# Comparison of LPG Bottle Distribution Cost using North West Corner and Least Cost Methods (Case Study at PT ABC in Samarinda)

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**Abstract.** PT ABC is a distributor of LPG cylinder products that has responsibilities to distribute 3kg LPG bottles to resellers (merchants/retail agents). The existing distribution route is not yet efficient, thus, there is room for reduction in the total distribution cost. The main goal of this research is to decide the optimized distribution method using North West Corner Method and Least Cost Method, with Modified Distribution Methods to check the results. The results of overall transportation expenses acquired using North West Corner with the assist of MODI and Least Cost Method produce the same cost, that's IDR 3,003,888 for one delivery or IDR 24,031,104 for 8 deliveries with a total of 48,000 cylinders each month. The of Least Cost Method in proven effective since it can reduce the total cost up to 46.6%.

**Keywords:** LPG cylinders, Distribution, North west corner, Least cost, MODI

## 1 Introduction

The relationship between a company and its customers is always based on demand and supply, so there will always be distribution activities, including the fulfillment of energy demand. As one of energy sources, bottled Liquefied Petroleum Gas (LPG) is highly needed by the commercial and residential sectors in Indonesia. With long distirbution chain that involves reverse logistics for the empty cylinders, last-mile delivery done through retail agents, and various bottled sizes (3 kgs, 12 kgs, and 50 kgs), the distribution activities of this energy source has its own challenges.

Because of its long, unique distribution process, the distribution network of bottled LPG should be arranged „strategically," compromising the need of achieving good competitive position while keeping the cost low [1]. One of the most effective ways to achieve a competitive distribution strategy is through transportation. PT ABC is one of many LPG agents in the city

ICO-SEID 2022, November 23-24, Jakarta, Indonesia

DOI 10.4108/eai.23-11-2022.2339153

of Samarinda, East Kalimantan. It does not have any distribution strategy yet. To get an optimized, efficient and effective dstribution, PT ABC should plan the transportation strategy, started with route optimization or simply said as the transportation modelling. This model will find the least-cost of shipping supplies of subsidized LPG bottles from the points of origin to the points of destination. To apply transportation model, the data that should be provided includes the origin points and the capacity or supply per period of each origin, the destination points and the demand per period at each, and the cost of shipping from one unit from each origin to each destination [2].

The first stage to solve a transportation model problem is finding the initial feasible scenario by applying either North West Corner (NWC) or Least Cost Method (LCM). Optimizing distribution pattern to reduce distance traveled or total transport costs is the main purpose of learning transportation model [3]. Since PT ABC has five facilities that functions as the supply points and six destinations points, a good distribution planning is mandatory to minimize the total transportation costs (the existing cost is IDR 45 millions per month to deliver the LPG bottles to five retail agents). The why-why diagram to illustrate the problem faced by PT ABC can be seen in the following **Figure 1**.

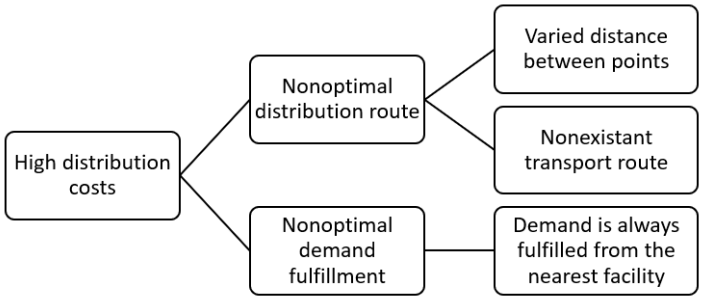


**Fig. 1.** Why-why Diagram of PT ABC‘s transportation problem

As seen in **Figure 1** above, there are two main causes of the high total distribution cost: nonoptimal distribution route because there is not any transportation route planning and nonoptimal demand fulfillment because no demand allocation strategy yet. For PT ABC, there are five facilities that can fulfill demand to six destination points. Each demand is always fulfilled by the nearest facility. To solve this subsidized LPG distribution problem, this research focuses in analyzing the transportation model that can provide the optimizied total distribution costs through allocating demand and deciding transport routes.

There are three methods that can be used to plan and compute optimal demand fulfillment: Vogel Approximation Method (VAM), North West Corner (NWC), and Least Cost Method (LCM). The followings explain in details the difference between the three methods.

a. Vogel Approximation Method (VAM) or the iterative procedure calculated to find out the initial feasible solution of the transportation problem, which is based on the relative magnitudes of the unit shipping costs rather than the absolute values [4]; or
b. North West Corner (NWC) method, the easiest way to find the total transportation cost, based on the normative rules or supply allocation in the transportation matrix without

consideration in the economic framework. It is always started by fulfilling all demand of the leftmost column with the supply from the first row in the allocation matrix [5]; or

c. Least Cost Method (LCM) which is actually a popular heuristics algorithm developed by Dantzig in 1963. This method is similar to the Spanning Tree Approach where demand allocation is first fulfilled by the lowest distribution cost cell to have the least cost of transport [6]. In a certain condition, allocating demand can be done randomly. This method is the easiest heuristics, but it consumes more time to find the lowest cost in transportation matrix [7].

In this research, the first iteration will be completed through the last two methods: NWC and LCM, while Modified Distribution (MODI) method is going to be applied when the cost is not yet considered optimum. This method is a developed stepping stone method from the case of transportation model. MODI studies the minimization of transport cost to fulfill the demand of a number of supply points to several destinations. The objective is to develop and integral transportation schedule that meets all demands at a minimum cost [8].

A number of research using two step exact algorithms, or the combination of VAM, NCW, or LCM with MODI, have already been done, such as the reduction in rice distribution cost using both VAM and MODI [9], the optimum building material distribution cost using NCW and MODI [10], and also the use of LCM and MODI to optimize the distribution process of Petrogranik (organic) fertilizer [11].

## 2 Research Methodology

Since this research is about optimizing distribution routes, the objective function is stated as follows:

$$\text{Min } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij} \quad (1)$$

With the following constraints:

$$\sum_{i=1}^{m} X_{ij} = a_i : i = 1,2\ldots,m \quad (2)$$

$$\sum_{i=1}^{n} X_{ij} = b_i : j = 1,2\ldots,n \quad (3)$$

Where:
$Z$ = Total transportation costs
$C_{ij}$ = Transportation cost for each product from supply point i to destination point j
$X_{ij}$ = Number of products distributed from supply point i to destination point j
$a_i$ = Maximum capacity of supply point i
$b_j$ = Demand of destination point j
$m$ = Number of supply points
$n$ = Number of demand points

To simplify the problem, the following assumptions are used while solving the model:
1. The distribution of bottled LPG is done twice a week (8 times a month);
2. Truck capacity for each delivery is 3,000 LPG cylinders (bottles);

3. PT ABC never experiences any stockout of subsidized LPG products.

While the stages of completing this research is shown in the following **Figure 2.**

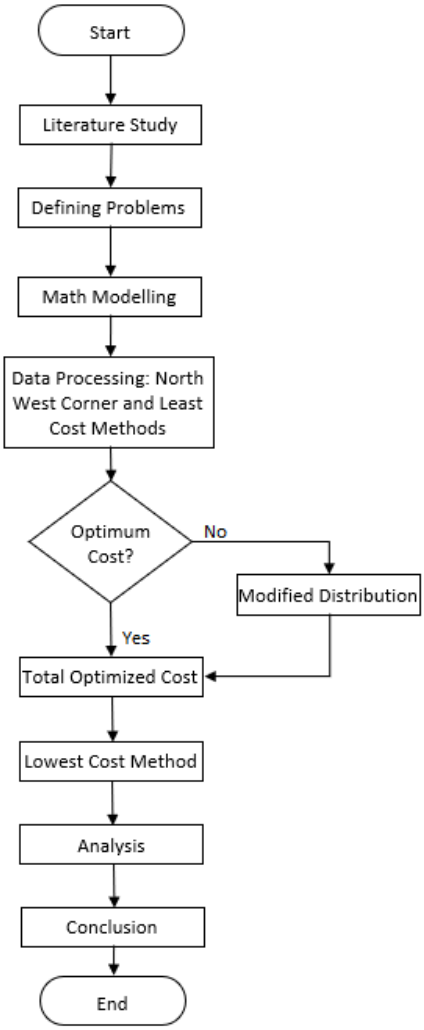


**Fig. 2.** Research Flowchart

As described in **Figure 2**, the transportation route strategy is started by iterating total distribution costs using North West Corner (NWC) method and Least Cost Method (LCM). When the optimum cost is not achieved, another step is taken: the Modified Distribution method (MODI). The steps taken to complete MODI are as follows [12]:

a. Computing each value of every row and column following this formula:

$$u_i + v_j = c_{ij} \tag{4}$$

Where $u_i$ = value of a certain cell based on the row
$v_j$ = value of a certain cell on the column
$c_{ij}$ = cost for each cell

b. Substituting the value of $u_i = 0$;

c. Calculating the opportunity cost of the unoccupied cells by using the following formula:

$$c_{ij} - (u_i + v_j) \quad (5)$$

d. Choosing the largest positive opportunity cost, starting from the unoccupied cell and assigning minus and plus signs alternatively;
e. Repeat the iteration.

# 3 Result and Discussion

## 3.1 Dataset

PT ABC distributes subsized LPG bottles through 5 facilities to fulfill demands of 6 retail agents. For each delivery, this company transports 6,000 botlles with the twice a week cycle. The dataset used for this research is secondary data taken from Ratnasari et.al. research in 2019 [13]. The following Table 1 describes the average cost of distribution by PT ABC:

**Table 1.** Distribution Cost

| **Facility** | ***Average Cost* (IDR)** | ***Max Cost* (IDR)** | ***Min Cost* (IDR)** |
|---|---|---|---|
| 1 | 1,403,750 | 1,950,000 | 1,170,000 |
| 2 | 1,570,000 | 1,837,500 | 1,350,000 |
| 3 | 1,503,750 | 1,762,500 | 1,237,500 |
| 4 | 1,405,000 | 1,762,500 | 1,237,500 |
| 5 | 1,616,000 | 2,100,000 | 1,387,500 |

Based on Table 1, facility number 5 has the highest average distribution cost, while the lowest average is facility number 1. The illustration of transport completed with the average stock and demand of each point can be seen in the following **Figure 3**, while in Table 2 illustrates the transportation matrix.

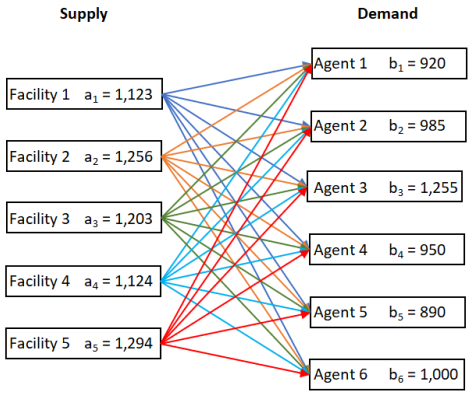


**Fig. 1.** Transport Network of PT ABC

**Table 2.** Transportation Matrix

| Origin \ Destination | 1 | 2 | 3 | 4 | 5 | 6 | Supply |
|---|---|---|---|---|---|---|---|
| **1** | 152 | 934 | 934 | 1,738 | 913 | 956 | 1,123 |
| **2** | 1,756 | 319 | 878 | 1,317 | 1,038 | 319 | 1,256 |
| **3** | 1,330 | 1,296 | 102 | 2,251 | 443 | 205 | 1,203 |
| **4** | 525 | 1,002 | 715 | 1,955 | 692 | 739 | 1,124 |
| **5** | 1,438 | 863 | 246 | 2,506 | 329 | 246 | 1,294 |
| **Demand** | **920** | **985** | **1,255** | **950** | **890** | **1,000** | **6,000** |

## 3.2 Calculation

The existing (baseline) condition requires PT ABC to spend IDR 45,000,000 for distribution cost every month. The first calculation for this research is started with the North West Corner (NWC) method as described in Table 3. The total distribution cost following this method is IDR 3,812,054 per delivery.

**Table 3.** North West Corner Method Calculation

| Origin \ Destination | 1 | 2 | 3 | 4 | 5 | 6 | Supply |
|---|---|---|---|---|---|---|---|
| 1 | **920** 152 | **203** 934 | 934 | 1,738 | 913 | 956 | 1,123 |
| 2 | 1,756 | **782** 319 | **474** 878 | 1,317 | 1,038 | 319 | 1,256 |
| 3 | 1,330 | 1,296 | **781** 102 | **422** 2,251 | 443 | 205 | 1,203 |
| 4 | 525 | 1,002 | 715 | **528** 1,955 | **596** 692 | 739 | 1,124 |
| 5 | 1,438 | 863 | **52** 246 | 2,506 | **294** 329 | **1,000** 246 | 1,294 |
| **Demand** | **920** | **985** | **1,255** | **950** | **890** | **1,000** | **6,000** |

Transport cost = (920×152) + (203×934) + (782×319) + (474×878) + (781×102) + (422×2,251) + (528×1,955) + (596×692) + (294×329) + (1,000×246) = **IDR 3,812,054**

Computing $U_i$ and $V_j$; $U_i = 0$, A = facility; B = retail agent

| | | | |
|---|---|---|---|
| $A_1B_1$ : | $v_1 + u_1 = 152$ | $v_1 = 152 - 0$ | = 152 |
| $A_1B_2$ : | $v_2 + u_1 = 934$ | $v_2 = 934 – 0$ | = 934 |
| $A_2B_2$ : | $v_2 + u_2 = 319$ | $u_2 = 319 – 934$ | = -615 |
| $A_2B_3$ : | $v_3 + u_2 = 878$ | $v_3 = 878 - (-615)$ | = 1,493 |
| $A_3B_3$ : | $v_3 + u_3 = 102$ | $u_3 = 102 – 1,493$ | = -1,391 |
| $A_3B_4$ : | $v_4 + u_3 = 2,251$ | $v_4 = 2,251 - (-1,391)$ | = 3,642 |
| $A_4B_4$ : | $v_4 + u_4 = 1,955$ | $u_4 = 1,955 – 3642$ | = -1,687 |
| $A_4B_5$ : | $v_5 + u_4 = 692$ | $v_5 = 692 - (-1,687)$ | = 2,379 |
| $A_5B_5$ : | $v_5 + u_5 = 329$ | $u_5 = 329 – 2,379$ | = -2,050 |
| $A_5B_6$ : | $v_6 + u_5 = 246$ | $v_6 = 246 - (-2,050)$ | = 2,296 |

Cost $C_{ij}$ for every route:

| | | | |
|---|---|---|---|
| $A_1B_3$ : | $\Delta_{13} = c_{13} - ( u_1 + v_3 )$ | = 934 - ( 0 + 1,493 ) | = **-559** |
| $A_1B_4$ : | $\Delta_{14} = c_{14} - ( u_1 + v_4 )$ | = 1,738 - ( 0 + 3,642 ) | = **-1,904** |
| $A_1B_5$ : | $\Delta_{15} = c_{15} - ( u_1 + v_5 )$ | = 913 - ( 0 + 2,379 ) | = **-1,466** |
| $A_1B_6$ : | $\Delta_{16} = c_{16} - ( u_1 + v_6 )$ | = 956 - ( 0 + 2,296 ) | = **-1,340** |
| $A_2B_1$ : | $\Delta_{21} = c_{21} - ( u_2 + v_1 )$ | = 1,756 - ( -615 + 152 ) | = 2,219 |
| $A_2B_4$ : | $\Delta_{24} = c_{24} - ( u_2 + v_4 )$ | = 1,317 - ( -615 + 3,642 ) | = **-1,710** |

$A_2B_5$ : $\Delta_{25} = c_{25} - ( u_2 + v_5 )$ = 1,038 - ( -615 + 2,379 ) = **-726**
$A_2B_6$ : $\Delta_{26} = c_{26} - ( u_2 + v_6 )$ = 319 - ( -615 + 2,296 ) = **-1,362**
$A_3B_1$ : $\Delta_{31} = c_{31} - ( u_3 + v_1 )$ = 1,330 - ( -1,391 + 152 ) = 2,569
$A_3B_2$ : $\Delta_{32} = c_{32} - ( u_3 + v_2 )$ = 1,296 - ( -1,391 + 934 ) = 1,753
$A_3B_5$ : $\Delta_{35} = c_{35} - ( u_3 + v_5 )$ = 443 - ( -1,391 + 2,379 ) = **-545**
$A_3B_6$ : $\Delta_{36} = c_{36} - ( u_3 + v_6 )$ = 205 - ( -1,391 + 2,296 ) = **-700**
$A_4B_1$ : $\Delta_{41} = c_{41} - ( u_4 + v_1 )$ = 525 - ( -1,687 + 152 ) = 2,060
$A_4B_2$ : $\Delta_{42} = c_{42} - ( u_4 + v_2 )$ = 1,002 - ( -1,687 + 934 ) = 1,755
$A_4B_3$ : $\Delta_{43} = c_{43} - ( u_4 + v_3 )$ = 715 - ( -1,687 + 1,493 ) = 909
$A_4B_6$ : $\Delta_{46} = c_{46} - ( u_4 + v_6 )$ = 739 - ( -1,687 + 2,296 ) = 130
$A_5B_1$ : $\Delta_{51} = c_{51} - ( u_5 + v_1 )$ = 1,438 - ( -2,050 + 152 ) = 3,336
$A_5B_2$ : $\Delta_{52} = c_{52} - ( u_5 + v_2 )$ = 863 - ( -2,050 + 934 ) = 1,979
$A_5B_3$ : $\Delta_{53} = c_{53} - ( u_5 + v_3 )$ = 246 - ( -2,050 + 1,493 ) = 803
$A_5B_4$ : $\Delta_{54} = c_{54} - ( u_5 + v_4 )$ = 2,506 - ( -2,050 + 3,642 ) = 914

Applying NWC method resulted to nonoptimal transportation cost, since there are negative values while computing the $C_{ij}$ with the highest value is at A1B4 (-1,904). That is why, another iteration with Modified Distribution (MODI) method is needed to get an optimal result as described in the following Table 4.

**Table 4.** MODI method for NWC second iteration

| Origin \ Destination | 1 | 2 | 3 | 4 | 5 | 6 | Supply |
|---|---|---|---|---|---|---|---|
| **1** | 152 **920** | 934 | 934 | 1,738 **203** | 913 | 956 | 1,123 |
| **2** | 1,756 | 319 **985** | 878 | 1,317 **271** | 1038 | 319 | 1,256 |
| **3** | 1,330 | 1,296 | 102 **1,203** | 2,251 | 443 | 205 | 1,203 |
| **4** | 525 | 1,002 | 715 | 1,955 **476** | 692 **648** | 739 | 1,124 |
| **5** | 1,438 | 863 | 246 **52** | 2,506 | 329 **242** | 246 **1,000** | 1,294 |
| **Demand** | **920** | **985** | **1,255** | **950** | **890** | **1,000** | **6,000** |

Transport cost = (920×152) + (203×1,738) + (985×319) + (271×1,317) + (1,203×102) + (476×1,955) + (648×692) + (52×246) + (242×329) + (1,000×246) = **IDR 3,003,888**

Computing $U_i$ and $V_j$; $U_i = 0$, A = facility; B = retail agent

| | | | |
|---|---|---|---|
| $A_5B_3$ : | $v_3 + u_5 = 246$ | $v_3 = 246 - 0$ | $= 246$ |
| $A_5B_5$ : | $v_5 + u_5 = 329$ | $v_5 = 329 - 0$ | $= 329$ |
| $A_5B_6$ : | $v_6 + u_5 = 246$ | $v_6 = 246 - 0$ | $= 246$ |
| $A_3B_3$ : | $v_3 + u_3 = 102$ | $u_3 = 102 - 246$ | $= -144$ |
| $A_4B_5$ : | $v_5 + u_4 = 692$ | $u_4 = 692 - 329$ | $= 363$ |
| $A_4B_4$ : | $v_4 + u_4 = 1{,}955$ | $v_4 = 1{,}955 - 363$ | $= 1{,}592$ |
| $A_1B_4$ : | $v_4 + u_1 = 1{,}738$ | $u_1 = 1{,}738 – 1{,}592$ | $= 146$ |
| $A_2B_4$ : | $v_4 + u_2 = 1{,}317$ | $u_2 = 1{,}317 – 1{,}592$ | $= -275$ |
| $A_1B_1$ : | $v_1 + u_1 = 152$ | $v_1 = 152 - 146$ | $= 6$ |
| $A_2B_2$ : | $v_2 + u_2 = 319$ | $v_2 = 319 - (-275)$ | $= 594$ |

Cost $C_{ij}$ for every route:

| | | | |
|---|---|---|---|
| $A_1B_2$ : | $\Delta_{12} = c_{12} - ( u_1 + v_2 )$ | $= 934 - ( 146 + 594 )$ | $= 194$ |
| $A_1B_3$ : | $\Delta_{13} = c_{13} - ( u_1 + v_3 )$ | $= 934 - ( 146 + 246 )$ | $= 542$ |
| $A_1B_5$ : | $\Delta_{15} = c_{15} - ( u_1 + v_5 )$ | $= 913 - ( 146 + 329 )$ | $= 438$ |
| $A_1B_6$ : | $\Delta_{16} = c_{16} - ( u_1 + v_6 )$ | $= 956 - ( 146 + 246 )$ | $= 564$ |
| $A_2B_1$ : | $\Delta_{21} = c_{21} - ( u_2 + v_1 )$ | $= 1756 - ( -275 + 6 )$ | $= 2{,}025$ |
| $A_2B_3$ : | $\Delta_{23} = c_{23} - ( u_2 + v_3 )$ | $= 878 - ( -275 + 246 )$ | $= 907$ |
| $A_2B_5$ : | $\Delta_{25} = c_{25} - ( u_2 + v_5 )$ | $= 1{,}038 - ( -275 + 329 )$ | $= 984$ |
| $A_2B_6$ : | $\Delta_{26} = c_{26} - ( u_2 + v_6 )$ | $= 319 - ( -275 + 246 )$ | $= 348$ |
| $A_3B_1$ : | $\Delta_{31} = c_{31} - ( u_3 + v_1 )$ | $= 1{,}330 - ( -144 + 6 )$ | $= 1{,}468$ |
| $A_3B_2$ : | $\Delta_{32} = c_{32} - ( u_3 + v_2 )$ | $= 1{,}296 - ( -144 + 594 )$ | $= 846$ |
| $A_3B_4$ : | $\Delta_{34} = c_{34} - ( u_3 + v_4 )$ | $= 2{,}251 - ( -144 + 1{,}592 )$ | $= 803$ |
| $A_3B_5$ : | $\Delta_{35} = c_{35} - ( u_3 + v_5 )$ | $= 443 - ( -144 + 329 )$ | $= 258$ |
| $A_3B_6$ : | $\Delta_{36} = c_{36} - ( u_3 + v_6 )$ | $= 205 - ( -144 + 246 )$ | $= 103$ |
| $A_4B_1$ : | $\Delta_{41} = c_{41} - ( u_4 + v_1 )$ | $= 525 - ( 363 + 6 )$ | $= 156$ |
| $A_4B_2$ : | $\Delta_{42} = c_{42} - ( u_4 + v_2 )$ | $= 1{,}002 - ( 363 + 594 )$ | $= 45$ |
| $A_4B_3$ : | $\Delta_{43} = c_{43} - ( u_4 + v_3 )$ | $= 715 - ( 363 + 246 )$ | $= 106$ |
| $A_4B_6$ : | $\Delta_{46} = c_{46} - ( u_4 + v_6 )$ | $= 739 - ( 363 + 246 )$ | $= 130$ |
| $A_5B_1$ : | $\Delta_{51} = c_{51} - ( u_5 + v_1 )$ | $= 1{,}438 - ( 0 + 6 )$ | $= 1{,}432$ |
| $A_5B_2$ : | $\Delta_{52} = c_{52} - ( u_5 + v_2 )$ | $= 863 - ( 0 + 594 )$ | $= 269$ |
| $A_5B_4$ : | $\Delta_{54} = c_{54} - ( u_5 + v_4 )$ | $= 2{,}506 - ( 0 + 1592 )$ | $= 914$ |

Applying MODI resulted to an optimized distribution cost (IDR 3,003,888) for each delivery, thus the total distribution cost $C_{ij}$ for each month is IDR 24,031,104 or 46.6% lower than the existing.

The second method trial is using Least Cost as described in the following Table 5.

**Table 5.** Least Cost Method Calculation

| Origin \ Destination | 1 | 2 | 3 | 4 | 5 | 6 | Supply |
|---|---|---|---|---|---|---|---|
| 1 | 152 **920** | 934 | 934 | 1,738 **203** | 913 | 956 | 1,123 |
| 2 | 1,756 | 319 **985** | 878 | 1,317 **271** | 1,038 | 319 | 1,256 |
| 3 | 1,330 | 1,296 | 102 **1,203** | 2,251 | 443 | 205 | 1,203 |
| 4 | 525 | 1,002 | 715 | 1,955 **476** | 692 **648** | 739 | 1,124 |
| 5 | 1,438 | 863 | 246 **52** | 2,506 | 329 **242** | 246 **1,000** | 1,294 |
| **Demand** | **920** | **985** | **1,255** | **950** | **890** | **1,000** | **6,000** |

Transport cost = (920×152) + (203×1,738) + (985×319) + (271×1,317) + (1,203×102) + (476×1,955) + (648×692) + (52×246) + (242×329) + (1,000×246) = **IDR 3,003,888**

Computing $U_i$ and $V_j$; $U_i = 0$, A = facility; B = retail agent

$A_5B_3$ : $v_3 + u_5 = 246$ $v_3 = 246 - 0$ = 246
$A_5B_5$ : $v_5 + u_5 = 329$ $v_5 = 329 - 0$ = 329
$A_5B_6$ : $v_6 + u_5 = 246$ $v_6 = 246 - 0$ = 246
$A_3B_3$ : $v_3 + u_3 = 102$ $u_3 = 102 - 246$ = -144
$A_4B_5$ : $v_5 + u_4 = 692$ $u_4 = 692 - 329$ = 363
$A_4B_4$ : $v_4 + u_4 = 1{,}955$ $v_4 = 1{,}955 - 363$ = 1,592
$A_1B_4$ : $v_4 + u_1 = 1{,}738$ $u_1 = 1{,}738 – 1{,}592$ = 146
$A_2B_4$ : $v_4 + u_2 = 1{,}317$ $u_2 = 1{,}317 – 1{,}592$ = -275
$A_1B_1$ : $v_1 + u_1 = 152$ $v_1 = 152 - 146$ = 6
$A_2B_2$ : $v_2 + u_2 = 319$ $v_2 = 319 - (-275)$ = 594

Cost $C_{ij}$ for every route:

$A_1B_2$ : $\Delta_{12} = c_{12} - ( u_1 + v_2 )$ = 934 - ( 146 + 594 ) = 194
$A_1B_3$ : $\Delta_{13} = c_{13} - ( u_1 + v_3 )$ = 934 - ( 146 + 246 ) = 542
$A_1B_5$ : $\Delta_{15} = c_{15} - ( u_1 + v_5 )$ = 913 - ( 146 + 329 ) = 438
$A_1B_6$ : $\Delta_{16} = c_{16} - ( u_1 + v_6 )$ = 956 - ( 146 + 246 ) = 564
$A_2B_1$ : $\Delta_{21} = c_{21} - ( u_2 + v_1 )$ = 1756 - ( -275 + 6 ) = 2,025
$A_2B_3$ : $\Delta_{23} = c_{23} - ( u_2 + v_3 )$ = 878 - ( -275 + 246 ) = 907

$A_2B_5$ : $\Delta_{25} = c_{25} - ( u_2 + v_5 )$ = 1,038 - ( -275 + 329 ) = 984
$A_2B_6$ : $\Delta_{26} = c_{26} - ( u_2 + v_6 )$ = 319 - ( -275 + 246 ) = 348
$A_3B_1$ : $\Delta_{31} = c_{31} - ( u_3 + v_1 )$ = 1,330 - ( -144 + 6 ) = 1,468
$A_3B_2$ : $\Delta_{32} = c_{32} - ( u_3 + v_2 )$ = 1,296 - ( -144 + 594 ) = 846
$A_3B_4$ : $\Delta_{34} = c_{34} - ( u_3 + v_4 )$ = 2,251 - ( -144 + 1,592 ) = 803
$A_3B_5$ : $\Delta_{35} = c_{35} - ( u_3 + v_5 )$ = 443 - ( -144 + 329 ) = 258
$A_3B_6$ : $\Delta_{36} = c_{36} - ( u_3 + v_6 )$ = 205 - ( -144 + 246 ) = 103
$A_4B_1$ : $\Delta_{41} = c_{41} - ( u_4 + v_1 )$ = 525 - ( 363 + 6 ) = 156
$A_4B_2$ : $\Delta_{42} = c_{42} - ( u_4 + v_2 )$ = 1,002 - ( 363 + 594 ) = 45
$A_4B_3$ : $\Delta_{43} = c_{43} - ( u_4 + v_3 )$ = 715 - ( 363 + 246 ) = 106
$A_4B_6$ : $\Delta_{46} = c_{46} - ( u_4 + v_6 )$ = 739 - ( 363 + 246 ) = 130
$A_5B_1$ : $\Delta_{51} = c_{51} - ( u_5 + v_1 )$ = 1,438 - ( 0 + 6 ) = 1,432
$A_5B_2$ : $\Delta_{52} = c_{52} - ( u_5 + v_2 )$ = 863 - ( 0 + 594 ) = 269
$A_5B_4$ : $\Delta_{54} = c_{54} - ( u_5 + v_4 )$ = 2,506 - ( 0 + 1592 ) = 914

Applying the Least Cost Method developed an optimized result (the same transportation costs result compared to trial 1 using NWC and MODI methods). The first iteration of LCM reported the total transportation cost is IDR 3,003,888 per delivery or the total distribution cost a month is IDR 24,031,104. This total cost successfully reduced as much as 46.6% of the baseline.

### 3.3 Analysis

The following Table 6 illustrates the comparisons between NWC and LCM methods.

**Table 6.** Comparisons between North West Corner and Least Cost Method

| Components | North West Corner | Least Cost Method |
|---|---|---|
| *Initial* bfs | nonoptimal | optimal |
| bfs initial cost (IDR) | 3,812,054 | 3,003,888 |
| Number of iterations | 2 | - |
| Total Cost (for each delivery) | **3,003,888** | **3,003,888** |

Table 6 describes the initial Basic Feasible Solution (bfs), the number of iterations, and the total cost for every delivery of each method used. The NWC resulted nonoptimal since there are negative values while computing $C_{ij}$ cost and resulted to the total cost of IDR 3,812,054 for each delivery or as much as IDR 30,496,432 each month. This result is 32.2% lower than the existing cost which is IDR 45,000,000. To further optimize the result, MODI method is applied with 2 iterations, resulting to IDR 3,003,888 for distribution cost of each delivery.

Looking at LCM, it gave optimal result while calculating the intial bfs. The cost it produced is IDR 3,003,888 per delivery and it is actually the same cost with the NWC method after the second iteration with MODI. This result shows that the monthly cost of IDR 24,031,104 or the 46.6% reduction in total distribution cost can be obtained by simply applying one of these two optimization methods for PT ABC's route distribution strategy. From the calculation and the results in table 6, LCM is proven more effective compared to NWC since it can find the lowest cost for the whole transportation matrix.

## 4 Conclusion and Further Research

By applying North West Corner with Modified Distribution method and comparing it with Least Cost Method, PT ABC is able to get a more effective and efficient distribution strategy. Both NWC+MODI and LCM resulted to a 46.6% reduction in total distribution cost, since the two methods reduce the total distribution cost from IDR 45,000,000 to IDR 24,031,104 per month. For further research, the application of Vogel Approximation Method (VAM) with more destination (agents/resellers) points or the other heuristics and metaheuristics methods can be completed to check for a more hollistic distribution strategy.

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