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ANALYSIS OF TRANSPORTATION METHODS IN MANAGING THE DISTRIBUTION OF SOLO ICE TEA IN SOUTH TANGERANG

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Abstract

The contemporary beverage industry in Indonesia is growing rapidly along with the increasing public interest in fresh and practical products, one of which is Es Teh Solo. In the product distribution process, transportation cost efficiency is an important factor to maintain competitiveness and business sustainability. This study aims to analyze the application of transportation methods as part of operations research in optimizing the distribution costs of Es Teh Solo from the factory in South Tangerang to three destination areas, namely South Jakarta, Bogor, and Depok. The methods used include North West Corner (NWC), Least Cost (LC), Vogel's Approximation Method (VAM), and Stepping Stone (SS). The results show that the NWC, VAM, and Stepping Stone methods produce the same minimum cost, which is Rp 8,650,000, while the Least Cost method produces a higher cost, which is Rp 13,020,000. The Stepping Stone method is used to test the optimality of the solution and proves that the value of Rp 8,650,000 is the optimal solution for the Es Teh Solo distribution system. Thus, the application of transportation methods is proven to be effective in minimizing distribution costs and assisting efficient logistics decision making for the company.
Keywords: *operations research, transportation methods, cost optimization, distribution, Es Teh Solo*

Abstrak

Industri minuman kekinian di Indonesia berkembang pesat seiring meningkatnya minat masyarakat terhadap produk yang segar dan praktis, salah satunya Es Teh Solo. Dalam proses distribusi produk, efisiensi biaya transportasi menjadi faktor penting untuk menjaga daya saing dan keberlanjutan usaha. Penelitian ini bertujuan untuk menganalisis penerapan metode transportasi sebagai bagian dari riset operasi dalam mengoptimalkan biaya distribusi Es Teh Solo dari pabrik di Tangerang Selatan menuju tiga daerah tujuan, yaitu Jakarta Selatan, Bogor, dan Depok. Metode yang digunakan meliputi North West Corner (NWC), Least Cost (LC), Vogel's Approximation Method (VAM), dan Stepping Stone (SS). Hasil penelitian menunjukkan bahwa metode NWC, VAM, dan Stepping Stone menghasilkan biaya minimum yang sama, yaitu sebesar Rp 8.650.000, sedangkan metode Least Cost menghasilkan biaya lebih tinggi, yaitu Rp 13.020.000. Metode Stepping Stone digunakan untuk menguji optimalitas solusi dan membuktikan bahwa nilai Rp 8.650.000 merupakan solusi optimal bagi sistem distribusi Es Teh Solo. Dengan demikian, penerapan metode transportasi terbukti efektif dalam meminimalkan biaya distribusi dan membantu pengambilan keputusan logistik yang efisien bagi perusahaan.
Kata kunci: riset operasi, metode transportasi, optimasi biaya, distribusi, Es Teh Solo

I. INTRODUCTION

The contemporary beverage industry in Indonesia continues to grow in line with the growing public preference for refreshing, convenient, and flavorful beverages. One product currently attracting attention is Es Teh Solo. The distribution process is a crucial element in a product's supply chain. To meet customer demand across various regions, Es Teh Solo requires an optimal distribution system. In this regard, transportation methods are one approach that can be used to minimize shipping costs while maintaining product quality. Applying this method to Es Teh Solo's distribution is expected to help the company determine the most efficient shipping route, both in terms of time and cost, so that the product reaches consumers on time and in optimal condition. Through this research, it is hoped that distribution analysis using transportation methods can provide practical solutions for Es Teh Solo in optimal logistics management.

History of Es Teh Solo

Es Teh Solo is a cold sweet tea drink originating from Solo (now Surakarta), a city in Central Java, Indonesia. Es Teh Solo was first introduced in the 1960s in Solo, known as the city of culture. Initially, Es Teh Solo was made using local black tea brewed using traditional methods. The process of making this tea is quite simple: tea leaves are brewed with hot water, then sugared and cooled with ice cubes, resulting in a sweet and refreshing drink.

The tea used is usually black tea, which is known for its strong flavor. However, one of the hallmarks of Iced Teh Solo is its dominant sweetness, due to the large amount of sugar added, providing a distinctive and refreshing flavor. This drink was originally served in large containers at food stalls or street vendors in Solo and the surrounding area, with the aim of attracting consumers seeking something refreshing. Gradually, Iced Teh Solo began to gain attention outside Solo and became part of Indonesia's culinary identity, especially in Java.

After becoming popular in Solo, Iced Teh Solo began to spread to other cities in Indonesia. Many food stalls and restaurants serve Iced Teh Solo as a beverage option. In fact, several beverage brands have also begun selling Iced Teh Solo in ready-to-drink bottles or cans. This drink is also considered part of Solo's distinctive cultural heritage, with its sweet taste and convenient presentation. Furthermore, Solo Iced Tea is very popular among various groups, from young to old, due to its refreshing taste and relatively affordable price.

Currently, Solo Iced Tea also comes in various variations. Some add lime juice for a refreshing sour taste, while others use larger or smaller ice cubes, depending on individual tastes. Solo Iced Tea remains a popular beverage in Indonesia and can be found in many places, from large restaurants to small food stalls.

Based on this background, this study aims to analyze the implementation and solution steps of transportation methods using three approaches: NWC, LC, and VAM, to determine the minimum distribution costs of Solo Iced Tea products.

II. THEORETICAL STUDIES

Operations Research

Operations research is a scientific discipline widely used as a tool to analyze and solve various operational problems within an organization. Operations research is a science that uses mathematical models, statistics, and algorithms to assist in optimal decision-making in complex systems. Its primary goal is to minimize costs or maximize profits/efficiency in the use of limited resources. The goal of Operations Research is to find the best (optimal) way to minimize costs, maximize profits, efficiency, or productivity. Examples of applications include production scheduling, inventory management, transportation and distribution, assignment problems, and network and logistics planning. Therefore, operations research is the parent science to various optimization methods, one of which is Linear Programming.

Linear Programming

"Linear programming is a method for solving problems involving the allocation or allocation of limited resources among several competing activities, in the best possible way to obtain an optimal solution. Linear programming is a method for optimizing a linear relationship that includes an objective function and certain constraints to find the optimal value" (Ayu Azizah et al., 2023). An example of a linear programming application is determining how many products should be produced to maximize profits, given the constraints of raw materials, labor hours, and machine capacity.

Transportation Method

The Transportation Method is a special model in Linear Programming for optimizing distribution costs from multiple sources to multiple destinations. Transportation methods are techniques used to optimally manage the distribution of the same product from multiple sources to multiple destinations at the lowest possible cost (Rini et al., 2024). The goal is to determine the quantity of goods shipped from each source to each destination at the lowest possible total cost, while still satisfying the following: capacity (supply) at each source and demand at each destination. Because all functions and constraints are linear, transportation problems are a subcategory of Linear Programming.

III. RESEARCH METHODS

This research uses a quantitative approach with the transportation method as an analytical tool to optimize product distribution costs. The data used include supply capacity, demand, and transportation costs between locations, collected through field observations and literature review. The analysis was conducted using the North West Corner (NWC), Least Cost (LC), and Vogel's Approximation Method (VAM) to obtain an initial solution, as well as the Stepping Stone (SS) method to test the optimality of minimum distribution costs.

The transportation method is a quantitative approach that can help companies determine product distribution costs, especially when the company has more than one shipping facility and destination. The transportation method relates to the distribution of a single product from multiple sources with limited supply to multiple destinations with specific demand at minimum distribution costs. There is only one type of product, and a destination can meet its demand from one or more sources.

To achieve minimum costs, product allocation must be carefully managed, as there are differences in allocation costs, both from source to destination and vice versa. The characteristics of the transportation method are as follows:

1. There are a specific number of sources and destinations.
2. The quantity of goods distributed from each source and the demand at each destination is specific.
3. The quantity of goods shipped from a source to a destination is based on the demand or capacity of the source.
4. The transportation cost from a source to a destination is fixed.

Mathematically, the transportation problem is as follows:

Objective function:

$$\text{Minimum } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ii}\, X_{ii}$$

With constraints:

$$\sum_{i=1}^{m} ai = \sum_{j=1}^{n} bj$$

Dengan keterangan :

$C_{ii=}$ transportation cost per unit of goods from source i to destination j

$X_{ii=}$ the number of goods distributed from source i to destination j

$a_{i=}$ the quantity of goods offered or the capacity of the source i

$b_{j=}$ the number of items requested or ordered by the destination j

M= many sources

N= many goals

A transportation problem is said to be balanced (balanced program) if the sum of supply at source i is equal to the sum of demand at destination j.

This can be written as:

$$\sum_{i=1}^{m} ai = \sum_{j=11}^{n} ai\ bj$$

The first step in solving a transportation problem is to determine an initial feasible solution. There are four methods for determining an initial feasible solution:

1. Northwest Corner Method

"The North West Corner (NWC) method is used to solve transportation problems by filling in the initial transportation allocation table, starting from the northwest corner of the leftmost box (upper left corner), allocating as much as possible while not violating the existing constraints, namely the amount of supply and demand" (Prastika Setiany & Mufti Prasetiyo, 2023). Allocation is carried out sequentially downward, then moving to the next column until all supply and demand are met. When solving problems using this method, several things must be considered, one of which is when demand equals supply or production output is distributed in balance with demand, meaning the number of units of goods available and required are equal.

According to Silaen (2018) in (Firdaus et al., 2023), the North West Corner (NWC) method is the simplest method with the following steps:

a. Filling cells or allocation begins at the top left corner (northwest corner) of the table.
b. Allocate the maximum amount or as much as possible according to what is available at the factory/source or according to market/consumer demand, so that it is feasible to meet consumer demand/needs.
c. If there is still inventory but it has met the demand of the first consumer/market, allocate the remaining inventory to the right cell so that all inventory is allocated.
d. If all inventory has been allocated from the first source, allocation moves to the cell below it with allocation from the second source.

e. This allocation process continues in the same manner until all inventory is allocated with no remainder. If you pay attention, the allocation path always takes the form of a ladder, namely from $x11 \rightarrow x21 \rightarrow x22 \rightarrow x32 \rightarrow x33$, or $x11 \rightarrow x12 \rightarrow x22 \rightarrow x23 \rightarrow x33$.
f. Calculate the total cost obtained, the cost is said to be optimal if the table has been fulfilled according to the supply row and demand column.
g. System requirements analysis includes Functional Requirements Analysis and Non-Functional Requirements Analysis.

According to Dwiyanti et al., 2024, the advantages and disadvantages of this method are as follows:

Advantages:

- This method is the easiest method for the initial calculation steps to find the optimal solution, but it does not consider costs.

Disadvantages:

- This method is not only for finding the initial calculation solution, but it does not immediately find the optimal solution.
- This method only allocates products based on the criteria of the upper left and lower right corners, which are the basis cells. The North West Corner (NWC) method is less efficient and takes the longest time to find the optimal table.

2. Least Cost Method

"Least cost is a method that can optimize transportation and distribution costs. The advantages of the least cost method include ease of understanding because it is determined based on the lowest cost. The disadvantages of the least cost method are usually evident in the final results. The final results of the least cost method do not necessarily indicate optimal figures, so researchers need to conduct re-examination using other methods" (Lestari et al., 2021). The steps for completing the Least Cost method according to Lestari (Syahdan & Arianti, 2023) are as follows:

a. Select the variable (box) with the smallest transportation cost, then allocate as much supply or demand as possible.
b. For the smallest cost, Xij = the minimum (Si and Dj) that will exhaust row i or column j. The exhausted row i or column j will be eliminated.

c. For the remaining boxes (boxes that are not eliminated), select the smallest cost again and allocate as much as possible to row i or column j. This process will continue until all supply and demand are satisfied.

3. Vogel's Approximation Method (VAM)

"The VAM method is simpler to use because it eliminates the need for a closed path. The VAM method is implemented by first finding the difference between the smallest and the next smallest costs for each column and row. Next, select the largest cost difference and allocate as many items as possible to the cell with the smallest cost" (Auliya et al., 2023). This method often produces a better initial solution than the northwest or lowest cost method. In determining the initial solution, the VAM uses the concept of a penalty cost, which is calculated as the difference between the two smallest costs in cells within a row or column.

The steps in solving the Vogel's Approximation Method, according to Yanto (2019) in (Syahdan & Arianti, 2023), are as follows:

a. Arrange the requirements for each resource and transportation costs into a matrix.
b. Find the difference between the two smallest costs, namely the second smallest cost, for each row and column in the matrix (Cij).
c. Select the largest difference value among all the difference values in the column and row.
d. Fill in one rectangle within the selected column or row, namely the rectangle with the lowest cost among the other rectangles in that column or row. Fill in as much as possible.
e. Delete the row and column because they are already completely filled and cannot be filled in again.
f. Redetermine the cost difference (difference) in step 2 for the remaining columns and rows. Repeat steps 3 through 5 until all columns and rows are allocated.
g. Once all the values are filled in, calculate the total transportation cost.
h. If there are two cost difference values that are the same size, for example, one located in a column, look at the rectangle in the column or row with the largest value. If this rectangle has the lowest cost among the rectangles in its row and column, then fill in the maximum location in this rectangle. If the cost is not the lowest, then choose the rectangle to be filled based on either the selected row or the selected column.

4. SS (Stepping Stone) Method

"The Stepping Stone Method is a method for finding the optimal solution to a transportation problem (minimizing TC). This method is based on trial and error, involving the movement of occupied cells (stones) to empty cells (water). This transfer must, of course, reduce costs. Therefore, empty cells must be selected so that transportation costs are low and the transfer is feasible" (Sinaga, 2023).

The steps in implementing the Stepping Stone Method, according to (Basriati et al., 2021), are as follows:

a. Check for empty cells by alternately jumping horizontally or vertically, starting from occupied cells.
b. Calculate the cost of each empty cell. Starting from the empty cell, mark it positive and proceeding to the cells it jumps to, with the first jump marked negative, the second jump positive, and so on, alternating. Positive and negative signs indicate that the allocation value will increase and decrease accordingly.
c. If the calculation results from the empty cell check are all positive, then the transportation table is at its minimum and the largest negative value will be selected.
d. After selecting the cost calculation that produces the largest negative value, select the cell with the smallest allocation unit for the negative jump. Then, the smallest allocation unit will be added to the negative jump.
e. Repeat steps 2 through 4 until there are no negative values in the empty cell check.
f. Obtain the optimal solution to the transportation problem.

Transportation Table:

Tujuan / Sumber	**A**	**B**	**C**	**Qs Penawaran**
1	X_1	X_2	X_3	Y_1
2	X_4	X_5	X_6	Y_2
3	X_7	X_8	X_9	Y_3
Qd Permintaan	W_1	W_2	W_3	Z

X: Shows the transportation cost per unit incurred. The X value has a different number in each box depending on the transportation alternative used.

Y: Shows the total capacity of the shipping source facility.

W: Shows the total demand from each destination.

Z: Shows the total demand and capacity. The sum of W and Y must be the same.

IV. RESEARCH RESULTS

Solo iced tea distributors are distributors that supply Solo tea ingredients. As tea producers, Solo tea distributors have several distribution points spread across various regions, which creates transportation cost allocation regulations. Distribution of tea products has not been a problem faced by distributors in the three regions served by the distributor and needs to be addressed through transportation methods to achieve optimal distribution costs.

Question:

A tea company produces a product to be distributed to three consumers. The company has three factories located in South Tangerang, targeting the needs of factories in South Jakarta, Bogor, and Depok.

Table 1. Production Quantity / Service Offering for Solo Ice Tea

Perusahaan Daerah Asal	**Qs / Kapasitas Penawaran**	**Usaha Daerah Tujuan**	**Qd / Permintaan**
Tangerang Selatan	290	Es Teh Solo Kota Jakarta Selatan	125
Tangerang Selatan	380	Es Teh Solo Kota Bogor	415
Tangerang Selatan	230	Es Teh Solo Kota Depok	360
Jumlah Qs / Kapasitas Penawaran = 900		Jumlah Qd / Kuantitas Permintaan = 900	

The table above shows the shipping costs incurred by distributors in the three business destinations: South Jakarta, Bogor, and Depok. Based on the available data and referring to the research problem formulation, the purpose of this data analysis is to analyze the optimal distribution costs for Es Teh Solo products. The focus is to determine the minimum costs required for product transportation from the main production location (tea products) to various destination factories (for marketing). Furthermore, this study aims to find the optimal allocation of goods from each production source to the destination locations.

Daily distribution costs to each destination business range from IDR 24,000 to IDR 94,000 per day per distributor, including fuel costs.

Table 2. Transportation Costs for Product Distribution from 3 Distributors for 3 Destination Areas

Perusahaan Daerah Asal	**Jakarta Selatan**	**Bogor**	**Depok**
Tangerang Selatan I	4.000	20.000	70.000
Tangerang Selatan II	10.000	8.000	6.000
Tangerang Selatan III	50.000	30.000	9.000

From the data in the table above, an initial transportation method model can be created as follows:

Table 3. Initial Transportation Model for Solo Iced Tea Distributors

Tujuan Sumber	Jakarta Selatan	Bogor	Depok	Qs Kapasitas Penawaran
Tangerang Selatan I	4.000	20.000	70.000	290
Tangerang Selatan II	10.000	8.000	6.000	380
Tangerang Selatan III	50.000	30.000	9.000	230
Qd Kuantitas Permintaan	125	415	360	900

Since Qd / Quantity Demand and Qs / Capacity Demand are the same, the initial solution table begins with the NWC method.

a. Transportation Model Data Solution Method

i. NWC (North West Coast) Method

Procedure:

1. Fill in the cells starting from the top left corner and ending at the bottom right corner.
2. Allocate the maximum quantity that can be shipped from source 1, but not exceeding the demand from destination A.
3. Continue to the right cell if there is still excess capacity from source 1, or downward if source 1 cannot meet the demand from destination A.
4. Place a dash (x) in the cells that have exhausted their capacity/have had their demand met.
5. Repeat steps 3 and 4 until all demand is met.
6. Multiply the number of items shipped by the cell cost, the transportation cost.

Table 4. Initial NWC (North West Corner) Transportation Method Solo Iced Tea Distributor

Tujuan Sumber	Jakarta Selatan	Bogor	Depok	Penawaran
Tangerang Selatan I	4.000 125	20.000 165	70.000 x	290
Tangerang Selatan II	10.000 x	8.000 250	6.000 130	380
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	230
Permintaan	125	415	360	900

Solution:

1. Replenishment begins at Factory 1, which ships 125 items to South Jakarta City, as demand from South Jakarta is 125, meaning demand in South Jakarta has been met.
2. Next, Factory 1 ships 165 items to Bogor City, representing the remaining capacity of Factory 1, meaning Factory I has reached its capacity.

3. Next, Factory II ships 250 items to Bogor City to meet demand from Bogor City.
4. Next, Factory II ships 130 items to Depok City, representing the remaining capacity of Factory II.
5. The final shipment from Factory III ships 230 items to Bogor City to meet demand in Bogor City.
6. Since all demand in all cities has been met and the factories have reached their full capacity, the next step is to calculate transportation costs.

Factory I:
- South Jakarta City: 125 x 4,000 = 500,000
- Bogor City: 165 x 20,000 = 3,300,000

Factory II:
- Bogor City: 250 x 8,000 = 2,000,000
- Depok City: 130 x 6,000 = 780,000

Factory III:
- Depok City: 230 x 9,000 = 2,070,000

Total transportation cost = Rp 8,650,000

Conclusion:

Using the NWC method, the cost of transporting goods from the South Tangerang factory to South Jakarta, Bogor, and Depok is Rp 8,650,000.

ii. Least Cost (LC) Method

Processing Steps:
1. Cell filling or allocation begins by filling the cell with the lowest cost.
2. The size of the cell to be filled is adjusted based on its capacity and demand as much as possible.
3. If the capacity or demand has been met, then in the next calculation, the row or column for that capacity and demand will no longer be included in the next allocation.
4. Repeat these steps until the demand capacity is met.

Table 5. Initial LC (Least Cost) Method for Solo Iced Tea Distributors

Tujuan Sumber	**Jakarta Selatan**	**Bogor**	**Depok**	**Penawaran**
Tangerang Selatan I	4.000 125	20.000	70.000	~~290~~ 165
Tangerang Selatan II	10.000	8.000	6.000	380

	x			
Tangerang Selatan III	50.000 x	30.000	9.000	230
Permintaan	125 sudah terpenuhi	415	360	900

Explanation:

Allocate to the cell with the lowest cost. In this case, the lowest cost is factory 1 to South Jakarta City (125), which means that the demand at factory A has been met.

Table 6. Initial LC (Least Cost) Method for Solo Iced Tea Distributor

Tujuan **Sumber**	**Jakarta Selatan**	**Bogor**	**Depok**	**Penawaran**
Tangerang Selatan I	4.000 125	20.000	70.000 x	~~290~~ 165
Tangerang Selatan II	10.000 x	8.000	6.000 360	~~380~~ 20
Tangerang Selatan III	50.000 x	30.000	9.000 x	230
Permintaan	125 sudah terpenuhi	415	360 sudah terpenuhi	900

Explanation:

Reallocate the cell with the lowest cost. Cells with already met capacity or demand are not included in the next allocation. Therefore, based on the table above, the selected cell is Factory II in Depok City, with the lowest cost of 6,000. Because capacity is greater than demand, the minimum demand for Depok City is filled first, amounting to 360. Therefore, demand from Depok City has been fully distributed, and Factory III cell is closed because it is not included in the next allocation.

Table 7. Initial LC (Least Cost) Method for Solo Iced Tea Distributor

Tujuan **Sumber**	**Jakarta Selatan**	**Bogor**	**Depok**	**Kapasitas**
Tangerang Selatan I	4.000 125	20.000	70.000 x	~~290~~ 165
Tangerang Selatan II	10.000 x	8.000 20	6.000 360	~~380~~ 20 sudah terpenuhi
Tangerang Selatan III	50.000 x	30.000	9.000 x	230
Permintaan	125	~~415~~	360	

	sudah terpenuhi	395	sudah terpenuhi	900

Explanation:

Furthermore, the lowest cost is found in cell 2 in Bogor City, with a cost of 8,000. Here, demand in Bogor City is 415, and Factory II's capacity is 380. However, Factory II's previous capacity of 360 was already met, leaving 20 remaining. Because demand exceeded capacity, Depok City's minimum capacity of 20 was first filled. Therefore, Factory II's capacity has been fully distributed.

Table 8. Initial LC (Least Cost) Method for Solo Iced Tea Distributors

Tujuan Sumber	**Jakarta Selatan**	**Bogor**	**Depok**	**Kapasitas**
Tangerang Selatan I	4.000 125	20.000 165	70.000 x	~~290~~ ~~165~~ sudah terpenuhi
Tangerang Selatan II	10.000 x	8.000 20	6.000 360	~~380~~ ~~20~~ sudah terpenuhi
Tangerang Selatan III	50.000 x	30.000 230	9.000 x	230 sudah terpenuhi
Permintaan	~~125~~ sudah terpenuhi	~~415~~ ~~395~~ 230 sudah terpenuhi	~~360~~ sudah terpenuhi	900

Explanation:

- The final solution is two cells: Cell 1 for Bogor City and Cell 3 for Bogor City, with manual work taking into account demand and capacity. Starting from the lowest cost, namely cell 1 Bogor City, with a cost of 20,000 with a demand of 415, but the previous demand has been fulfilled by 20 and the remaining 395, and a capacity of 290, but the previous capacity has been fulfilled by 125 and the remaining 165. Because demand is greater than capacity, the minimum capacity of Factory I is first filled, which is 165. Therefore, Factory I's capacity has been fully distributed. Next, the remaining cell 3 Bogor City with a demand of 415 and has been fulfilled by 185 and the remaining 230, with a capacity of Factory III of 230. Therefore, the capacity of Factory III and the demand from Bogor City have been distributed and allocated entirely to Factory III, amounting to 230, while the demand from Bogor City is less than 230. This means that the total capacity of Factory III and Bogor City has been fulfilled by 230.

- Because all the demands of all cities have been fulfilled, and all the factory capacities have been fully distributed, the next step is to calculate the transportation costs.

Transportation Cost Calculation:

- Factory I to South Jakarta: 125 x 4,000 = 500,000
- Factory I to Bogor: 165 x 20,000 = 3,300,000
- Factory II to Bogor: 20 x 8,000 = 160,000
- Factory II to Depok: 360 x 6,000 = 2,160,000
- Factory III to Bogor: 230 x 30,000 = 6,900,000

Total = Rp 13,020,000

Conclusion:

Using the LC method, the transportation cost of goods from the South Tangerang factory to South Jakarta, Bogor, and Depok is Rp 13,020,000.

iii. VAM (Vogel Approximation Method)

Steps:

1. Calculate the difference between the two smallest costs in each row and column. This is called the penalty cost or opportunity cost.
2. Select the row or column with the largest penalty cost. If the penalty costs in each row or column are the same, select the penalty cost with the lowest transportation cost.
3. From the selected cells, allocate the quantity of goods equal to the maximum value of the capacity or demand for the column or row.
4. Repeat the above steps by calculating the rows or columns that have been filled until all demand and capacity are met.

Solution:

Calculate the penalty cost for each column from the row by subtracting the two smallest costs from each column. Then, select the largest penalty from the row and column and allocate it as much as possible to the lowest-cost cell, based on capacity and subsequent demand.

Table 8. Initial VAM (Vogel Approximation Method) for Solo Iced Tea Distributors

Stage I Solution

Tujuan / Sumber	Jakarta Selatan	Bogor	Depok	Kapasitas	Penalti
Tangerang Selatan I	4.000	20.000	70. 000	290	20.000 – 4.000 = 16.000

Tangerang Selatan II	10.000	8.000	6.000	380	8.000 – 6.000 = 2.000
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	~~230~~	30.000 – 9.000 = 21.000
Permintaan	125	415	360	900	
Penalti	10.000 – 4.000 = 6.000	20.000 – 8.000 = 12.000	9.000 – 6.000 = 3.000		

Explanation:

1. Calculate the penalty cost for each row and column by subtracting the two smallest costs from each row and column.
2. Select the largest penalty cost from the row or column.
3. Allocate as much as possible to the lowest-cost cell, based on capacity and demand.
4. The calculation shows that Factory III's capacity is met, with 230 units already used, and demand from Depok City has reached 230 units, leaving 130 remaining.

Table 9. Initial VAM (Vogel Approximation Method) for Solo Iced Tea Distributors

Completion of Phase II:

Tujuan / Sumber	Jakarta Selatan	Bogor	Depok	Kapasitas	Penalti
Tangerang Selatan I	4.000	20.000	70. 000 x	290	20.000 – 4.000 = 16.000
Tangerang Selatan II	10.000	8.000	6.000 130	~~380~~ 250	8.000 – 6.000 = 2.000
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	~~230~~	-
Permintaan	125	415	~~360~~ ~~130~~ 0	900	
Penalti	10.000 – 4.000 = 6.000	20.000 – 8.000 = 12.000	70.000 – 6.000 = 64.000		

Explanation:

1. Calculate the penalty cost for each row and column by subtracting the two smallest costs from each row and column.
2. Select the largest penalty cost from each row or column.
3. Allocate as much as possible to the lowest-cost cell, based on capacity and demand.

4. The calculation shows that Depok City's demand has been met, amounting to 360 units. The remaining capacity calculation for Factory III is 230 units + 130 units, the minimum cost obtained from Phase II.

Table 10. Initial VAM (Vogel Approximation Method) for Solo Iced Tea Distributors

Completion of Phase III:

Tujuan / Sumber	Jakarta Selatan	Bogor	Depok	Kapasitas	Penalti
Tangerang Selatan I	4.000 125	20.000	70. 000 x	~~290~~ 165	20.000 – 4.000 = 16.000
Tangerang Selatan II	10.000 x	8.000	6.000 130	~~380~~ 250	10.000 – 8.000 = 2.000
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	~~230~~ Terpenuhi	-
Permintaan	~~125~~ Terpenuhi	415	~~360~~ ~~130~~ 0 Terpenuhi	900	
Penalti	10.000 – 4.000 = 6.000	20.000 – 8.000 = 12.000	-		

Explanation:

1. Calculate the penalty cost for each row and column by subtracting the two smallest costs from each row and column.
2. Select the largest penalty cost from the row or column.
3. Allocate as much as possible to the cell with the lowest cost, based on capacity and demand.
4. The calculation shows that South Jakarta City's demand has been met, with 125 units, and Factory I's capacity has been utilized to 125 units.

Table 11. Initial VAM (Vogel Approximation Method) for Solo Iced Tea Distributors

Completion of Stage IV:

Tujuan / Sumber	Jakarta Selatan	Bogor	Depok	Kapasitas	Penalti
Tangerang Selatan I	4.000 125	20.000 165	70. 000 x	~~290~~ 165 Terpenuhi	
Tangerang Selatan II	10.000 x	8.000 250	6.000 130	~~380~~ 250 Terpenuhi	

Tangerang Selatan III	50.000 x	30.000 x	9.000 230	~~230~~ Terpenuhi	-
Permintaan	~~125~~ Terpenuhi	415 Terpenuhi	~~360~~ ~~130~~ 0 Terpenuhi	900	
Penalti			-		

Explanation:

1. The remaining unmet capacity from Factory I is 165 units and from Factory II is 250 units. The remaining unmet demand from Bogor City is 415 units, so the shortfall in City C will be met by the remaining capacity from Factory I and II, resulting in a profit.

2. Calculation of Total Cost:

Factory I, South Jakarta: 125 x 4,000 = 500,000

Factory I, Bogor: 165 x 20,000 = 3,300,000

Factory II, Bogor: 250 x 8,000 = 2,000,000

Factory II, Depok: 130 x 6,000 = 780,000

Factory III, Bogor: 230 x 9,000 = 2,070,000

Total = Rp 8,650,000

Conclusion:

Using the VAM method, the cost of transporting goods from the South Tangerang factory to South Jakarta, Bogor, and Depok is Rp. 8,650,000

2.3.4 Stepping Stone Method

Literacy

Step 1

Table 12. Initial Stepping Stone Method for Solo Iced Tea Distributor

Tujuan Sumber	Jakarta Selatan (A)	Bogor (B)	Depok (C)	Kapasitas
Tangerang Selatan I	4.000 125	20.000 - 165	70.000 + x	290
Tangerang Selatan II	10.000 x	8.000 250 +	6.000 130 -	380
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	230
Permintaan	125	415	360	900

IC = 70,000 – 20,000 + 8,000 – 6,000 = 52,000

Step 2

Table 13. Initial Stepping Stone Method Solo Iced Tea Distributor

Tujuan Sumber	Jakarta Selatan (A)	Bogor (B)	Depok (C)	Kapasitas
Tangerang Selatan I	4.000 125	20.000 165	70.000 x	290
Tangerang Selatan II	10.000 x	8.000 250	6.000 130	380
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	230
Permintaan	125	415	360	900

IIA = 10,000 - 8,000 + 20,000 - 4,000 = 18,000

Step 3

Table 14. Initial Stepping Stone Method for Solo Iced Tea Distributor

Tujuan Sumber	Jakarta Selatan (A)	Bogor (B)	Depok (C)	Kapasitas
Tangerang Selatan I	4.000 125	20.000 165	70.000 x	290
Tangerang Selatan II	10.000 x	8.000 250	6.000 130	380
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	230
Permintaan	125	415	360	900

IIIA = 50,000 - 9,000 + 6,000 – 8,000 + 20,000 – 4,000 = 55,000

Step 4

Table 15. Initial Method SS (Stepping Stone) Solo Iced Tea Distributor

Tujuan Sumber	Jakarta Selatan	Bogor (B)	Depok (C)	Kapasitas
Tangerang Selatan I	4.000 125	20.000 165	70.000 x	290
Tangerang Selatan II	10.000 x	8.000 250	6.000 130	380
Tangerang Selatan III	50.000 x	30.000 x	9.000 230	230
Permintaan	125	415	360	900

IIIB = 30,000 - 9,000 + 6,000 - 8,000 = 19,000.

STEPPING STONE SOLUTION METHOD

Literacy

∑(4,000 x 125) + (20,000 x 165) + (8,000 x 250) + (6,000 x 130) + (9,000 x 230)

= (500,000) + (3,300,000) + (2,000,000) + (780,000) + (2,070,000)

= Rp 8,650,000

Table 16. Optimum Transportation Literacy Transportation Method

Sel	Produk	Biaya Transportasi	Total Biaya Transportasi
IA	4.000	125	500.000
IB	20.000	165	3.300.000
IIB	8.000	250	2.000.000
IIC	6.000	130	780.000
IIIC	9.000	230	2.070.000
Total			8.650.000

The table above concludes that the three factories will ship their products, with Factory I shipping 290 tea products, Factory II shipping 380 tea products, and Factory III shipping 230 tea products. The minimum amount is IDR 8,650,000.

V. CONCLUSION

The application of transportation methods as part of operations research can provide optimal solutions for managing the distribution of Es Teh Solo. Through the application of four analytical methods: North West Corner (NWC), Least Cost (LC), Vogel's Approximation Method (VAM), and Stepping Stone (SS), the results showed that the minimum distribution cost was achieved at IDR 8,650,000 using the NWC, VAM, and SS methods. The LC method, however, resulted in a higher cost of IDR 13,020,000.

The optimality test results using the Stepping Stone method indicate that IDR 8,650,000 is the most efficient and optimal distribution cost, and can be used as a basis for the company in making logistics decisions. This research confirms the effectiveness of transportation methods in optimizing costs and distribution allocation, especially for beverage industries like Es Teh Solo, which require a fast and cost-effective delivery system.

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