JISTech (Journal of Islamic Science and Technology)
JISTech, 9(1), 58-70, Januari – Juni 2024
ISSN: 2528-5718
http://jurnal.uinsu.ac.id/index.php/jistech

OPTIMIZING RICE TRANSPORTATION PROBLEMS USING TOTAL OPPORTUNITY COST MATRIX-MODIFIED EXTREMUM DIFFERENCE METHOD (TOCM-MEDM)

Nuriman Astuti Batubara[1], Ismail Husein[2]
[1,2] Islamic State of North Sumatera, Medan, Indonesia
Email : nuriman0703201030@uinsu.ac.id

Abstrak

Beras sebagai makanan pokok yang dikonsumsi hampir seluruh masyarakat Indonesia setiap harinya, diperlukan suplai beras yang memadai untuk memenuhi kebutuhan masyarakat. Perum Bulog sebagai perusahaan pemerintah yang bergerak di bidang distribusi pangan salah satunya beras berperan penting dalam pengelolaan stok pangan beras. Selama proses pendistribusian beras Perum Bulog Sub Divre Medan mengeluarkan biaya transportasi dengan jumlah yang tidak sedikit. Untuk memecahkan permasalahan tersebut, perusahaan perlu menggunakan metode yang tepat. Salah satu metode yang dapat digunakan untuk permasalahan distribusi adalah metode transportasi. Ada dua langkah untuk menyelesaikan permasalahan transportasi: solusi awal dan solusi optimal. Solusi awal menggunakan *Total Opportunity Cost Matrix-Modified Extremum Difference Method* (TOCM-MEDM) dan solusi optimal dengan metode MODI. Tujuan penelitian ini adalah untuk meminimalkan biaya transportasi pada Perum Bulog Sub Divre Medan. Hasil penelitian menunjukkan bahwa penggunaan TOCM-MEDM mengeluarkan biaya Rp. 151. 103.050 dan setelah uji optimalisasi dengan MODI berkurang menjadi Rp. 141.635.000 sehingga perusahaan dapat menghemat biaya transportasi hingga 9%, dari biaya awal Rp. 154.847.000 menjadi Rp. 141.635.000. Singkatnya, dengan menggunakan *Total Opportunity Cost Matrix-Modified Extremum Difference Method* (TOCM-MEDM), solusi pertama dan solusi optimal Metode MODI adalah metode yang tepat untuk meminimalkan biaya operasional distribusi beras di Perum Bulog Sub Divre Medan.

Kata Kunci*:* total opportunity cost matrix-modified extremum difference method (TOCM-MEDM); MODI; masalah transportasi, optimasi.

Abstract

Rice as a staple food consumed by almost all Indonesia people every day, an adequate supply of rice is needed to meet the needs of the community. Perum Bulog as a government company engaged in food distribution, one of which is rice, plays an important role in the management of rice food stocks. During the rice distribution process, Perum Bulog Sub Divre Medan incurred transportation costs with a large amount. To solve these problems, companies need to use the right methods. One of the methods that can be used for distribution problems is the transportation method. There are two steps to solving transportation problems: the initial solution and the optimal solution. The initial solution uses the Total Opportunity Cost Matrix-Modified Extremum Difference Method (TOCM-MEDM) and the optimal solution with the MODI method. The purpose of this study is to minimize transportation costs at Perum Bulog Sub Divre Medan. The results of the study show that the use of TOCM-MEDM costs Rp. 151. 103,050 and after the optimization test with MODI it was reduced to Rp. 141,635,000 so that the company could save transportation costs up to 9%, from the initial cost of Rp. 154,847,000 to Rp. 141,635,000. In short, by using the Total Opportunity Cost Matrix-Modified Extremum Difference Method (TOCM-MEDM), the first solution and optimal solution of the MODI Method is the right method to minimize the operational costs of rice distribution in Perum Bulog Sub Divre Medan.

Keywords: total opportunity cost matrix-modified extremum difference method (TOCM-MEDM); MODI; transportation problems, optimization.

Introduction

Linear programming (PL) is one of the methods in operations research to solve optimization problems (maximum or minimum) by using linear equations and inequalities to find optimal solutions by taking into account existing limitations (Lestiana, 2020). One type of linear program model, namely transportation problems, is used to solve distribution problems (allocation), business problems, and production planning (Girón G et al., 2021). The case of transportation arises when a person tries to determine how to send (distribute) one type of goods from various sources (*supply points*) to multiple destinations (*delivery points*) in a way that minimizes costs (Prayogi & Panjaitan, 2022). However, in general, the number of goods distributed from each point of supply is fixed or limited, but the quantity requested at each point of demand varies.

Perum Bulog Sub Divre Medan is a company that operates in the field of food distribution, one of which is rice. One part of the operation of Perum Bulog Sub Divre Medan is distributing rice to several cities/regencies in North Sumatra. In the process of distributing rice, the company incurs a lot of costs due to different distances and destinations. Related to the problem faced by Perum Bulog Sub Divre Medan is the amount of transportation costs that must be incurred every month. To solve these problems, careful distribution planning is needed. One method to optimize distribution costs is to use the transportation method (Kartika et al., 2019).

There are 2 stages to get the optimal solution to the transportation problem (Ratnasari et al., 2019), namely finding a feasible initial basic solution and finding an optimal solution based on the initial basic solution. The first stage is optimal local, as it can achieve optimal or near-optimal solutions. The second stage is global optimal, because it can achieve optimal solutions (Amaliah, 2020). In the first stage, the author uses the *Total Opportunity Cost Matrix – Modified Extremum Diffrence Method* (TOCM-MEDM) method. TOCM-MEDM was introduced by [7] as an approach to obtain the initial solution results from the modified results of TOCM. The process of TOCM-MEDM work begins by making a case on the transportation problem table and converting it into a TOCM matrix. It then determines the row and column values by taking the largest and smallest row values. From these results, proceed to determine the highest penalty cost by looking at the penalty cost from the result of the smallest and largest cost reduction in the row and column cells. Then calculate the minimum allocation for each row and column to balance *supply* and *demand* (Muhtarulloh et al., 2023). The second stage is to test the optimization of the initial solution obtained using *Modified Distribution* (MODI).

Therefore, this study uses *the Total Opportunity Cost Matrix - Modified Extremum Diffrence Method* (TOCM-MEDM) with *Modified Ditribution* (MODI) to optimize transportation problems in the distribution of Perum in Medan District to minimize rice transportation costs.

Research Methods

This research is a quantitative research. The data used in this study is data in January 2024 obtained from Perum Bulog Sub Divre Medan, namely rice inventory data for each warehouse, rice distribution data in each city/regency and data on the cost of remittance per kg of rice from each warehouse to the destination. The steps of data analysis in this study are to compile an initial table of the *Total Opportunity Cost Matrix-Modified Extremum Difference Method* (TOCM-MEDM) transportation, then the optimization test will be continued with *the Modified Distribution* (MODI) method.

2.1 Total Opportunity Cost Matrix-Modified Extremum Difference Method (TOCM-MEDM)

The *Total Opportunity Cost Matrix-Modified Extremum Difference Method* (TOCM-MEDM) method was proposed by (Hossain et al., 2020). This method is a modification of the TOCM method (Madamedon, 2023). TOCM-MEDM is a new method used to determine initial solutions to transportation problems without many iterations (Barata, 2020). The stages of determining the initial solution with TOCM-MEDM are as follows:

Step 1: Subtract the smallest cost from each cost along the line on the transportation table.
Step 2: Apply the same process (Step 1) to each column.
Step 3: Next convert it to a TOCM matrix where the value of each cell is the sum of the results from Stage 1 and Stage 2.

Step 4: Determine the penalty cost for each TOCM row and column by taking the difference between the highest and lowest costs in each row and column.
Step 5: Select the highest penalty cost on the row or column that appears. Then select the row/column that shows the lowest cost.
Step 6: Complete the allocation of the unit with the lowest transportation cost to the row or column with the highest penalty cost. If there is more than one unit with the lowest cost, allocate it to the section with the maximum allocation.
Step 7: Do the same (Stage 6) so that all requests can be fulfilled.
Step 8: Finally, calculate the total cost of transportation using the original transportation cost.

2.2 Modified Distribution (MODI)

The MODI method allocates products using a refined index based on the value of each row and column (Alfianti et al., 2021). Here are the steps of the MODI method:

1. Use TOCM-MEDM as the initial solution determination.
2. For each base cell (fill box), count $u_i + v_j = c_{ij}$. u_i shows a row to i v_j indicates a column to j and c_{ij} is the cost on the cell ij
3. Calculate K_{ij} i.e. all the value of the cost change for each non-basis variable using the formula $c_{ij} - u_i - v_j = K_{ij}$
4. Choose the non-base variable that has the K_{ij} largest negative value. It is then allocated according to the stepping stone path on the selected cell.
5. Repeat the step until K_{ij} there is no negative or zero value.

Results and Discussion

1. Data on Distribution of Perum Bulog Sub Divre Medan
   Data obtained from the Medan Sub-Division Bulog Perum used in this research are as follows:

Table 1. Data on Rice Inventory of Perum Bulog Sub Divre Medan

No	Warehouse	Inventory (Kg)
1	Paya Pasir	325,680
2	Pulo Brayan Darat I	825,720
3	Pulo Brayan Barat II	844,820
4	Mabar	815,700
5	Stabat Baru	349,870
AMOUNT		3,161,790

The rice supplies in the Perum Bulog Sub Divre Medan warehouse will then be distributed to 6 (six) regions as destinations, namely Medan City, Binjai City, Deli Serdang Regency, Tebing Tinggi City, Langkat Regency and Serdang Bedagai Regency. The demand for each region is sequentially 90,000 Kg, 62,000 Kg, 654,500 Kg, 53,500 Kg, 148,000 Kg and 42,000 Kg. Transportation costs incurred by Perum Bulog Sub Divre Medan to deliver rice to several districts and cities range from IDR 50 to IDR 250 for each delivery of 1 (one) kilogram. The details of the transportation costs that must be incurred by Perum Bulog Sub Divre Medan for rice delivery are shown in the following table:

Table 2. Data on rice transportation costs at the warehouse of Perum Bulog, Medan Subdivision

No	Warehouse	City/Regency	Transportation Costs (Rp/Kg)
1	Paya Pasir	Medan	175
		Binjai	125
		Deli Serdang	170
		Tebing Tinggi	100
		Langkat	110
		Serdang Bedagai	105
2	Pulo Brayan Barat I	Medan	145
		Binjai	85
		Deli Serdang	150
		Tebing Tinggi	140
		Langkat	190
		Serdang Bedagai	185
3	Pulo Brayan Barat II	Medan	147
		Binjai	87
		Deli Serdang	150
		Tebing Tinggi	143
		Langkat	190
		Serdang Bedagai	185
4	Mabar	Medan	115
		Binjai	100
		Deli Serdang	160
		Tebing Tinggi	142
		Langkat	190
		Serdang Bedagai	200
5	Stabat Baru	Medan	135
		Binjai	125
		Deli Serdang	165
		Tebing Tinggi	204
		Langkat	115
		Serdang Bedagai	190

Table 3. Transport Table for Perum Bulog Sub Divre Medan

Warehouse	Destination						*Supply*
	MDN	SON	DS	TT	LNG	SB	
PP	175	125	170 2,000	100 53,500	110	105 12,000	325,680
PBD I	145 2,000	85	150 62,000	140	190 6,000	185 4,000	825,720
PBD II	147 44,000	87	150 362,500	143 8,000	190 14,000	185 2,000	844,820
MB	155 44,000	100 28,000	160 323,000	142	190 18,000	200 24,000	815,700
ST	135	125 26,000	165 6,000	204	115 110,000	190	349,870
Demand	90,000	62,000	654,500	53,500	148,000	42,000	3,161,790 1,050,000

Table 4. Addition of Dummy to TOCM-MEDM

Warehouse	Destination							Supply
	MDN	BIN	DS	TT	LNG	SB	*Dummy*	
PP	175 x_{11}	125 x_{12}	170 x_{13}	100 x_{14}	110 x_{15}	105 x_{16}	0 x_{17}	325.680
PBD I	145 x_{21}	85 x_{22}	150 x_{23}	140 x_{24}	190 x_{25}	185 x_{26}	0 x_{27}	825.720
PBD II	147 x_{31}	87 x_{32}	150 x_{33}	143 x_{34}	190 x_{35}	185 x_{36}	0 x_{37}	844.820
MB	155 x_{41}	100 x_{42}	160 x_{43}	142 x_{44}	190 x_{45}	200 x_{46}	0 x_{47}	815.700
ST	135 x_{51}	125 x_{52}	165 x_{53}	204 x_{54}	115 x_{55}	190 x_{56}	0 x_{57}	349.870
Demand	90.000	62.000	654.500	53.500	148.000	42.000	2.111.790	3.161.790

Information:

PP : Paya Pasir PBD I : Pulau Brayan Darat I PBD II : Pulo Brayan Darat II
MB : Mabar ST : Stabat Baru

MDN : Medan BIN : Binjai DS : Deli Serdang
TT : Tebing Tinggi LNG : Langkat SB : Serdang Bedagai

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

Minimum Z= 170(2.000)+100(53.500)+105(12.000) + 145(2.000)+150(62.000)+190(6.000)+185(4.000) + 147(44.000)+ 150(262.500)+143(8.000)+190(14.000)+185(2.000) + 155(44.000)+100(28.000) + 143(8.000)+190(14.000)+ 185(2.000) + 155(44.000)+100(28.000) + 160(323.000)+190(18.000)+200(24.000)+125(26.000)+165(6.000)+ 115(110.000) = 154.847.000

2. Method Total Opportunity Cost Matrix -Modified Extremum Difference Method (TOCM-MEDM)

The transportation problem above is an unbalanced transportation problem with the number of supply constraints being greater than the number of demand constraints. The figure shows that the total inventory capacity data is 3,161,790 Kg while the demand capacity is 1,050,000 Kg. To balance the transportation problem above, a dummy column will be added with the required demand being 3,161,790 – 1,050,000 = 2,111,790 Kg and all transportation costs in the dummy column are zero [12].

Step 1. Subtract the smallest cost from each cost along the row in the transportation table. The smallest cost in each row PP, PBD I, PBD II, MB and ST has the same smallest cost, namely 0. Then all cells in the row will be reduced by 0 and the results will be placed on the top right of the cost of the cell in question according to the following figure:

Tabel 5. Subtraction Results from the Smallest Value of Each Row

Warehouse	Destination							Supply
	MDN	SON	DS	TT	LNG	SB	DUMMY	
PP	175175	125125	170 170	100 100	110 110	105 105	0 0	325,680
PBDI	145145	85 85	150 150	140 140	190 190	185185	0 0	825,720
PBDII	147147	87 87	150 150	143 143	190190	185 185	0 0	844,820
MB	155155	100100	160 160	142 142	190190	200 200	0 0	815,700
ST	135135	125125	165 165	204 204	115115	190 190	0 0	349,870
Demand	90,000	62,000	53,500	654,500	148,000	42,000	2,111,790	3,161,790

Step 2. Next, the same thing will be done for each column, subtracting the cost of each column from the smallest cost in each column, respectively, as follows: 135 85, 150, 100, 110 and 105, after that the subtraction results for each column will be written at the bottom right of the costs in the corresponding cells.

Tabel 6. Subtraction Results from the Smallest Value for Each Column

Warehouse	Destination						*Dummies*	*Supply*
	MDN	SON	DS	TT	LNG	SB		
PP	215	165	190	100	110	105	0	325,680
PBD I	155	85	150	180	270	265	0	825,720
PBD II	159	115	150	186	270	265	0	844,820
MB	175	165	170	184	270	295	0	815,700
ST	135	165	180	308	120	275	0	349,870
Demand	90,000	62,000	654,500	53,500	148,000	42,000	2,111,790	3,161,790

Step 3, Add up the row subtraction results and column subtraction results obtained in figure. 4, where the results will be written into the TOCM table.Using Eq [13]following:

$$TOCM_{ij} = \left(c_{ij} - c_{ik}\right) + \left(c_{ij} - c_{kj}\right) \quad (2)$$

$x_{11} = 175 + 40 = 215$ $x_{12} = 125 + 40 = 165$ $x_{13} = 170 + 20 = 190$ etc.
Can be seen in the following table:

Tabel 7. Total Opportunity Cost Matrix (TOCM)

Warehouse	Destination							Supply
	MDN	SON	DS	TT	LNG	SB	DUMMY	
PP	175 40	125 40	170 20	100 0	110 0	10 50	0 0	325,680
PBDI	145 10	85 0	150 0	140 40	190 80	185 80	0 0	825,720
PBDII	147 12	87 2	150 0	143 43	190 80	185 80	0 0	844,820
MB	155 20	100 15	160 10	142 42	190 80	200 95	0 0	815,700
ST	135 0	125 40	165 15	204 104	115 5	190 85	0 0	349,870
Demand	90,000	62,000	53,500	654,500	148,000	42,000	2,111,790	3,161,790

Step 4, Then determine the penalty cost for each TOCM row by subtracting the highest cell cost and the lowest cell cost from each row. Then do the same for each column. Where PB: Row Penalty and PK: Column Penalty.

Tabel 8. Row Pointer and Column Pointer Calculation

Warehouse	Destination							*Supply*	PB
	MDN	SON	DS	TT	LNG	SB	*Dummies*		
PP	215	165	190	100	110	105	0	325,680	215
PBD I	155	85	150	180	270	265	0	825,720	270
PBD II	159	89	150	186	270	265	0	844,820	270
MB	175	115	170	184	270	295	0	815,700	295
ST	135	165	180	308	120 148,000	275	0	349,870- 148,000 =201,870	308
Demand	90,000	62,000	654,500	53,500	148.00- 148,000 =0	42,000	2,111,790	3,161,790	
PK	80	80	40	208	160	190	0		

Step 5, Select the penalty fee in the row or column that appears. Then select the row/column that shows the lowest costs. If there are the same cost values, choose one of them. In the figure above, the highest penalty fee is 308. Next, we will look for the smallest transportation fee that corresponds to ignoring the dummy, which is 120 in the cell (Stabat Baru-Langkat). Allocate to cell min (349,870, 148,000) = 148,000. This shows that all demand in the city of Langkat has been met and the total remaining supply is 201,870. The results of this step can be seen in the following table:

Tabel 9. Highest Penalty Costs and First Allocation (ST, LNG)

Warehouse	Destination							*Supply*	PB
	MDN	SON	DS	TT	LNG	SB	*Dummies*		
PP	215	165	190	100	110	105	0	325,680	215
PBD I	155	85	150	180	270	265	0	825,720	270
PBD II	159	89	150	186	270	265	0	844,820	270
MB	175	115	170	184	270	295	0	815,700	295
ST	135	165	180	308	120	275	0	349,870	308
Demand	90,000	62,000	654,500	53,500	148.00	42,000	2,111,790	3,161,790	
PK	80	80	40	208	160	190	0		

Step 6, Complete the allocation of the unit with the lowest transportation cost to the ST lineand allocate as much as possible to that cell by adjusting supply and demand, namely cell C51(ST, MDN).

Tabel 10. Highest Penalty Fee and First Allocation (ST, MDN)

Warehouse	Destination							*Supply*	PB
	MDN	BIN	DS	TT	LNG	SB	*Dummies*		
PP	215	165	190	100 53,500	110 148,000	105 42,000	0 230,180	325,680	215
PBD I	155	85 62,000	150 654,500	180	270	265	0 109.220	825,720	270
PBD II	159	89	150	186	270	265	0 844,820	844,820	270
MB	175	115	170	184	270	295	0 815,700	815,700	295
ST	135 90,000	165	180	308	120	275	0 111,870	201,870-90,000 = 111,870	308
Demand	90,000 - 90,000 =0	62,000	654,500	53,500	0	42,000	2,111,790	3,161,790	
PK	80	80	40	208	160	190	0		

Do the same thing until all supplies on the ST line are 0.

Step 7, repeat step 6 in the same way until all requests from the destination are fulfilled. So that the following rice allocation results are obtained using TOCM-MEDM:

Tabel 11. Results of Rice Allocation Using the TOCM-MEDM Method

Warehouse	Destination							*Supply*	PB
	MDN	SON	DS	TT	LNG	SB	*Dummies*		
PP	215	165	190	100	110	105	0	325,680	215
PBD I	155	85	150	180	270	265	0	825,720	270
PBD II	159	89	150	186	270	265	0	844,820	270
MB	175	115	170	184	270	295	0	815,700	295
ST	135 90,000	165	180	308	120 148,000	275	0	201,870-90,000 = 111,870	308
Demand	90,000 - 90,000 =0	62,000	654,500	53,500	0	42,000	2,111,790	3,161,790	
PK	80	80	40	208	160	190	0		

Step 8, Once demand is met and supply has been exhausted, the total minimum cost for the rice transportation problem will be calculated using the Total Opportunity Cost Matrix - Modified Extremum Difference Method (TOCM-MEDM) as follows:

$$Z_{\min} = (325.680\times 0)+(604.630\times 150)+(53.500\times 140)+(42.000\times 185)+(125.590\times 0)+(844.820\times 0)+(815.700\times 0)+ (90.000\times 135)+(62.000\times 125)+(49.870\times 165)+(148.000\times 115)=151.103.050$$

This means that the total minimum transportation costs that must be incurred are IDR. 151,103,050.

3. Optimization Test with Modified Distribution Method (MODI)

By carefully examining and comparing several viable solutions, decision makers can identify the most cost-effective strategy for transportation needs [14]. Next, optimization testing will be carried out using the Modified Distribution (MODI) method. Following are the steps for working with the MODI method:

Iteration 1

Step 1: Determine the value u_i for each line and v_j for each column using the base cell relationship (i, j), using the formula $c_{ij} = u_i + v_j$, for all base variables and assumed values $u_1 = 0$. Filling in the first index value is done on the first row, namely Paya Pasir with Dummy, namely

$x_{17} : c_{17} = u_1 + v_7 \qquad 0 = 0 + v_7 \rightarrow v_7 = 0$

Filling in the Pulo Brayan Darat I index value into Dummy is obtained:

$x_{27} : c_{27} = u_2 + v_7 \qquad 0 = u_2 + 0 \rightarrow u_2 = 0$

Filling in the Pulo Brayan Darat I index value to Serdang Bedagai, we get:

$x_{26} : c_6 = u_2 + v_6 \quad 185 = 0 + v_6 \rightarrow v_6 = 185$ etc.

So all the values u And v obtained as presented in the following figure :

Tabel 12. Ui Value and Vj Value Results Using Base Cell Relationships

Warehouse	Destination							*Supply*	u_i
	MDN	BIN	DS	TT	LNG	SB	*Dummy*		
PP	175	125	17	100	110	105 42.000	0 283.680	325.680	$u_1 = 0$
PBD I	145	85	150 60.4.630	140 53.500	190	185	0 167.590	825.720	$u_2 = 0$
PBD II	147	87	150	143	190	185	0 844.820	844.820	$u_3 = 0$
MB	155	100	160	142	190	200	0 815.700	815.700	$u_4 = 0$
ST	135 90.000	125 62.000	165 49.870	204	115 148.000	190	0	349.870	$u_5 = 15$
Demand	90.000	62.000	654.500	53.500	148.000	42.000	2.111.790	3161790	
v_j	$v_1 =$ 120	$v_2 =$ 110	$v_3 =$ 150	$v_4 =$ 140	$v_5 = 100$	$v_6 = 185$	$v_7 = 0$		

Step 2: Next, Calculate the cost of changes K_{ij} for each non basis variable (Empty cell) use the formula

$$K_{ij} = c_{ij} - u_i - v_j \, . \qquad (3)$$

For example: Filling in the Paya Pasir index values for Medan, Binjai, Deli Serdang, Tebing Tinggi, Langkat and Serdang Bedagai respectively, you get:

$K_{11} = c_{11} - u_1 - v_1$ $K_{11} = 175 - 0 - 120 \rightarrow K_{11} = 55$ $K_{12} = c_{12} - u_1 - v_2$ $K_{12} = 125 - 0 - 110 \rightarrow K_{12} = 15$

$K_{13} = c_{13} - u_1 - v_3$ $K_{13} = 170 - 0 - 150 \rightarrow K_{13} = 20$ $K_{14} = c_{14} - u_1 - v_4$ $K_{14} = 100 - 0 - 140 \rightarrow K_{14} = -40$

$K_{15} = c_{15} - u_1 - v_5$ $K_{15} = 110 - 0 - 100 \rightarrow K_{15} = 10$ $K_{16} = c_{16} - u_1 - v_6$ $K_{16} = 105 - 0 - 185 \rightarrow K_{16} = -80$

Do the same to get the index value for each non-basic variable.

Step 3: In the calculation results above there are values K_{ij} negative, then the initial feasible solution is not optimal. Therefore it was chosen K_{ij} with value K_{ij} smallest negative as entering variable, namely K_{16} with a value of -80.

Step 4: Allocate a number of costs to entering variables K_{ij} which corresponds to the stepping stone process and repeats the first step

Pay attention to the negative cells that the loop passes through, namely K17 and K26, then allocate the least amount of rice, namely 42,000. Next, the number 42,000 will be operated based on the cell sign that the loop is passing through and the results can be seen in the following table:

Tabel 13. Rice Allocation Iteration 1

Warehouse	Destination							*Supply*	u_i
	MDN	BIN	DS	TT	LNG	SB	*Dummies*		
PP	175	125	17	100	110	(+) 105	(-) 0 325,680	325,680	u_1 = 0
PBD I	145	85	150 60.4.630	140 53,500	190	(-) 185 42,000	(+) 0 125,590	825,720	u_2 = 0
PBD II	147	87	150	143	190	185	0 844,820	844,820	u_3 = 0
MB	155	100	160	142	190	200	0 815,700	815,700	u_4 = 0
ST	135 90,000	125 62,000	165 49,870	204	115 148,000	190	0	349,870	u_5 = 15
Demand	90,000	62,000	654,500	53,500	148,000	42,000	2,111,790	3161790	
v_j	v_1 = 120	v_2 = 110	v_3 = 150	v_4 = 140	v_5 = 100	v_6 = 185	v_7 = 0		

Tabel 14. Results of Rice Allocation Iteration 1

Warehouse	Destination							*Supply*	u_i
	MDN	BIN	DS	TT	LNG	SB	*Dummy*		
PP	175	125	17	100	110	105 42.000	0 283.680	325.680	u_1 = 0
PBD I	145	85	150 60.4.630	140 53.500	190	185	0 167.590	825.720	u_2 = 0
PBD II	147	87	150	143	190	185	0 844.820	844.820	u_3 = 0
MB	155	100	160	142	190	200	0 815.700	815.700	u_4 = 0
ST	135 90.000	125 62.000	165 49.870	204	115 148.000	190	0	349.870	u_5 = 15
Demand	90.000	62.000	654.500	53.500	148.000	42.000	2.111.790	3161790	
v_j	v_1 = 120	v_2 = 110	v_3 = 150	v_4 = 140	v_5 = 100	v_6 = 185	v_7 = 0		

Because in the first iteration there are still negative values so that iteration 1 is not optimal. The next step is to recalculate the index values for the base cells and non-base cells for the second iteration to find out what the values are there are still negative values. If there are negative values, continue steps 3 and 4 until there are no negative values to get optimal results.

Tabel 15. Results of Rice Allocation Iteration 6

Warehouse	Destination							*Supply*	u_i
	MDN	BIN	DS	TT	LNG	SB	*Dummies*		
PP	175	125	170	100 53,500	110 148,000	105 42,000	0 283,680	325,680	$u_1 = 0$
PBD I	145	85 62,000	150 654,500	140	190	185	0 167,590	825,720	$u_2 = 0$
PBD II	147	87	150	143	190	185	0 844,820	844,820	$u_3 = 0$
MB	155	100	160	142	190	200	0 815,700	815,700	$u_4 = 0$
ST	135 90,000	125	165	204	115	190	0	349,870	$u_5 = 15$
Demand	90,000	62,000	654,500	53,500	148,000	42,000	2,111,790	3161790	
v_j	$v_1 = 120$	$v_2 = 110$	$v_3 = 150$	$v_4 = 140$	$v_5 = 100$	$v_6 = 185$	$v_7 = 0$		

After carrying out several iterations, the optimal solution value using the MODI method was obtained in the sixth iteration with the following results:

Based on the table above, it is obtained:

$K_{14} = 53.500$, $K_{15} = 148.000$, $K_{16} = 42.000$, $K_{22} = 62.000$, $K_{23} = 654.500$ And $K_{51} = 90.000$

so that the total transportation costs are obtained

$$Z_{\min} = (53.500\times 100) + (148.000\times 110) + (42.000\times 105) + (230.180\times 0) + (62.000\times 85) + (654.500\times 150) + (109.220\times 0) + (844.820\times 0) + (815.700\times 0) + (90.000\times 135) + (111.870\times 0) = 141.635.000$$

Conclusion

Based on the results of the research and discussion, it can be concluded that the steps in determining the optimal transportation cost solution are as follows: Collecting data on the transportation cost of rice distribution, making a transportation table based on the transportation cost data obtained, formulating the data from the transportation table into a mathematical model. Based on the results of the analysis, by applying the *Total Opportunity Cost Matrix -Modified Extremum Difference Method* (TOCM-MEDM) and *Modified Distribution* (MODI) transportation models to the rice distribution of Perum Bulog Sub Divre Medan, it is possible to quote the transportation cost from the total initial cost of the previous transportation of Rp. 154,847,000 after calculating using TOCM-MEDM, the initial result is obtained Rp. 151,103,050 then after the optimization test with the MODI method becomes IDR 141,635,000. there was a decrease in costs of Rp.13,212,000 so that Perum Bulog Sub Divre Medan would save costs up to 9%.

Refences

[1] H. T. Lestiana, "Pengantar Program Linier," p. 69, 2020.

[2] M. F. Girón G, J. R. López B, and K. J. Sornoza B, "Solución al problema del transporte de Aplicación práctica," *Ecuadorian Sci. J.*, vol. 5, no. 4, pp. 61–73, 2021, doi: 10.46480/esj.5.4.170.

[3] S. Y. Prayogi and M. I. Panjaitan, "Penerapan Metode Vogel's Approximation Method (VAM) Dalam Optimalisasi Biaya Transportasi Pengiriman Barang Berbasis Sistem Informasi (Studi Kasus: PT. Coca-Cola Amatil Indonesia (CCAI) Medan)," *J. Inf. Technol. Account.*, vol. 5, no. 1, pp. 69–75, 2022.

[4] R. Kartika, M. A. Basari, Y. Iskandar, and L. Adhitia, "Optimasi Distribusi Dengan Metode Transportasi," *Sustain. Compet. Advant.*, vol. 9, no. 1, pp. 189–206, 2019, [Online]. Available: http://jp.feb.unsoed.ac.id/index.php/sca-1/article/viewFile/1408/1437

[5] Y. Ratnasari, D. Yuniarti, and I. Purnamasari, "Optimasi Pendistribusian Barang Dengan Menggunakan Vogel's Approximation Method dan Stepping Stone Method (Studi Kasus : Pendistribusian Tabung Gas LPG 3 Kg Pada PT . Tri Pribumi Sejati)," *J. EKSPONENSIAL*, vol. 10, no. 2, pp. 165–174, 2019, [Online]. Available: http://jurnal.fmipa.unmul.ac.id/index.php/exponensial/article/view/575

[6] B. Amaliah, *Pengembangan Metode Initial Basic Feasible Solution Dengan Menggunakan Pendekatan Heuristik Untuk Mencapai Solusi Optimal Pada Transportation Problem*. 2020.

[7] M. M. Hossain, M. M. Ahmed, M. A. Islam, and S. I. Ukil, "An Effective Approach to Determine an Initial Basic Feasible Solution: A TOCM-MEDM Approach," *Open J. Optim.*, vol. 09, no. 02, pp. 27–37, 2020, doi: 10.4236/ojop.2020.92003.

[8] F. Muhtarulloh, S. N. Juliana, and E. R. Wulan, "Solusi Layak Awal Masalah Transportasi Menggunakan Total Opportunity Cost Matrix-Modified Extemum Difference Method," *J. Sains Mat. dan Stat.*, vol. 9, no. 1, p. 48, 2023, doi: 10.24014/jsms.v9i1.20506.

[9] S. Madamedon, "A Total Opportunity Cost Matrix Tiebreaker Vogel 's Approximation Method for Transportation Problems," no. December, 2023.

[10] O. A. Barata, *Metode Total Opportunity Cost Matrix – Modified Extremum Difference (TOCM-MEDM) Untuk Untuk Penentuan Solusi Awal Masalah Transportasi*, vol. 5, no. 1. 2020.

[11] W. Alfianti, R. Kurnia, R. Oktaviani, and M. Fauzi, "Penerapan Metode Modified Distribution (Modi) Untuk Optimalisasi Biaya Distribusi Produk Alat Kesehatan," *J. Lebesgue J. Ilm. Pendidik. Mat. Mat. dan Stat.*, vol. 2, no. 2, pp. 166–179, 2021, doi: 10.46306/lb.v2i2.66.

[12] I. A. Setiani, Helmi, and M. Pasaribu, "Menggunakan Metode Modifikasi Asm," vol. 12, no. 5, pp. 443–452, 2023.

[13] S. Basriati, E. Safitri, and L. Vionita, "Optimalisasi Biaya Pendistribusian Beras Menggunakan Metode TOCM-SUM Approach," *Semin. Nas. Teknol. Informasi, Komun. dan Ind. 12*, pp. 576–581, 2020, [Online]. Available: http://ejournal.uin-suska.ac.id/index.php/SNTIKI/article/view/11173

[14] M. Abid and M. Saqlain, "Decision-Making for the Bakery Product Transportation using Linear Programming," vol. 1, no. 1, pp. 1–12, 2023.

[15] N. Hafizah and I. Husein, "Determining the Shortest Route for LPG Gas Cylinder Distribution Using the Clarke and Wright Savings Algorithm," *ZERO J. Sains, Mat. dan Terap.*, vol. 7, no. 2, pp. 175–183, 2023, [Online]. Available: https://scholar.google.com/citations?view_op=view_citation&hl=en&user=Dbz-4UUAAAAJ&pagesize=100&citation_for_view=Dbz-4UUAAAAJ:7Hz3ACDFbsoC