	295	
V_j	499,5	473,75	484,05	514,95	448	378,475	448	468,6	473,75	489,2	-25,75		

- b) Calculating the index to be increased (improvement index) with the formula $I_{ij} = C_{ij} - U_i - V_j$ where I_{ij} is the index to be increased (opportunity cost). This calculation is performed on non-basic variables or unfilled cells. Because all improvement indices are positive, the solution is said to be optimal, so the amount of transportation costs for shipping vehicles using the Modified Distribution Method (MODI) is the same as the costs for shipping transportation using the Vogel's Approximation Method-VAM, which is IDR 142,728. 100.

3. Difference in transportation distribution costs

The application of the VAM and MODI transportation methods can minimize transportation costs and decrease distribution costs by Rp. 10,266,525 or 6.71%. By using the transportation method, the results obtained are more optimal and can increase profits or profits for the company.

4. CONCLUSION

The conclusions obtained are the application of the Vogel's Approximation Method (VAM) as an initial settlement solution and the Modified Distribution Method (MODI) method as an optimization test, there is a decrease in distribution costs of IDR 10,266,525 or 6.71%. So that it can minimize and optimize transportation distribution costs and can increase company profits or income. The application of the transportation method to the company makes the shipping process optimal where the most shipments are from Banda Aceh to Meulaboh as many as 104 units, from Medan to Lhokseumawe as many as 75 units. Meanwhile, the least delivery of vehicles was from Banda Aceh to Lhokseumawe as many as 2 units, while from Medan to Pantan Labu as many as 4 units.

REFERENCES

- Abdel-Basset, M., Gunasekaran, M., Mohamed, M., & Smarandache, F. (2019). A novel method for solving the fully neutrosophic linear programming problems. *Neural computing and applications*, 31, 1595-1605.
- Dimiyati, T. T., & Dimiyati, A. (1994). *Operation Research: Model-model Pengambilan Keputusan*. Bandung: PT. Sinar Baru Algesindo.
- Baloch, N., Shaikh, A. A., Shaikh, W. A., & Qureshi, S. (2022). Balanced Transportation Problems with an Alternative Methodology for the Allocation Table Method. *STATISTICS, COMPUTING AND INTERDISCIPLINARY RESEARCH*, 4(1), 99-111.
- Hiller, S. F., & Lieberman, J. G. (2010). *Introduction to Operations Research, Ninth Edition*. America: McGraw-Hill.
- Ma, Z., Wei, X., Hong, X., Lin, H., Qiu, Y., & Gong, Y. (2021, May). Learning to count via unbalanced optimal transport. In *Proceedings of the AAAI Conference on Artificial Intelligence* (Vol. 35, No. 3, pp. 2319-2327).
- Mosca, A., Vidyarthi, N., & Satir, A. (2019). Integrated transportation–inventory models: A review. *Operations Research Perspectives*, 6, 100101.
- Nasendi, B. D., & Anwar, A. (1985). *Program linier dan Variasinya*. Jakarta: Gramedia.
- Rivindran, A. (1987). *Operation Research Principle and Practice*. India: John Wiley.
- Taylor III, B. W. (2001). *SAINS MANAJEMEN Pendekatan Matematika untuk Bisnis*. From *Introduction to Manajement Science*, by Chaerul D. Djakman and Vita Silvira. Jakarta: Salemba Empat.
- Zhan, F., Yu, Y., Cui, K., Zhang, G., Lu, S., Pan, J., ... & Miao, C. (2021). Unbalanced feature transport for exemplar-based image translation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 15028-15038).
- Zhang, Y., Kou, X., Song, Z., Fan, Y., Usman, M., & Jagota, V. (2022). Research on logistics management layout optimization and real-time application based on nonlinear programming. *Nonlinear Engineering*, 10(1), 526-534.