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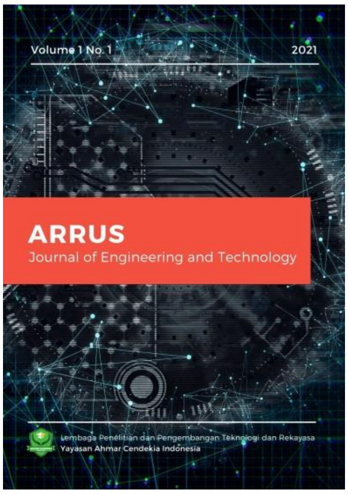

RESEARCH ARTICLE

Optimation of Transportation Cost Distribution in PT Saprotan Utama Nusantara Uses Transportation Models

Bekti Nugrahadi, Rifky Ian Sadewa, Yunita Primasanti, & Erna Indriastiningsih

Industrial Engineering Department, Faculty of Sains, Engineering & Health, Sahid University of Surakarta, Surakarta, Indonesia

*Corresponding author: Bekti Nugrahadi, Industrial Engineering Department, Faculty of Sains, Engineering & Health, Sahid University of Surakarta, Surakarta, Indonesia

E-mail: bekti.nugrahadi@usahidsolo.ac.id

Abstract: PT Saprotan Utama Nusantara is a company that operates in the field of agricultural products, one of which is herbicide fertilizer. The distribution costs for herbicide products incurred by the company in 2020 to 2023 have quite a large value, in 2020 amounting to Rp 148.523.000, in 2021 amounting to Rp 157.500.000, in 2022 amounting to Rp 145.800.000 and in 2023 amounting to Rp 147.900.000. These costs are not optimal and fluctuate so they have an impact on company profits. The aim of this research is to produce optimal distribution cost values using a transportation model. Then data processing was carried out using a transportation model with the North West Corner, Least Cost, Vogel Approximation, Stepping Stone and POM QM software methods. In the distribution of herbicide fertilizer from January to December 2023, data processing was carried out at PT Saprotan Utama Nusantara as a comparison between actual costs and optimal costs using a transportation model. The company's total costs during the year reached Rp 147.900.000, but after implementing the transportation model, the optimal costs were Rp 124.650.000. This shows a cost savings of Rp 23.250.000.

Keywords: Transportation Model, North West Corner, Least Cost, Vogel Approximation, Software POM-QM

1. Introduction

One of the activities aimed at facilitating the smooth and efficient delivery of goods from producers to consumers, ensuring their usefulness and necessity, is the goal of distribution. This is exemplified by companies engaged in distribution, which facilitate the flow of goods from production facilities to consumers (Rosmita et al., 2018).

Decision-making regarding route selection or cost optimization in distribution, as well as considerations of distance and travel time, are frequent challenges encountered in the distribution process. The costs incurred by companies in distributing goods from warehouses to consumers can be substantial, depending on the quantity of units shipped (Fatimah & Wibawanto, 2015). The developed optimization model effectively determines optimal transport support for projects, reducing costs and risks while maintaining control over transportation processes (Rusanova et al., 2021). Good transportation systems in logistics can improve logistical efficiency, reduce operating costs, and improve service quality (Sembiring et al., 2020).

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PT Saprotan Utama Nusantara is a distribution company of agricultural products, supplying single, compound, soluble, organic fertilizers, herbicides, and plant seeds. The company operates two warehouses in Semarang, serving as facilities to streamline product distribution. The destinations for PT Saprotan Utama Nusantara's shipments include Demak, Purwodadi, Klaten, Boyolali, Karanganyar, Sragen, and Surakarta.

In distributing its herbicide products to each destination area in 2020, PT Saprotan Utama Nusantara incurred costs amounting to Rp 148.523.000. In 2021, the company faced substantial expenses totaling Rp 157.500.000, followed by a decrease in 2022 to Rp 145.800.000. However, in 2023, the distribution costs rose again to Rp 147.900.000. The fluctuating nature of the expenditure from 2020 to 2023 indicates suboptimal cost management by the company, resulting in significant financial strain. Hence, it is imperative for the company to plan its distribution costs optimally to avoid reducing its profits. The transportation model can solve the problem of determining delivery of goods by minimizing total distribution costs (Hasanah et al., 2020). So this research aims to optimize distribution costs for herbicide products using transportation methods.

2. Research Materials and Methods

2.1 Description of Materials

In the data processing stage, the North West Corner, Least Cost, and Vogel Approximation methods will be employed. Subsequently, in the final stage, the Stepping Stone method will be utilized, with processing facilitated through POM-QM software.

Table 1. Demand Data and Distribution Costs

Source	Destination	Demand	Cost
Semarang	Demak	4500 kg	Rp 14.760.000
Gudang 1	Purwodadi	6500 kg	Rp 16.560.000
38.000 kg	Klaten	8500 kg	Rp 37.560.000
	Boyolali	8500 kg	Rp 32.160.000
Semarang	Karanganyar	6500 kg	Rp 12.360.000
Gudang 2	Sragen	5500 kg	Rp 10.560.000
23.500 kg	Surakarta	7500 kg	Rp 23.940.000
Total		47.500 kg	Rp 147.900.000

The first step in determining distribution costs is to gather relevant data related to the discussed issue. Data collected concerning the distribution costs of herbicides, demand quantities, and distribution costs of herbicides from January 2023 to December 2023 are presented in Table 1. The table indicates that the total distribution cost of herbicides amounts to Rp 147.900.000, with destinations including Demak, Purwodadi, Klaten, Boyolali, Karangnyar, Sragen, and Surakarta. The data on supply and demand quantities, as per Table 1, reveal that the supply from Semarang Gudang 1 totals 38.000 kg and Semarang Gudang 2 totals 23.500 kg, with demand quantities varying for each destination.

Table 2. Distribution Costs per Kilogram to Destinations

Distribution Cost / Kg		Destination
Semarang Warehouse 1	**Semarang Warehouse 2**	
Rp. 235	Rp. 185	Demak
Rp. 185	Rp. 235	Purwodadi
Rp. 335	Rp. 285	Klaten
Rp. 285	Rp. 335	Boyolali
Rp. 135	Rp. 135	Karanganyar
Rp. 185	Rp. 135	Sragen
Rp. 285	Rp. 235	Surakarta

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In Table 2, it can be observed that the shipment of herbicide fertilizer to each destination is calculated per kilogram. In this context, the researcher selects to evaluate the distribution costs at PT Saprotan Utama Nusantara with the objective of seeking the most efficient cost solution and minimizing the distribution costs of herbicide products issued by the company, aiming to optimize costs for January 2024.

2.2 North West Corner Method

The North West Corner method is an easy-to-use technique for finding an initial solution for arranging distribution costs. The Northwest Corner Transportation Method (NWC) effectively optimizes item shipping costs, aiding companies in determining shipping costs.(Pasaribu, 2019). The following steps explain how to use the North West Corner method.

Ke / Dari	T1	T2	T3	Supply
A1	X_{11} C_{11}	X_{12} C_{12}	X_{13} C_{13}	S1
A2	X_{21} C_{21}	X_{22} C_{22}	X_{23} C_{23}	S2
A3	X_{31} C_{31}	X_{32} C_{32}	X_{33} C_{33}	S3
Demand	D1	D2	D3	$\sum S_i$ $\sum D_j$

Figure 1. North West Corner Method

The following steps explain how to use the North West Corner method (Gultom et al., 2022)

a) Begin at the northwest corner of the table and allocate as much as possible to X_{11} without exceeding the supply or demand constraints. This means that X_{11} will be set to the minimum value between S_1 and D_1.
b) This will result in a decrease in the availability of source 1 and/or a reduction in the demand for destination 1. Consequently, no more goods can be allocated to the fulfilled row or column, leading to the removal of that row or column. The strategy involves allocating as many items as possible to the adjacent cells in the remaining available rows or columns. If both the row and the column are fully allocated, the next step is to move to the next cell diagonally.
c) Continue this process until all supply has been allocated and all demand has been completely full-filed.

2.3 Least Cost Method

The data processing stages using the Least Cost method aim to minimize distribution costs by systematically allocating to the cells with the smallest costs. This approach ensures that all demand is met and all capacity is utilized.

Establish a procedure by assigning high values to the variables with the smallest costs in the table. After adjusting the supply and demand, repeat the process by assigning high values to the variables with the next smallest unit costs. For instance, X_{12} and X_{31} have the smallest costs (C_{12}=C_{31}). Randomly select X_{12}. The supply and demand for X_{12} in column T_2 and row A_1 are met.

By filling column T_2, no supply remains in row A_1. Subsequently, the next smallest unit cost is X_{31}. Therefore, X_{31} can satisfy both row A_3 and column T_1. By filling row A_3, the demand in column T_1 becomes zero. The next smallest cost element is C_{23}. The supply and demand for X_{23} intersect at column T_3, leaving 10 units of supply in row A_2. Another element that hasn't been allocated yet is C_{11}.

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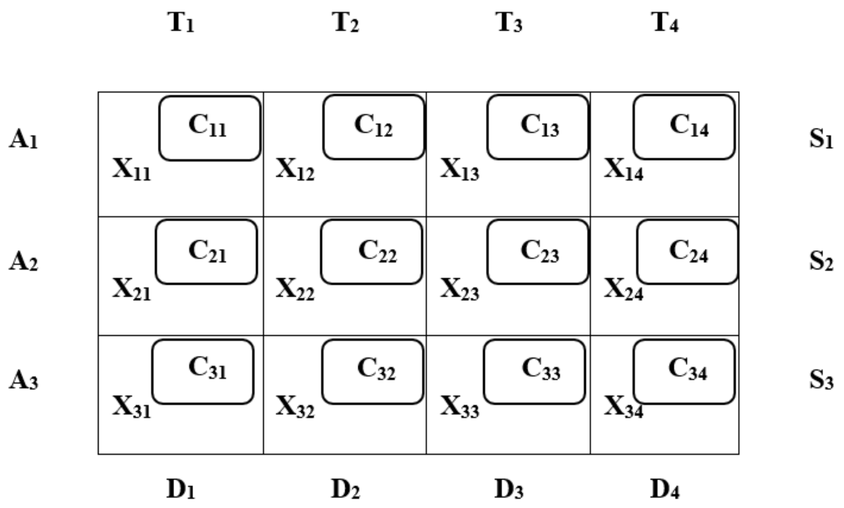

Figure 2. Least Cost Method

When there is no more supply in row A_{11} and no more demand in column T_1, the result is X_{11}. By eliminating column T_1, the remaining supply in row A_1 becomes zero. The remaining basic variables are X_{14} and X_{24}, in the given order.

The total cost associated with this solution is $((C_{11} \times X_{11}) + (C_{12} \times X_{12}) + (C_{14} \times X_{14}) + (C_{23} \times X_{23}) + (C_{24} \times X_{24}) + (C_{31} \times X_{31}))$, which is lower than the cost obtained using the North West Corner method (Gultom et al., 2022).

2.4 Vogel's Approximation Method

The Vogel's Approximation Method (VAM) provides a more detailed approach to determining distribution costs compared to the North West Corner or Least Cost methods. The least cost method can give rise to the possibility of deleting better cells because you have to leave a row or column according to the constraints, with the VAM method you can prevent this by choosing the price of the two smallest costs (Kurniawan, 2022). Using Vogel's Approximation Method to optimize product distribution can reduce transportation costs and improve customer satisfaction and reliability rating. The initial step in using VAM involves calculating the row and column penalties by finding the difference between the smallest and the second smallest costs in each row and column.

a) Calculate Penalties: Determine penalties by finding the difference between the lowest and the second-lowest costs in each row and column.
b) Identify Highest Penalty: Select the row or column with the highest penalty. In case of a tie, choose one randomly.
c) Allocate and Adjust: Allocate as much as possible to the cell with the lowest cost in the selected row or column, adjust the supply and demand, and eliminate the fulfilled row or column. If both a row and a column are fulfilled simultaneously, cross out one and assign zero to the remaining one.
d) Recalculate Penalties: Exclude rows and columns with zero supply or demand from the penalty calculations and repeat the process from step 2.

The process stops when only one row or column remains uncrossed. If the remaining uncrossed row or column has a positive supply or demand, use the least cost method to assign the basic variable. If all remaining rows and columns have zero supply and demand, assign a zero basic variable using the least cost method and then stop.

Initially, identify the penalty for each row and column. For row A_3, the largest penalty is found, and C_{13} is the lowest unit cost in that row. Therefore, X_{31} is assigned, satisfying both the demand in column T_1 and the supply in row A_3. With the supply in row A_3 fully met, the row is eliminated. Next, penalties are recalculated, excluding the crossed-out row. If penalties

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for column T_3 and row A_1 are considered, X_{23} is alocated, fulfilling column T_3 and adjusting row A_2. The Vogel's Approximation Method (VAM) results in allocations such as X_{22}, X_{12}, X_{14}, X_{34}. Even though VAM may present two identical penalties, careful selection ensures a good solution (Gultom et al., 2022).

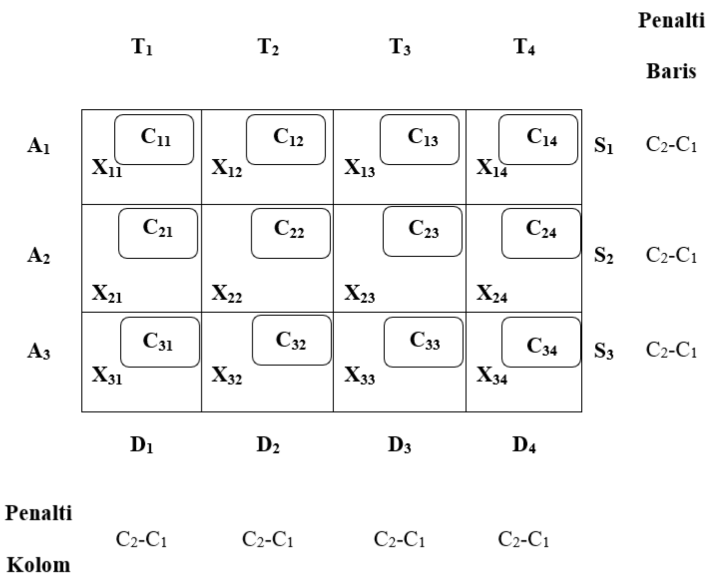

Figure 3. Vogel's Approximation Method

2.5 Stepping Stone Method

In the initial results, no optimality test is conducted, which means the results are not guaranteed to be optimal. During optimization, the results are allocated in the initial phase using an optimality indicator. In linear programming, the optimality condition O_{ij} is defined as Z_j-C_j. If $O_{ij} \leq 0$ in a non-basic cell, the solution is already optimal. If not, the basis needs to be adjusted until an optimal solution is obtained.

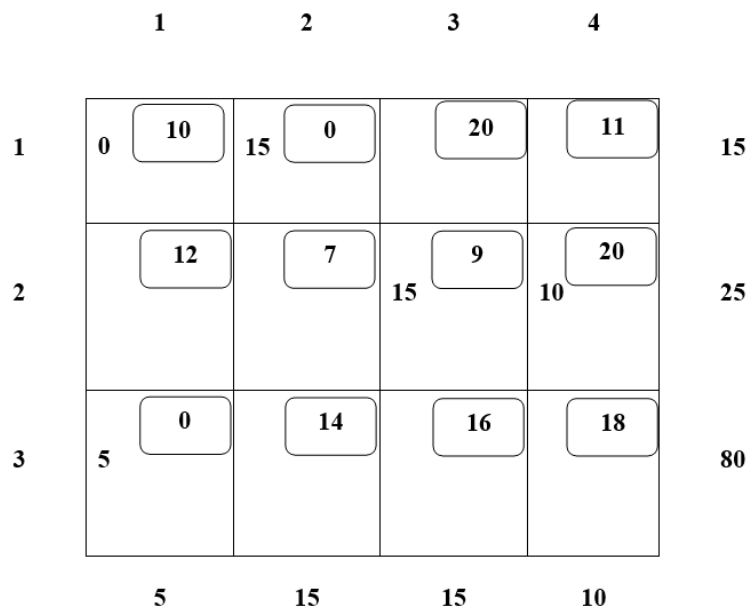

Figure 4. Stepping Stone Method

The steps for calculating O_{ij} are follows (Gultom et al., 2022):

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a) Calculate Opportunity Cost (Oij): For each non-basic cell, compute $O_{ij}= Z_j-C_j$, where Z_j is the total cost associated with the current solution and C_j is the cost in the non-basic cell.
b) Check Optimality: If $O_{ij} \leq 0$ for all non-basic cells, the solution is optimal.
c) Adjust the Basis: If any $O_{ij} \leq 0$, select the cell with the highest positive O_{ij} to enter the basis. Identify the cell to leave the basis using the minimum ratio rule.
d) Recompute the Solution: Perform the necessary row and column operations to update the solution and repeat the process until $O_{ij} \leq 0$ for all non-basic cells.

By iterating through these steps, the optimal solution can be found.

2.6 POM-QM Software

The application provides mathematical analysis of management science, operations, and quantitative methods. It includes calculation methods for decision analysis, goal programming, game theory, linear programming, and more. POM-QM offers mathematical analysis for operations management, quantitative methods, and management science. It features calculation methods for PERT/CPM, linear programming, decision analysis, transportation problems, statistical functions, game theory, goal programming, and others. The POM-QM for Windows application helps solve assignment method problems quickly and precisely, minimizing total cost or time required to carry out tasks (Aryata & Marendra, 2022).

In this study, the POM-QM software is used to automatically generate calculations and serve as a comparison for the results obtained manually through the North West Corner method, Least Cost method, and Vogel Approximation method.

3. Results and Discussion

In the data processing stage, the North West Corner method, Least Cost method, and Vogel Approximation method will be used. In the final stage, the Stepping Stone method will be applied, and processing will be conducted using POM-QM software to optimize costs for January 2024.

3.1 North West Corner Method

During the initial phase of implementing the North West Corner method, allocation is carried out in the top-left corner cell. Subsequently, allocation proceeds to the surrounding cells that are still available for filling. This process continues until all cells are fulfilled, as illustrated shown on Figure 5.

Tujuan / Sumber	Demak	Purwo-dadi	Klaten	Boyolali	Karang-anyar	Sragen	Sura-karta	Dummy	Supply
Semarang Gudang 1	235 4500	185 6500	335 8500	285 8500	135 6500	185 3500	285	0	38.000
Semarang Gudang 2	185	235	285	335	135	135 2000	235 7500	0 14.000	23.500
Demand	4500	6500	8500	8500	6500	5500	7500	14.000	61.500

Figure 5. North West Corner Result

In Figure 5 above, the last cell is filled with a dummy supply from Semarang Warehouse 2 with a supply amount of 14.000. When there is an imbalance between total supply and

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demand, a dummy is added to balance the model and eliminate any discrepancies. In Figure 5, the total supply is shown to be 61.500 kg, while the total demand is 47.500 kg.

The additional amount of 14,000 kg will not be directly assigned but will be allocated to the dummy cells. The shipping cost to these dummy segments is considered zero because these cells do not represent actual transported quantities; instead, they account for unmet demand. The values in the dummy cells do not affect the method for determining the optimal solution.

Table 3. North West Cost Calculation

No	Supply and Demand	Capacity	Cost /Kg	Total
1	Semarang Gudang 1 ke Demak	4500	235	Rp 1.057.500
2	Semarang Gudang 1 ke Purwodadi	6500	185	Rp 1.202.500
3	Semarang Gudang 1 ke Klaten	8500	335	Rp 2.847.500
4	Semarang Gudang 1 ke Boyolali	8500	285	Rp 2.422.500
5	Semarang Gudang 1 ke Karanganyar	6500	135	Rp 877.500
6	Semarang Gudang 1 ke Sragen	3500	185	Rp 647.500
7	Semarang Gudang 2 ke Sragen	2000	135	Rp 270.000
8	Semarang Gudang 1 ke Surakarta	7500	235	Rp 1.762.500
	Total			Rp 11.087.500

For this allocation, the total transportation cost using the North West Corner method is:

Z=(235x4500)+(185x6500)+(335x8500)+(285x8500)+(135x6500)+(185x3500)+

(135x2000)+(235x7500)+(0x14.000)=Rp 11.087.500

Rp 11.087.500 x 12 months = Rp 133.050.000

The result obtained from the utilization of the North West Corner method is Rp 11.087.500, representing the distribution cost of PT Saprotan Utama Nusantara in delivering herbicide products to destination cities per month. The total shipping cost for one year is recorded at Rp 133.050.000, indicating a decrease compared to the previous company expenditure of Rp 147.900.000. By employing the North West Corner method, the company successfully saves shipping costs amounting to Rp 14.850.000.

3.2 Least Cost Method

The data processing stage utilizing the Least Cost method aims to minimize distribution costs through systematic allocation of cells with the lowest costs. This ensures fulfillment of all demands while maximizing cell capacities.

Sumber \ Tujuan	Demak	Purwo-dadi	Klaten	Boyolali	Karang-anyar	Sragen	Sura-karta	Dummy	Supply
Semarang Gudang 1	235	185 6500	335 2500	285 8500	135 6500	185	285	0 14.000	38.000
Semarang Gudang 2	185 4500	235	285 6000	335	135	135 5500	235 7500	0	23.500
Demand	4500	6500	8500	8500	6500	5500	7500	14.000	61.500

Figure 6. Least Cost Result

The calculation steps employing the Least Cost method are illustrated in Figure 6 above, it is demonstrated that the final cell is filled from the Semarang Warehouse 2 source with a supply quantity of 14.000, without any remaining supply or demand quantities.

Table 4. Least Cost Calculation

No	Supply and Demand	Capacity	Cost /Kg	Total
1	Semarang Gudang 1 ke Purwodadi	6500	185	Rp 1.202.500
2	Semarang Gudang 1 ke Klaten	2500	335	Rp 837.500
3	Semarang Gudang 1 ke Boyolali	8500	285	Rp 2.422.500
4	Semarang Gudang 1 ke Karanganyar	6500	135	Rp 877.500
5	Semarang Gudang 2 ke Demak	4500	185	Rp 842.500
6	Semarang Gudang 2 ke Klaten	6000	285	Rp 1.710.000
7	Semarang Gudang 2 ke Sragen	5500	135	Rp 742.500
8	Semarang Gudang 2 ke Surakarta	7500	235	Rp 1.762.500
	Total			Rp 10.387.500

For this allocation, the total transportation cost using the Least Cost method is:

Z=(185x6500)+(335x2500)+(285x8500)+(135x6500)+(185x4500)+(285x6000)

+(135x5500)+(235x7500)+(0x14.000)=Rp 10.387.500

The result obtained from the application of the Least Cost method is Rp 10.387.500, representing the distribution cost of PT Saprotan Utama Nusantara in delivering herbicide products to destination cities per month. With a total shipping cost for one year amounting to Rp 124.650.000, which is lower compared to the costs processed using the North West Corner method and lower than the company's expenditure of Rp 147.900.000.

Hence, the difference between the values obtained using the Least Cost method and the North West Corner method is Rp 8.500.000, with a difference from the company's expenditure of Rp 23.250.000. Therefore, the Least Cost method is more optimal for data processing compared to the North West Corner method.

3.3 Vogel's Approximation Method

The Vogel method provides a more detailed procedure for determining distribution cost outcomes compared to the North West Corner or Least Cost methods. The following is the calculation using the Vogel Approximation method illustrated in Figure 7.

Tujuan / Sumber	Demak	Purwo-dadi	Klaten	Boyolali	Karang-anyar	Sragen	Sura-karta	Dummy	Supply	Penalty I	Penalty II	Penalty II
Semarang Gudang 1	235 / 2500	185 / 6500	335	285 / 8500	135 / 6500	185	285	0 / 14.000	38.000	50	0	0
Semarang Gudang 2	185 / 2000	235	285 / 8500	335	135	135 / 5500	235 / 7500	0	23.500	50	50	0
Demand	4500	6500	8500	8500	6500	5500	7500	14.000	61.500			
Penalty I	50	50	50	50	0	50	50					
Penalty II	50	50	50	50	0	0	50					
Penalty III	50	0	50	50	0	0	50					
Penalty IV	50	0	0	50	0	0	50					
Penalty V	50	0	0	0	0	0	50					
Penalty VI	50	0	0	0	0	0	0					
Penalty VII	0	0	0	0	0	0	0					

Figure 7. Vogel's Approximation Result

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The utilization of the Vogel method involves an initial step in determining row and column penalties by calculating the difference between the second smallest cost and the smallest cost, such as C_{S1SR} 185 – C_{S1KR} 135 = 50. The obtained penalty results in columns or rows have a total of 50, which are selected randomly based on the highest demand and then allocated to fulfill the demand constrained by supply.

Table 5: Vogel's Approximation Calculation

No	Supply and Demand	Capacity	Cost /Kg	Total
1	Semarang Gudang 1 ke Demak	2500	235	Rp 587.500
2	Semarang Gudang 1 ke Purwodadi	6500	185	Rp 1.202.500
3	Semarang Gudang 1 ke Boyolali	8500	285	Rp 2.422.500
4	Semarang Gudang 1 ke Karanganyar	6500	135	Rp 877.500
5	Semarang Gudang 2 ke Demak	2000	185	Rp 370.000
6	Semarang Gudang 2 ke Klaten	8500	285	Rp 2.422.500
7	Semarang Gudang 2 ke Sragen	5500	135	Rp 742.500
8	Semarang Gudang 2 ke Surakarta	7500	235	Rp 1.762.500
	Total			Rp 10.387.500

For this allocation, the total transportation cost using the Least Cost method is:

Z=(235x2500)+(185x6500)+(285x8500)+(135x6500)+(185x2000)+(285x8500)

+(135x5500)+(235x7500)+(0x14.000)=Rp 10.387.500

The result obtained from the utilization of the Vogel method is Rp 10.387.500, representing the distribution cost of PT Saprotan Utama Nusantara in delivering herbicide products to destination cities per month. With a total shipping cost for one year amounting to Rp 124.650.000, which equals the cost processed using the Least Cost method and is lower than the company's expenditure of Rp 147.900.000.

3.4 Stepping Stone Method

The next step is to emphasize distribution costs by incorporating the values of non-basic variables, which represent the allocation of goods to empty cells within the solution. Stepping Stone is a method for evaluating non-basic variables that focuses on improving the solution and adjusting the allocation obtained from the North West Corner method. Below is the calculation using the Stepping Stone method by allocating the results from the North West Corner method, as illustrated in Figure 8.

Tujuan / Sumber	Demak	Purwo-dadi	Klaten	Boyolali	Karang-anyar	Sragen	Sura-karta	Dummy	Supply
Semarang Gudang 1	235 4500	185 6500	335 8500	285 8500	135 6500	185 3500 -1	285 +1	0	38.000
Semarang Gudang 2	185	235	285	335	135	135 2000 +1	235 7500 -1	0 14.000	23.500
Demand	4500	6500	8500	8500	6500	5500	7500	14.000	61.500

Figure 8. Stepping Stone First Step

Basic variables : X_{S1P}, X_{S1K}, X_{S1B}, X_{S1KR}, X_{S1SR}, X_{S2SR}, X_{S2SK}

Non basic variables : X_{S1SK}, X_{S2D}, X_{S2P}, X_{S2K}, X_{S2B}, X_{S2KR}

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Initial transport costs : (4500x235)+(6500x185)+(8500x335)+(8500x285) +(6500x135)+(2500x185)+(2500x135)+(7500x235) +(14.000x0) = Rp 11.087.500

Looping calculation

S1SK = + CS1SK – CS2SK + CS2SR – CS1SR = + 285 – 235 + 135 - 185 = 0

S1Dummy = + 0 - 0 + 235 - 285 = -50

S2D = + 185 - 235 + 185 - 135 = 0

S2P = + 235 - 185 + 235 - 135 = 100

S2K = + 285 - 335 + 285 - 135 = 100

S2B = + 335 -285 + 135 - 135 = 0

S2KR = + 135 - 135 + 185 - 135 = 50

Tujuan / Sumber	Demak	Purwo-dadi	Klaten	Boyolali	Karang-anyar	Sragen	Sura-karta	Dummy	Supply
Semarang Gudang 1	235	185 6500	335 2500	285 8500	135 6500	185	285	0 14.000	38.000
Semarang Gudang 2	185 4500	235	285 6000	335	135	135 5500	235 7500	0	23.500
Demand	4500	6500	8500	8500	6500	5500	7500	14.000	61.500

Figure 9. Stepping Stone Result

It can be observed that the results in the looping calculation can analyze the costs of non-basic variables, which only have negative cost changes, namely Semarang Warehouse 1-Dummy amounting to -50. Then, Semarang Warehouse 1-Dummy is a non-basic variable that, when included, can lead to a decrease in costs. Therefore, it can be included as shown in Figure 9.

Table 6. Stepping Stone Calculation

No	Supply and Demand	Capacity	Cost /Kg	Total
1	Semarang Gudang 1 ke Purwodadi	6500	185	Rp 1.202.500
2	Semarang Gudang 1 ke Klaten	2500	335	Rp 837.500
3	Semarang Gudang 1 ke Boyolali	8500	285	Rp 2.422.500
4	Semarang Gudang 1 ke Karanganyar	6500	135	Rp 877.500
5	Semarang Gudang 2 ke Demak	4500	185	Rp 842.500
6	Semarang Gudang 2 ke Klaten	6000	285	Rp 1.710.000
7	Semarang Gudang 2 ke Sragen	5500	135	Rp 742.500
8	Semarang Gudang 1 ke Surakarta	7500	235	Rp 1.762.500
	Total			Rp 10.387.500

The result obtained from the utilization of the Stepping Stone method is Rp 10,387.500, representing the distribution cost of PT Saprotan Utama Nusantara in delivering herbicide products to destination cities per month. With a total shipping cost for one year amounting to Rp 124.650.000, which equals the costs processed using the Least Cost and Vogel methods, and is lower than the company's expenditure of Rp 147.900.000.

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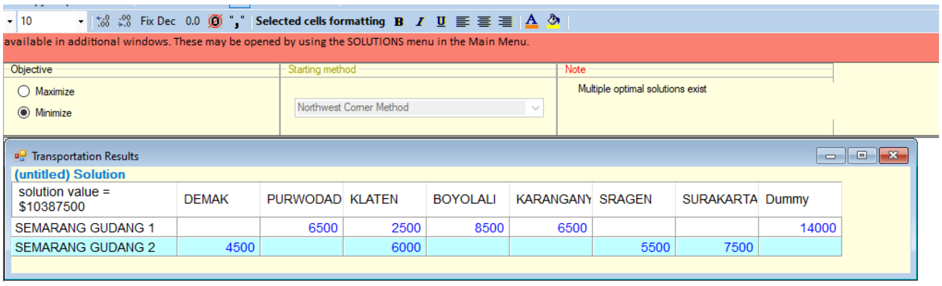
3.5 POM-QM Software

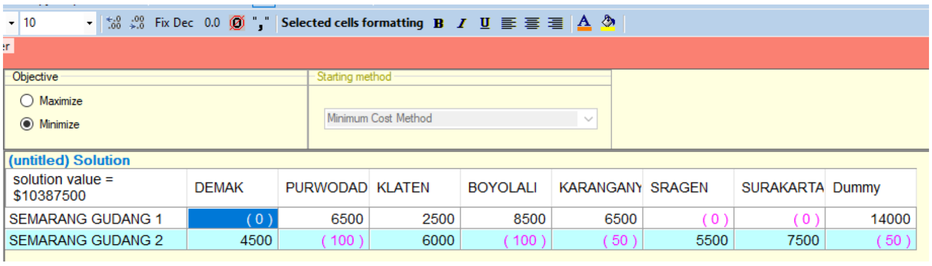
The utilization of POM-QM software serves as a comparison tool and facilitates transportation data processing automatically using its transportation module feature. It can determine cost outcomes by inputting transportation cost data from warehouse locations and destination cities, as well as entering demand and supply quantities into the provided columns. The following are the steps involved in data processing using the POM-QM software.



solution value = $10387500	DEMAK	PURWODAD	KLATEN	BOYOLALI	KARANGANY	SRAGEN	SURAKARTA	Dummy
SEMARANG GUDANG 1		6500	2500	8500	6500			14000
SEMARANG GUDANG 2	4500		6000			5500	7500	

Figure 10. POM-QM North West Corner Result

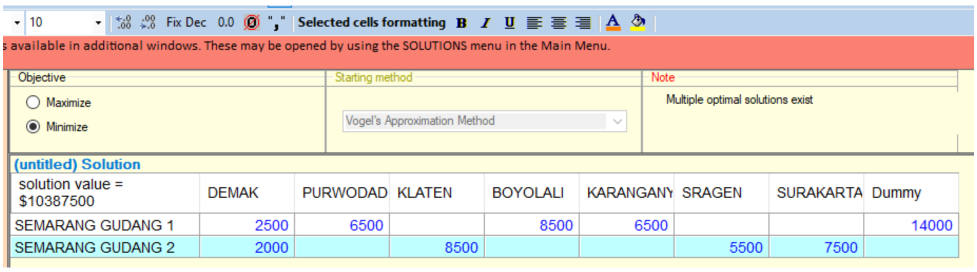
In the North West Corner calculation using the POM-QM software, a cost value of Rp 10.387.500 is obtained. This result is automatically processed using the Stepping Stone method within the POM-QM software.



solution value = $10387500	DEMAK	PURWODAD	KLATEN	BOYOLALI	KARANGANY	SRAGEN	SURAKARTA	Dummy
SEMARANG GUDANG 1	(0)	6500	2500	8500	6500	(0)	(0)	14000
SEMARANG GUDANG 2	4500	(100)	6000	(100)	(50)	5500	7500	(50)

Figure 11. POM-QM Least Cost Result

In the Least Cost/Minimum Cost calculation using the POM-QM software, a cost value of Rp 10.387.500 is obtained.



solution value = $10387500	DEMAK	PURWODAD	KLATEN	BOYOLALI	KARANGANY	SRAGEN	SURAKARTA	Dummy
SEMARANG GUDANG 1	2500	6500		8500	6500			14000
SEMARANG GUDANG 2	2000		8500			5500	7500	

Figure 12. POM-QM Vogel's Approximation Result

In the Least Cost/Minimum Cost calculation using the POM-QM software, a cost value of Rp 10.387.500 is obtained. Among the three methods mentioned, processing through POM-QM software yields identical values. Thus, it can be ascertained that the processing undergone in the transportation cost of herbicide products at PT Saprotan Utama Nusantara ensures an optimal value. Processing with POM-QM software yields the same value result as the Least Cost, Vogel, and Stepping Stone methods, with a value of Rp 147.900.000.

As per Table 7, the distribution costs per month are shown, and when multiplied by 12 to determine the total annual costs, they amount to Rp 124,650,000.

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Table 7. The Annual Distribution Cost.

No	Destination	Monthly Cost	Annually Cost
1	Demak	Rp. 832.500 x 12	Rp 9.990.000
2	Purwodadi	Rp. 1.202.500 x 12	Rp 14.430.000
3	Klaten	Rp. 837.500 x 12	Rp 10.050.000
		Rp 1.710.000 x 12	Rp 20.520.000
4	Boyolali	Rp. 2.422.500 x 12	Rp 29.070.000
5	Karanganyar	Rp. 877.500 x 12	Rp 10.530.000
6	Sragen	Rp. 742.500 x 12	Rp 8.910.000
7	Surakarta	Rp. 1.762.500 x 12	Rp 21.150.000
		Total Biaya	Rp 124.650.000

Table 8. Comparison Between the Company's Costs and the Optimal Costs.

No	Destination	Company's Cost	Optimal Cost
1	Demak	Rp. 14.760.000	Rp 9.990.000
2	Purwodadi	Rp. 16.560.000	Rp 14.430.000
3	Klaten	Rp. 37.560.000	Rp 30.570.000
4	Boyolali	Rp. 32.160.000	Rp 29.070.000
5	Karanganyar	Rp. 12.360.000	Rp 10.530.000
6	Sragen	Rp. 10.560.000	Rp 8.910.000
7	Surakarta	Rp. 23.940.000	Rp 21.150.000
	Total Biaya	Rp. 147.900.000	Rp 124.650.000

According to Table 8, there is a comparison between the company's costs and the optimal costs of the company in distributing herbicide fertilizers to each destination from January 2023 to December 2023, amounting to Rp 147.900.000. The optimal cost result after data processing with the transportation model is Rp 124.650.000 for all destinations throughout the year. There is a cost saving of Rp 23.250.000 between the company's distribution costs and the optimal transportation model costs.

4. Conclusion

In the distribution of herbicide fertilizers from January to December 2023, data processing was conducted at PT Saprotan Utama Nusantara to compare actual costs with optimal costs using a transportation model. The total company costs during that year amounted to Rp 147.900.000, but after implementing the transportation model, the optimal cost was reduced to Rp 124.650.000. This indicates a cost saving of Rp 23.250.000.

The optimal cost result is achieved due to the utilization of a transportation model that maximizes the distribution arrangement from the warehouse sources supplying herbicide fertilizer products to the destinations requiring them optimally in terms of both demand and distribution costs.

Although the North West Corner method is easy to implement, it tends to not yield optimal solutions. Meanwhile, the Least Cost method prioritizes routes with the lowest cost, Vogel's Approximation is more efficient in handling significant differences in transportation costs, and the Stepping Stone method systematically seeks optimal solutions by exploring potential movements between cells.

References

Aryata, I. M., & Marendra, I. G. (2022). Decision Making Strategy Using the Assignment Method with the POM-QM Application. *Jurnal Pengabdian Masyarakat Bestari*, 1(8), 747–758. https://doi.org/10.55927/jpmb.v1i8.1732

ISSN : 2776-7914 (Print) / 2807-3045 (Online)

Fatimah, N. L., & Wibawanto, H. (2015). North West Corner Method (NWCM) Dan Stepping Stone Method Semarang. *Edu Komputika Jurnal*, 2(1), 48–54.

Gultom, P., Manik, D. E. M., Lazawardi, D., & Nainggolan, Susan Grace V Simarmata, A. M. (2022). *Pengantar Riset Operasi* (1st ed.). Cipta Media Nusantara.

Hasanah, T. U., Utami, P., & Fauzi, M. (2020). Pengoptimalan Biaya Transportasi dengan Metoda North West Corner (NWC) dan Stepping Stone (SS) untuk Distribusi Produk Farmasi Optimization of Transportation Costs with Methode of North West Corner (NWC) and Stepping Stone (SS) for Distribution of Pharmac. *Jurnal Teknik Industri*, 6(1), 34–34.

Kurniawan, F. (2022). Penerapan Metode Vogels'S Aproximation Method (Vam) Dalam Menetukan Harga Pengiriman Dokumen. *Journal of Science and Social Research*, 5(2), 292. https://doi.org/10.54314/jssr.v5i2.924

Pasaribu, M. (2019). Implementation of Northwest Corner Transportation Method for Optimizing Item Shipping Cost. *Jurnal Teknologi Komputer*, 13(1), 1–4. http://login.seaninstitute.org/index.php/Loginˆ1LoginˆLoginˆ1Journalhomepage:http://login.seaninstitute.org/index.php/Login

Rosmita, Putri, M. A., & Rosmayani. (2018). Analisis Faktor-Faktor yang Mempengaruhi Saluran Distribusi Usaha Kecil Menengah (UKM) (Survei Pada Kue Bangkit "Syempana" Di Kota Pekanbaru). *Jurnal Valuta*, 4(2502–1419), 116–137.

Rusanova, S., Piterska, V., & Onyshchenko, S. (2021). Modelling the project transport support optimal option. *Technology Audit and Production Reserves*, 1(2(57)), 43–48. https://doi.org/10.15587/2706-5448.2021.225288

Sembiring, N., Tarigan, U., Tiana, Y. W., & Nasution, M. A. (2020). Distribution improvement in achieving customer satisfaction. *Journal of Physics: Conference Series*, 1542(1). https://doi.org/10.1088/1742-6596/1542/1/012003