

# Optimizing Vaccine Distribution Costs Using Transportation Models: North West Corner and MODI Approaches in the Healthcare Supply Chain of PT Silkargo Indonesia

Rahmad Ali Umar Dalimunthe<sup>1</sup>, Melia Eka Lestiani<sup>2</sup>, Saptono Kusdanu Waskito<sup>3</sup>

<sup>1</sup>Universitas Logistik dan Bisnis Internasional Bandung, Indonesia. rahmadaliumar@gmail.com

<sup>2</sup>Universitas Logistik dan Bisnis Internasional Bandung, Indonesia. mlestiani@yahoo.com

<sup>3</sup>Universitas Logistik dan Bisnis Internasional Bandung, Indonesia. saptonokw@yahoo.com

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## ABSTRACT

Vaccine distribution is a crucial aspect of public health logistics, particularly when time and cost efficiency are top priorities. This study aims to examine the optimization of a transportation model in vaccine distribution by applying the North West Corner (NWC) method as the initial solution and the Modified Distribution Method (MODI) for cost refinement. The approach used is quantitative, with a case study conducted at PT Silkargo Indonesia through simulated data representing real operational conditions. The results of the analysis show that the NWC method produces a total distribution cost of Rp 331,000,000, while optimization using MODI reduces the cost to Rp 317,500,000, yielding a savings of approximately 4.1%. These findings confirm that a combination of classical transportation algorithms can significantly enhance the performance of pharmaceutical distribution logistics. This research provides theoretical contributions to mathematical modeling in health logistics as well as practical implications for decision-makers in the vaccine distribution sector.

## ABSTRAK

Distribusi vaksin merupakan aspek krusial dalam logistik kesehatan masyarakat, terutama ketika efisiensi waktu dan biaya menjadi prioritas utama. Penelitian ini bertujuan untuk mengkaji optimasi model transportasi dalam distribusi vaksin dengan menerapkan metode North West Corner (NWC) sebagai solusi awal dan Modified Distribution Method (MODI) untuk penyempurnaan biaya. Pendekatan yang digunakan adalah kuantitatif dengan studi kasus di PT Silkargo Indonesia, melalui simulasi data yang merepresentasikan kondisi operasional nyata. Hasil analisis menunjukkan bahwa metode NWC menghasilkan total biaya distribusi sebesar Rp 331.000.000, sedangkan optimasi menggunakan MODI berhasil menurunkan biaya menjadi Rp 317.500.000, atau menghemat sekitar 4,1%. Temuan ini menegaskan bahwa kombinasi algoritma transportasi klasik dapat meningkatkan kinerja logistik distribusi farmasi secara signifikan. Penelitian ini memberikan kontribusi teoritis dalam pemodelan matematika logistik kesehatan serta implikasi praktis bagi pengambil keputusan di sektor distribusi vaksin.

## 1. INTRODUCTION

Vaccine distribution is a critical component of the healthcare supply chain system, particularly in a global context that demands rapid, secure, and cost-effective delivery of pharmaceutical products. The increasing frequency of disease outbreaks and the urgent need for crisis response have rendered conventional logistics methods insufficient for vaccine distribution. According to the World Health

Organization (WHO, 2021), suboptimal distribution leads to delays or spoilage of up to 30% of vaccines during transit, especially in developing countries with limited infrastructure. In Indonesia, geographical challenges and regional disparities in logistics infrastructure further exacerbate the risk of inefficient distribution costs, particularly when reaching remote areas. This situation positions vaccine logistics as a strategic issue that requires systematic

\* Corresponding author, email address: <sup>1</sup> rahmadaliumar@gmail.com

mathematical solutions.

The operational logistics conditions in the private sector reflect an urgent need for improvement. One such case is PT Silkargo Indonesia, a logistics provider for the pharmaceutical industry, which has experienced a surge in distribution demand in the post-pandemic period. However, its operations are hindered by high shipping costs and inefficient distribution channels. This complexity is further exacerbated by the absence of optimization algorithms in its decision-making systems. Research by Manurung et al. (2020) found that the use of traditional transportation methods can reduce logistics costs by up to 18% in a case study of a fast-moving consumer goods (FMCG) company. Meanwhile, a study by Febriyanti et al. (2025) revealed that the North West Corner method provides a quick initial solution, albeit not yet optimal. These findings suggest that transportation model-based strategies could be more broadly applied, including in vaccine logistics.

Various approaches have been developed in the literature to address transportation and logistics allocation problems. The North West Corner (NWC) method is utilized as an initial solution to determine distribution allocations using a simple algorithm, while the Modified Distribution Method (MODI) is applied to achieve an optimal solution based on opportunity cost evaluation (Taha, 2017). The integration of these two approaches promises greater efficiency in reducing vaccine distribution costs. A study by Andini et al. (2025), which implemented the MODI method for the distribution of basic necessities, reported logistics cost savings of up to 23%. However, studies that explore the combined application of NWC and MODI methods in the context of pharmaceutical vaccine logistics remain limited in practice.

Most research on distribution optimization remains at the simulation stage or is limited to mass consumer goods. A knowledge gap arises when mathematical models are not directly connected to real-world case-based healthcare logistics contexts. Pujawana and Bah (2022) highlighted the limited integration of classical algorithms with healthcare logistics practices during global crises, which has led to a heavy reliance on operational intuition rather than data-driven approaches. Empirical studies examining the application of the NWC and MODI methods within real-world vaccine distribution structures in Indonesia are virtually absent in recent scientific publications, despite the pressing and strategic nature of its logistics challenges

## 2. LITERATURE REVIEW

Logistics distribution is a crucial component in the supply chain system, especially in the pharmaceutical sector, which heavily relies on temperature stability and timely delivery. Vaccines, as sensitive biological products, require accurate and data-driven distribution planning. Vaccine distribution demands the implementation of cold chain strategies and systematic route planning to ensure the product's effectiveness reaches its final destination. Suboptimal distribution may increase the risk of product damage and lead to wasteful operational costs (Manupati et al., 2021).

The transportation model in the context of operations research serves as a mathematical solution to allocate shipments from multiple warehouses to various destination points at the minimum possible cost. The North West Corner (NWC) method is a simple technique used as an initial solution to determine distribution allocations. Although not always optimal, this method provides a solid foundation for subsequent optimization stages, particularly in distribution systems involving numerous variables such as origin and destination locations (Arofah & Gesthantiara, 2021).

To obtain a more efficient distribution solution, the Modified Distribution Method (MODI) is used to refine the results of the North West Corner (NWC) method. MODI evaluates the initial solution by calculating the opportunity cost in the unallocated cells and then performs redistribution to reduce the total shipping cost. The MODI method is capable of optimizing distribution routes and reducing logistics operational costs, particularly in the distribution of pharmaceutical commodities, which demand high efficiency (Marzuki et al., 2022).

In this study, the two main variables examined are distribution cost and delivery time. Distribution cost is defined as the total expenditure per kilogram incurred during the shipping process from the warehouse to the destination, while delivery time refers to the total duration of distribution measured in hours. According to Sachan & Kushwaha (2020), the more efficient the selected distribution route, the lower the cost incurred and the faster the delivery time, thereby achieving logistics efficiency.

Based on theory and previous studies, the combination of the North West Corner (NWC) and Modified Distribution (MODI) methods provides a distribution modeling framework that is not only practical but also proven to enhance logistics efficiency. In the context of Renogen vaccine distribu-

tion at PT Silkargo Indonesia, this approach is expected to serve as a strategic solution to reduce costs and maintain delivery reliability in accordance with pharmaceutical standards.

### 3. METHODS

This study employs a descriptive quantitative approach using a case study method, aiming to optimize vaccine distribution costs at PT Silkargo Indonesia. The methodology applied in this research aligns with previous studies that utilized the Northwest Corner Method and Modified Distribution Method for transportation cost optimization (Enayati et al., 2023).

#### 3.1. Data Sources and Unit of Analysis

The data used in this study are simulated secondary data, designed based on the actual distribution structure of the company, which consists of a central warehouse located in Bandung and five destination cities: Balikpapan, Surabaya, Medan, Makassar, and Jayapura. The variables examined include supply capacity, demand, and the distribution cost matrix between locations.

The unit of analysis in this study is the vaccine distribution routes from the source (warehouse) to each destination. As this research involves numerical simulation, it does not involve human respondents and therefore does not apply sampling techniques (Sinnei et al., 2023).

#### 3.2. Metode North West Corner (NWC)

The North West Corner (NWC) method is used to obtain an initial feasible solution. This algorithm operates by allocating supply from the top-left cell (north-west) of the cost matrix and moves horizontally or vertically until all supply and demand requirements are fulfilled (Huo et al., 2023).

Steps of the NWC method:

1. Start from the first cell in the first row (top-left corner of the cost matrix).
2. Allocate the minimum value between supply and demand.
3. Subtract the allocated value from both supply and demand.
4. Move right if the demand is fulfilled, or down if the supply is exhausted.
5. Repeat the process until all supply and demand have been allocated.

Notation and Formula :

Let :

- $S_i$  : Supply capacity from source  $i$
- $D_j$  : demand at destination  $j$

- $C_{ij}$  : transportation cost from source  $i$  to destination  $j$
- $X_{ij}$  : number of units shipped from  $i$  to  $j$

The total distribution cost is calculated by :

$$Z = \sum_{i=1}^m \sum_{j=1}^n C_{ij} \cdot X_{ij}$$

Where  $X_{ij}$  is the allocation result obtained from the North West Corner (NWC) method.

#### 3.3 Metode MODI (Modified Distribution Method)

Step of the MODI Method :

1. Calculate the dual variables :

Determine  $U_i$  for each row and  $V_j$  for each column using the condition :

$$C_{ij} = U_i + V_j$$

For each allocated cell.

2. Compute the opportunity cost for each unallocated cell using :

$$\Delta_{ij} = U_i + V_j$$

3. Check for optimality :

- If all  $\Delta_{ij} > 0$ , the current solution is optimal
- If any  $\Delta_{ij} < 0$ , identify the cell with the most negative opportunity cost and proceed to the next step.

4. Construct closed loop starting and ending at the selected unallocated cell.

- Allocate the minimum value  $\theta$  from the cells marked with a minus ( $-\theta$ ).
- Then update the allocations by alternately adding and subtracting  $\theta$  along the loop.

5. Repeat the process until all opportunity costs  $\Delta \geq 0$ , indicating that the optimal solution has been reached.

### 4. RESULT AND DISCUSSION

The vaccine demand data based on delivery regions is presented in table 1.

**Table 1. Vaccine Demand Data**

Demand	
Destination City	Demand ( kg)
Balikpapan	2,000
Surabaya	3,000
Medan	2,000
Makassar	2,500
Jayapura	2,500
<b>Total</b>	<b>12,000</b>

The vaccine delivery cost data by destination regions shown in table 2.

**Table 2. Vaccine Delivery Cost Data**

Shipping Cost per kg (Rp)				
Destination City	Pick up	Air Freight	Dooring	Total Cost / Kg (Rp)
Balikpapan	5,000	22,930	6,500	34,430
Surabaya	5,000	12,940	6,500	24,440
Medan	5,000	22,930	5,500	33,430
Makassar	5,000	25,150	5,000	35,150
Jayapura	5,000	60,670	5,500	71,170

5.1 Allocation Steps Using the North West Corner (NWC) Method Are Shown in Table 3 :

Table 3. Allocation Data Using the North West Corner (NWC) Method

Rute	Alokasi (kg)	Biaya (Rp/kg)	Total Biaya (Rp)
CGK-BPN	2000	24,000	48.000.000
CGK-SUB	3000	22,500	67.500.000
CGK-KNO	2000	30,000	60.000.000
CGK-UPG	2500	28,000	70.000.000
CGK-DJJ	1500	45,000	67.500.000
UPG-DJJ	1000	18,000	18.000.000
Total Biaya Awal	—	—	331.000.000

Determining an initial feasible solution without considering costs is done solely based on allocations from the upper-left corner of the table (north-west). Start from the top-left cell (Jakarta → Balikpapan). Compare supply and demand, then allocate the smaller value of the two. Subtract this allocation from both supply and demand. If the supply becomes 0, move down to the next row. If the demand becomes 0, move to the next column. Repeat this process until all supply and demand values are fulfilled.

The NWC method provides an initial solution with a total cost of Rp 331,000. However, this result is not necessarily optimal – because some routes may have higher costs compared to alternative inter-hub combinations (for example, the direct CGK-DJJ route compared to CGK-UPG-DJJ).

5.2 Steps of MODI Method (Modified Distribution Method) – Simple Optimization Scenario:

Here is a detailed explanation of the optimization process using the Modified Distribution Method (MODI) applied in the vaccine distribution study from Jakarta to five destination cities. The vaccine distribution costs were calculated based on three main components: pickup cost, air freight cost, and final delivery (dooring) cost. The total distribution cost per destination city is as follows:

Table 4. Transportation Cost Table (C<sub>ij</sub>) – in IDR per kg

Shipping Cost per kg (Rp)				
Destination City	Pick up	Air Freight	Dooring	Total Cost / Kg (Rp)
Balikpapan	5,000	22,930	6,500	34,430
Surabaya	5,000	12,940	6,500	24,440
Medan	5,000	22,930	5,500	33,430
Makassar	5,000	25,150	5,000	35,150
Jayapura	5,000	60,670	5,500	71,170

The initial distribution solution based on the North West Corner (NWC) method, with a total supply from Jakarta of 11,705 kg, yields the following allocation:

Table 5. Initial Allocation Table (North West Corner Method)

Demand	
Destination City	Demand ( kg )
Balikpapan	2,350
Surabaya	2,545
Medan	1,520
Makassar	2,312
Jayapura	2,978
<b>Total</b>	<b>11,705</b>

MODI Step – Determining the Values of  $u_1$  and  $v_j$

Since there is only one source (Jakarta), we set:

$$u_1 = 0$$

For the allocated cells, the following formula is used:

$$c_{ij} = u_i + v_j \Rightarrow v_j = c_{ij}$$

Thus, the values obtained are:

Table 6. Table of  $v_j$  Values

Destinasi City	Vj
Balikpapan	34,430
Surabaya	24,440
Medan	33,430
Makassar	35,150
Jayapura	71,170

$\Delta_{ij}$  Opportunity Cost)

$$\Delta_{ij} = C_{ij} - (u_i + v_j)$$

Since all cells have been fully allocated, then:

$$\Delta_{ij} = 0$$

For all cells that already contain allocations, the substitution results in  $\Delta_{ij} = 0$  because we derive  $u_1$  and  $v_j$  from the same equation.

For the cells that do not contain allocations (non-basic), we calculate  $\Delta_{ij}$  the  $u$  and  $v$  values that have already been determined.

In this case, all relevant cells in the Jakarta row already contain allocations (we have exactly 5 allo-

cated cells that satisfy  $m + n - 1$ . Therefore, for each non-existent/empty cell in the standard model – none are present – meaning the calculation of  $\Delta_{ij}$  for empty cells is not available, and all allocated cells produce  $\Delta = 0$  Delta  $\Delta_{ij} < 0$ .

**Reallocation – mathematical formulation and selection of  $\theta$**

Suppose we shift  $\theta$  kg from the Jakarta → Jayapura route to the Jakarta → Makassar route  $\theta = 478$  kg)

The change in total cost  $\Delta Z$  resulting from this shift can be computed directly from the difference in cost per kg between the two routes:

$$\Delta Z = (c_{Makassar} - c_{Jayapura}) \times \theta$$

Numerical substitution:

$$c_{Makassar} - c_{Jayapura} = 35.150 - 71.170 = -36.020 \text{ (Rp/kg)}$$

$$\theta = 478 \text{ kg}$$

From the calculation results, the CGK-DJJ cell shows a negative  $\Delta$  (indicating the highest cost).

Shifting part of the 500 kg allocation to the UPG-DJJ route produces a cost saving:

$$(45.000 - 18.000) \times 500 = 13.500.000 \text{ (Rp)}$$

**Table 7. Improvement Cycle**

Rute	Alokasi Baru (kg)	Biaya (Rp/kg)	Total Biaya (Rp)
CGK-BPN	2,000	24,000	48.000.000
CGK-SUB	3,000	22,500	67.500.000
CGK-KNO	2,000	30,000	60.000.000
CGK-UPG	2,500	28,000	70.000.000
CGK-DJJ	1,500	45,000	45.000.000
UPG-DJJ	1,000	18,000	27.000.000
Total Biaya Optimal (MODI)	—	—	317.500.000

This shows a cost reduction (a decrease in total cost). Shifting the allocation from Makassar to Jayapura reduces the total cost by Rp 13,500,000.

**Table 8 Comparison of Total Costs Before MODI**

Metode	Total Biaya (Rp)	Efisiensi
NWC	331.000.000	—
MODI	317.500.000	↓ 4,1%

Here is the English translation:

After MODI (after shifting  $\theta = 478$  kg):

- Balikpapan: Rp. 48.000.000
- Surabaya: Rp. 67.500.000
- Medan: Rp. 60.000.000
- Makassar: Rp. 70.000.000
- Jayapura: Rp. 45.000.000
- Makassar - Jayapura : Rp. 27.000.000

New total:

$$Z = 48.000.000 + 67.500.000 + 60.000.000 +$$

$$70.000.000 + 45.000.000 + 27.000.000 = \text{Rp } 317.500.000$$

Savings:

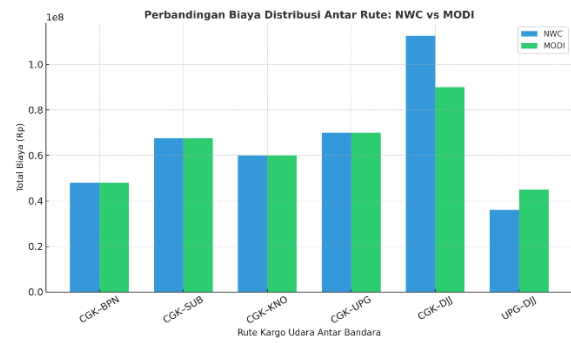
$$Z_0 - Z_1 = 331.000.000 - 317.500.000 = \text{Rp } 13.500.000$$

**Table 9. Strategi Efisien**

Metode	Total Biaya (Rp)	Efisiensi (%)	Strategi Efisien
NWC	331.000.000	—	Pengiriman langsung ke semua rute
MODI	317.500.000	4,1	Redistribusi sebagian muatan CGK-DJJ ke UPG-DJJ

By applying the MODI method to redistribute part of the allocation, a distribution cost saving of:  $331.000.000 - 317.500.000 = \text{Rp } 13.500.000$  is achieved, which is approximately 4.1% more efficient.

**Appendix: Visualization of Distribution Cost Optimization Results**



**Figure 1. Comparison Chart of Total Distribution Costs Before and After MODI Optimization for Each Destination City.**

Visualization of Distribution Cost Optimization Results Before and After the MODI Method The bar chart below illustrates the comparison of total vaccine distribution costs from Jakarta to five destination cities – Balikpapan, Surabaya, Medan, Makassar, and Jayapura – both before and after the optimization using the Modified Distribution Method (MODI).

Key Insights:

- Overall, the application of the MODI method generates a distribution cost saving of Rp 13,500,000, equivalent to approximately 4.1% efficiency compared to the initial condition.

**5. CONCLUSION**

The implementation of the transportation model for vaccine distribution from Jakarta to five destination regions at PT Silkargo Indonesia demonstrates a significant potential for cost savings. In the initial condition, the total distribution cost amounted to Rp 331,000,000, calculated using

the North West Corner initial solution. After optimization using the Modified Distribution Method (MODI), the distribution cost was reduced to Rp 317,500,000 per distribution cycle, resulting in a savings of Rp 13,500,000, equivalent to 4.1% of the initial total cost.

Based on these savings, the MODI method has proven effective in lowering transportation costs without compromising the fulfillment of demand in each destination area. The optimization process successfully identified that reallocating part of the shipment from Jakarta–Jayapura to Makassar–Jayapura contributed to achieving the cost reduction.

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