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Optimization of Crystal Ice Transport Problems using *TOCM-MEDM* and *TOCM-SUM Approach*

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ABSTRACT

Every company often experiences problems that occur in the distribution process. Distribution is an important aspect to reduce costs so that the costs incurred are minimized. Companies need the right strategy in distributing allocation. CV. Kembar Cemerlang Abadi experienced problems in the distribution allocation that was large enough so that the company got a small profit. This research aims to obtain an optimal solution in distributing ice crystals on CV. Eternal Brilliant Twins. The methods used in this study are the TOCM-MEDM method and *the TOCM-SUM Approach* method with optimal testing of *the Stepping Stone* method. Based on this case, the initial base fissile solution in *TOCM-MEDM* is obtained and in the Rp 3.662.500*TOCM-SUM Approach* a cost of . Furthermore, after the optimization test was carried out on Rp 3.192.500*the TOCM-MEDM*, a cost minimization was obtained and Rp 3.192.500*the TOCM-SUM Approach* was obtained that the optimal solution was the same as the initial base fissile solution. Based on the results of this study, the solution of distribution problems using *the TOCM-SUM Approach* method is better than the *TOCM-MEDM method.*

Keywords: TOCM-MEDM *method*, *TOCM-SUM approach* method, *stepping stone method*, transportation model.

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1. Introduction

Distribution is one of the important aspects in a company that aims to minimize a cost. Companies need a problem-solving strategy so that transportation costs are kept to a minimum and there are no problems of large costs coming out (Maswarni Hermawan. H & Kartono, 2019). One of them is on the CV. Kembar Cemerlang Abadi Pekanbaru City as a company to be researched.

CV. Kembar Cemerlang Abadi Pekanbaru City is a company engaged in producing Crystal Ice in large quantities. The distribution of Crystal Ice in this company requires a fairly high cost, if there is an increase in distribution transportation costs, the profits obtained by small companies will be increased. To maximize those benefits, companies must minimize the cost of distributing transportation. In minimizing distribution costs, a solution method is needed to obtain an optimal solution to transportation problems.

The transportation model is a formulation of solving transportation problems from several sources to several destinations. Each source has a certain delivery capacity, while each destination has certain demand constraints (Syaifuddin. D.T, 2011). In solving transportation problems, there are many methods that can be used (Muhtarulloh. F dkk, 2023). The method used is T*CPO-MEDM* and *TOCM-SUM Approach* and optimization tests using the *Stepping Stone*.

According to research (Hossain. M.M dkk, 2020), this method is new enough to solve the initial solution to the transportation problem. Furthermore, research by (Muhtarulloh. F dkk, 2023) About the Method *TOCM-MEDM* which contains the solution of transportation problems with the data of. Application of the method approach 4 × 4 *TOCM-MEDM* In this study, an optimal initial viable solution was produced. Based on research (Batubara. N.A & Husein. I, 2024), use of the *TOCM-MEDM* in completing the initial solution as well as the method *MODI* as an optimal result. Research by (Permatasari. A.N, 2023), comparing TOCM-MEDM and LCMM that both can be used to determine the initial theoretical solution of transportation problems whether the case is balanced or the case is unbalanced. Research by (Basriati. S dkk, 2020), determine the optimal cost of distribution using the *TOCM-SUM* Approach method as an initial solution. Solving transportation costs in product delivery using the *TOCM-SUM Approach* with optimization test using the *Stepping Stone* It was found that the company saved costs by 21% contained in the (Melisa & Ahmad. D, 2021).

The purpose of this study is to compare *TOCM-MEDM* and *TOCM-SUM Approach* as initial fissile solutions in transportation problems. So that the total cost of transportation to meet needs and/or supply constraints can be minimized. In addition, to achieve optimal solution completion with the help of *Stepping Stone*. After that, it can be known that methods can provide more efficient solutions when compared to other heuristics in the literature.

2. Literature Review

2.1 Transport Model

A transport model is a specific formulation of the development of linear programming that must be carried out before obtaining an optimal solution to a transport problem. The goal of the transportation model is to optimize costs as little as possible for maximum profits. According to [10], a transportation model can be formed as follows:

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

With constraints:

$$\sum_{j=1}^{n} x_{ij} = s_i \,, i = 1,2, \dots, m \tag{2}$$

$$\sum_{i=1}^{m} x_{ij} = d_j \,, j = 1,2, \dots, n \tag{3}$$

where:

Z : Total transportation cost;

x_{ij} : The number of goods to be distributed from to;ij
c_{ij} : Allocation cost per unit from;ij
s_i : A large inventory of goods at the source;i
d_j : The large demand for goods at the destination.j

Based on inventory capacity *(Supply)* and demand capacity *(demand)*, the completion of the transportation model is divided into two models, namely the balanced transportation model and the unbalanced transportation model (Wulan. E.R &Bahaudin, 2017).

2.2 *Total Opportunity Cost Matrix* (TOCM)

Method *TOCM* is the initial base fissile solution by reducing the *ROCM* and *COCM* which will then be shaped into a table. This method is also used to determine the cost *maximum pointer cost* (cost penalty), allocating as many selected cells as possible, and adding up the total transportation costs [5]. To calculate *TOCM* can be formulated into the equation below (Basriati. S dkk, 2020):

$$\mathrm{TOCM}_{ij} = (c_{ij} - c_{ik}) + (c_{ij} - c_{kj}) \tag{4}$$

Information:

TOCM_{ij} : *Total Opportunity Cost Matrix* from source (to-) to destination (to-);ij

c_{ij} : Transportation costs from inventory (to-) to demand (to-);ij

c_{ik} : The smallest fare element on the th line;i

c_{kj} : The smallest cost element in column to-.j

2.3 *Total Opportunity Cost Matrix – Modified Extremum Difference Method* (TOCM-MEDM)

Method *TOCM-MEDM* is a method introduced by Hossain (2020) where this method is quite new by reducing rows and columns and the results are entered into the table *TOCM* to calculate transportation costs. This method is the result of the development of the *TOCM* in processing the initial base fissile solution. Multiple steps *TOCM-MEDM* as follows (Hossain. M.M dkk, 2020) (Muhtarulloh. F dkk, 2023):

1. Perform row and column reduction. Putting the result of the line reduction in the upper right corner of the cost can be written, namely . Applying the same process to each column and putting the result of the column reduction in the lower left corner of the cost can be written i.e. $c_{ij}{}^{c_{ij}-c_{ik}} c_{ij} - c_{kj} c_{ij}$.
2. Summing the *results of ROCM* and *COCM* into the form of a *TOCM table*.
3. Reduce the cost of the largest and smallest cells for each row and *column of the TOCM* in determining the cost penalty.
4. Choose the largest cost penalty that is contained in a row or column.
5. Distribute the penalty value to the cells that have the smallest unit transportation costs in the row or column where the largest penalty costs appear.
6. Determine the remaining allocation, adjust between supply needs and constraints in each row and column.
7. Calculate the total cost of transportation. The way to calculate it is by adding up the cost of goods and the appropriate allocation cost from the transportation table.

2.4 *Total Opportunity Cost Matrix-Sum Approach* (TOCM-SUM)

Method *TOCM-SUM Approach* is a method to check the initial base fissile solution by adding *ROCM* and *COCM* for each beginning of the matrix. The steps in calculating the method *TOCM-SUM Approach* as follows (Khan. A.R dkk, 2015):

1. Determine the smallest cost of each row and column.
2. Perform row and column reduction.
3. Forming a *TOCM* table is obtained using Equation (4).
4. Selects the largest cost penalty from each row and column. Next, the distribution indicator on each cell is calculated with the following formula:(i, j)

$$\Delta_{ij} = \mathrm{TOCM}_{ij} - u_i - v_j \tag{5}$$

Information:
u_i : The largest fare in the th line;i
v_j : The largest cost in the th column.j
5. Distribute as much as possible to the cells that have the most minimum value. After that, check (has been fulfilled or not). If there is still something that has not been met, the previous step is repeated.Δ_{ij}
6. If it has been met, the results of multiplying the allocation by the initial transportation cost are added so that the minimum cost is obtained.

2.5 Stepping Stone *Method*

Method *Stepping Stone* is a method of solving transportation problems for optimal solutions (Tabroni & Mamay. K, 2021). The allocation of this method is the northwest corner (upper left corner) of the problem table by adjusting the demand capacity. In this method, there are provisions that need to be considered to form a path, namely in each path there is only one empty cell with a path route in the same direction or counterclockwise. According to (Basriati. S dkk, 2021), some of the steps that exist in the *Stepping Stone* as follows:
1. Checking empty cells is done by jumping perpendicular or horizontal alternately, resting on the filled cells.
2. Perform cost calculations on empty cells.
3. If the results that have been calculated in Step 1 are all positive, then the transport table has been minimum and the most negative number is selected.
4. After selecting the cost calculation that yields the largest negative number, select the cell with the smallest allocation unit on the negative jump. Next, add the smallest allocation unit to the jump that has a negative value.
5. Repeat Step 2 to Step 4 until there is no negative value in the empty cell calculation.
6. Obtain optimal solutions to transportation problems.

3. Research Methods

This study uses quantitative data types. The stages in this study are as follows:
1. Data collection, this study uses data from a thesis conducted by (Siregar. S.R, 2024) about the distribution of crystal ice.
2. Create a transport table from the data that has been obtained.
3. Check the balance of the transport table to see if the data is balanced or unbalanced. If the data is unbalanced then it is necessary to add *a dummy*.
4. Develop a transportation model.
5. Solving transportation problems using *the TOCM-MEDM* method and *the TOCM-SUM Approach* method.
6. Conduct optimization tests using *the Stepping Stone* method.
7. Obtain the optimal solution from the cost of distribution.
8. Draw conclusions.

4. Results and Discussion

The data used is the distribution of ice crystals from a company. The company in question is CV. Eternal Brilliant Twins. The company distributes ice crystals to five regions, namely: Panam, Rumbai, Marpoyan, Sukajadi and Kulim with five types of vehicles as means of transportation for the sender including: Box A Cars , B Box *Cars, Box C Cars*, Box D Cars *and Box E Cars* . Eternal Brilliant Twins as seen in Table 1:s

Table 1. Transportation Model on CV. Eternal Brilliant Twins

Source \ Purpose	Panam	Tassel	Marpoyan	Sukajadi	Kulim	Supplies
Box A Car	300 x_{11}	750 x_{12}	650 x_{13}	450 x_{14}	1000 x_{15}	1200
Box B Car	550 x_{21}	800 x_{22}	700 x_{23}	500 x_{24}	1100 x_{25}	1200
Car *Box* C	450 x_{31}	650 x_{32}	600 x_{33}	500 x_{34}	1200 x_{35}	1000
D Box Car	500 x_{41}	800 x_{42}	750 x_{43}	600 x_{44}	900 x_{45}	800
Mobil *Box* E	650 x_{51}	900 x_{52}	650 x_{53}	700 x_{54}	1300 x_{55}	1000
Demand	900	1150	1200	1000	950	5200 \ 5200

Based on Table 1, the following transportation models can be made:

Minimum $Z = 300x_{11} + 750x_{12} + 650x_{13} + 450x_{14} + 1000x_{15} + 550x_{21} + 800x_{22} + 700x_{23} + 500x_{24} + 1100x_{25} + 450x_{31} + 650x_{32} + 600x_{33} + 500x_{34} + 1200x_{35} + 500x_{41} + 800x_{42} + 750x_{43} + 600x_{44} + 900x_{45} + 650x_{51} + 900x_{52} + 650x_{53} + 700x_{54} + 1300x_{55}$

with constraints,

Supplies:

$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} = 1200;$
$x_{21} + x_{22} + x_{23} + x_{24} + x_{25} = 1200;$
$x_{31} + x_{32} + x_{33} + x_{34} + x_{35} = 1000;$
$x_{41} + x_{42} + x_{43} + x_{44} + x_{45} = 800;$
$x_{51} + x_{52} + x_{53} + x_{54} + x_{55} = 1000.$

Demand:

$x_{11} + x_{21} + x_{31} + x_{41} + x_{51} = 900;$
$x_{12} + x_{22} + x_{32} + x_{42} + x_{52} = 1150;$
$x_{13} + x_{23} + x_{33} + x_{43} + x_{53} = 1200;$
$x_{14} + x_{24} + x_{34} + x_{44} + x_{54} = 1000;$
$x_{15} + x_{25} + x_{35} + x_{45} + x_{55} = 950.$

4.1 Completion of *the TOCM-MEDM Method*

The first step is to reduce rows and columns. The second step is to calculate *the TOCM results.* Then, create a *TOCM table.* The following are the results of the TOCM on the CV. The Eternal Brilliant Twins can be seen in Table 2:

Table 2. *TOCM* on CV. Eternal Brilliant Twins

Source \ Purpose	Panam	Tassel	Marpoyan	Sukajadi	Kulim	Supplies
Box A Car	0	550	400	150	800	1200
Box B Car	300	450	300	50	800	1200
Car *Box* C	150	200	150	100	1050	1000
D Box Car	200	450	400	250	400	800
Mobil *Box* E	350	500	50	300	1050	1000
Demand	900	1150	1200	1000	950	5200

Next, calculate the cost penalty and then choose the penalty that has the greatest value. After that, the first allocation is the allocation to the cell with the smallest cost on the row of . If demand and supply have not been met then the iteration continues. After several iterations, the initial solution was obtained as follows: $\mathbf{(5,3)50}$

Table 3. Initial Solution Method *TOCM-MEDM*

Source \ Purpose	Panam	Tassel	Marpoyan	Sukajadi	Kulim	Supplies
Box A Car	300	750 **250**	650	450	1000 **950**	1200
Box B Car	550 **900**	800 **100**	700	500 **200**	1100	1200
Car *Box* C	450	650	600 **200**	500 **800**	1200	1000
D Box Car	500	800 **800**	750	600	900	800
Mobil *Box* E	650	900	650 **1000**	700	1300	1000
Demand	900	1150	1200	1000	950	5200

Based on Table 3, the total transportation costs in the *TOCM-MEDM method* are obtained as follows:

$$\text{Minimum } Z_0 = (750 \times 250) + (1000 \times 950) + (550 \times 900) + (800 \times 100) + (500 \times 200) + (600 \times 200) + (500 \times 800) + (800 \times 800) + (650 \times 1000)$$

$$Z_0 = 3.622.500.$$

Next, the optimization test uses *Stepping Stone*. The first step is to create a table of initial transportation solutions. The second step is to create *a loop* on the empty cells. The third step is to calculate the loop repair index. After that, choose the largest negative value and allocate the smallest cost around the empty cell by following the formed loop. Based on Table 3, the selected indicator is with x_{11}*a loop* formed and a result of . The cell serves as $c_{11} - c_{12} + c_{22} - c_{21} - 200c_{12}$*a leaving variable*. Therefore, the first allocation is made on x_{11}. If the supply and demand on the transport table have not been fully met then the iteration continues.

Repeat the same steps as before until no indicator is found that contains a negative value. The optimal solution is only obtained after six iterations. Here are the optimal solutions to the *TOCM-MEDM method*:

Table 4. Optimal Solution Method *TOCM-MEDM*

Source \ Purpose	Panam	Tassel	Marpoyan	Sukajadi	Kulim	Supplies
Box A Car	300 **900**	750	650 **150**	450	1000 **150**	1200
Box B Car	550	800 **150**	700 **50**	500 **1000**	1100	1200
Car *Box* C	450	650 **1000**	600	500	1200	1000
D Box Car	500	800	750	600	900 **800**	800
Mobil *Box* E	650	900	650 **1000**	700	1300	1000
Demand	900	1150	1200	1000	950	5200

Based on Table 4, the total transportation costs of *the TOCM-MEDM method* are obtained as follows:

$$\text{Minimum } Z_6 = (300 \times 900) + (650 \times 150) + (1000 \times 150) + (800 \times 150) + (700 \times 50) + (500 \times 1000) + (650 \times 1000) + (900 \times 800) + (650 \times 1000)$$

$$Z_6 = 3.192.500.$$

Thus, the results of the completion of the *TOCM-MEDM* method in Table 5 are as follows:

Table 5. Method Completion Results *TOCM-MEDM*

Method	Initial Solutions	Optimal Solution
TOCM-MEDM	Rp 3.662.500	Rp 3.192.500

4.2 Completion of *the TOCM-SUM Approach Method*

The first step is to reduce rows and columns. The second step is to create the *TOCM table* as shown in Table 2. The third step is to determine the maximum cost penalty for each row and column. Next, take into account the distributor indicator on each cell according to the equation. The largest values on rows and columns to calculate the distributor indicators are as follows: $(\mathbf{i},\mathbf{j})(\mathbf{5})$

$\mathbf{u_1} = \mathbf{800}$; $\mathbf{v_1} = \mathbf{350}$;
$\mathbf{u_2} = \mathbf{800}$; $\mathbf{v_2} = \mathbf{550}$;
$\mathbf{u_3} = \mathbf{1050}$; $\mathbf{v_3} = \mathbf{400}$;
$\mathbf{u_4} = \mathbf{450}$; $\mathbf{v_4} = \mathbf{300}$;
$\mathbf{u_5} = \mathbf{1050}$; $\mathbf{v_5} = \mathbf{1050}$.

After that, the most negative value is selected. The most negative values are found on and . Therefore, it was chosen as the first iteration so that the following results were obtained: $\Delta_{ij}\Delta_{32}\Delta_{53}\Delta_{32} = \mathbf{min(1000, 1150) = 1000}$

Table 6. First iteration of the method *TOCM-SUM Approach*

Source \ Purpose	Panam	Tassel	Marpoyan	Sukajadi	Kulim	Supplies
Box A Car	300	750	650	450	1000	1200
Box B Car	550	800	700	500	1100	1200
Car *Box* C	450 –	650 **1000**	600 –	500 –	1200 –	1000
D Box Car	500	800	750	600	900	800
Mobil *Box* E	650	900	650	700	1300	1000
Demand	900	1150	1200	1000	950	5200

Based on Table 7, the cost of supply and demand has not been fully met. Next, calculate the value of the new distributor indicator of each cell. The calculation of the distributor's indicator value continues to be carried out until the cost of supply and demand is met on the transportation table. The initial solution of the (i, j) *TOCM-SUM Approach* method was obtained after eight iterations. The following is presented Table 8 as an initial solution of the *TOCM-SUM Approach method*:

Table 7. Initial Solution Method *TOCM-SUM Approach*

Source \ Purpose	Panam	Tassel	Marpoyan	Sukajadi	Kulim	Supplies
Box A Car	300 **900**	750	650 **150**	450	1000 **150**	1200
Box B Car	550	800 **150**	700 **50**	500 **1000**	1100	1200
Car *Box* C	450	650 **1000**	600	500	1200	1000
D Box Car	500	800	750	600	900 **800**	800
Mobil *Box* E	650	900	650 **1000**	700	1300	1000
Demand	900	1150	1200	1000	950	5200

Based on Table 7, the total transportation costs in the *TOCM-SUM Approach method* are obtained as follows:

$$\text{Minimum } Z_0 = (300 \times 900) + (750 \times 150) + (1000 \times 150) + (800 \times 150) + (700 \times 50) + (500 \times 1000) + (650 \times 1000) + (900 \times 800) + (650 \times 1000)$$

$$Z_0 = 3.192.500.$$

Next, the optimization test uses *Stepping Stone*. The method used is the same as that found in the *TOCM-MEDM method*. Based on Table 7, the improvement index did not find any indicators that contained negative values. Therefore, it can be said that Table 7 is the initial solution as well as the optimal solution for the *TOCM-SUM Approach method*. The following are the results of the completion of this method:

Table 8. Method Completion Results *TOCM-SUM Approach*

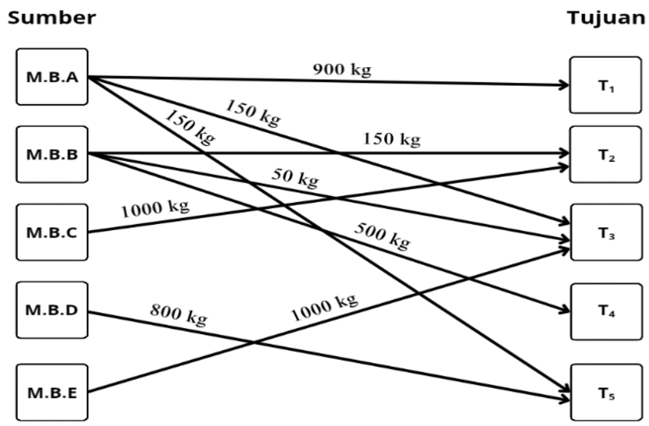
Method	Initial Solutions	Optimal Solution
TOCM-SUM Approach	Rp 3.192.500	Rp 3.192.500

The following are the findings from the initial base fissile solution and the optimal solution of *the TOCM-MEDM* method and *the TOCM-SUM Approach* method:

Table 9. Method Completion Results *TOCM-MEDM* and *TOCM-SUM Approach*

Method	Initial Solutions	Optimal Solution
TOCM-MEDM *Method*	Rp 3.662.500	Rp 3.192.500
TOCM-SUM Approach *Method*	Rp 3.192.500	Rp 3.192.500

Based on research, the TOCM-SUM Approach *method* is more efficient because it immediately provides optimal results without the need for further iteration. Thus, this approach is better applied in the case of crystal ice distribution on CV. Eternal Brilliant Twins. Furthermore, thedistribution route on CV. The Eternal Brilliant Twin can be illustrated into Figure 1 as follows:



Picture 1. Crystal Ice Distribution Route on CV. Eternal Brilliant Twins

Results of crystal ice distribution pathways on CV. Cemerlang Abadi Twins with delivery by different Box Cars. The results of the routes or routes for distributing crystal ice products obtained were that Box A Car distributed 900 kg of crystal ice to the Panam area with a delivery rate of IDR 300, 150 kg to the Marpoyan area with a delivery rate of IDR 650 and 150 kg to the Kulim area with a delivery rate of IDR 1000. Box B Car distributed 150 kg of crystal ice products to the Rumbai area with a delivery rate of IDR 800, 50 kg to the Marpoyan area. with a delivery rate of IDR 700 and the Sukajadi area with a delivery rate of IDR 500. Car Box C distributes 1000 kg of crystal ice to the Rumbai area with a delivery rate of IDR 650. Car Box D distributes 800 kg of crystal ice to the Kulim area with a delivery rate of IDR 900. Car Box E distributes 1000 kg of crystal ice to the Marpoyan area with a delivery rate of IDR 650.

5. Conclusion

Based on this case, the initial base fissile solution in the *TOCM-MEDM method* is obtained as . Meanwhile, the Rp 3.662.500 *TOCM-SUM Approach* method is obtained as . Furthermore, after conducting optimal testing on the Rp 3.192.500 *TOCM-MEDM* method, a minimum cost was obtained and in the Rp 3.192.500 *TOCM-SUM Approach method*, it was obtained that the result of the optimal solution was the same as the initial base fissile solution. The distribution on the *TOCM-SUM Approach* method proved to be superior in providing the optimal initial solution compared to the *TOCM-MEDM method* in this case. The application of this method helps companies in minimizing transportation costs and improving the efficiency of the distribution process.

6. CRediT Authorship Contribution Statement

Author contributions (CRediT): Restiti Noor Syarifah Kusumawati—; Data curation; Formal analysis; Investigation; Project administration; Validation; Visualization; Writing – original draft; Writing – review & editing. Elfira Safitri -Conceptualization; Resources; Software Supervision; Validation; Writing – review & editing. Sri Basriati -Formal analysis; Investigation; Resources; Software. Mohammad Soleh- Formal analysis; Investigation; writing – editing final.

7. Declaration of Competing Interest

The authors declare no known competing financial interests or personal relationships that could have influenced, or be perceived to influence, the work reported in this paper, and have nothing further to disclose.

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9. Data Availability

Data will be made available on request.

10. Ethical Approval

Ethical approval was not required for this study because it did not involve human participants or access to patient-identifying information; the authors neither used nor had access to any personal data.

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