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# Implementation of the North West Corner Rule and Loop Construction Method to Minimize Material Distribution Cost on Ameroro Dam Access Road Project (Package II)

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***Abstract*—Construction projects consist of several work items and require resources to achieve the success of project work including materials and costs. The material required in large quantities in the implementation cannot always be fulfilled by one material source alone, therefore several material sources are needed so that the material demand needs can be met. Especially if it consists of several project locations and must be fulfilled by several material sources. This study aimed to minimize the distribution cost of class A LPA material from the source of material collection, namely in Konaweha, Pondidaha and Moramo to the Ameroro Dam Access Road project site (Package II), namely the Entrance to the Dam Segment 1, Segment 2 and Segment 3. The results were obtained by implementing the North West Corner Rule and Loop Construction methods can minimize the cost of material distribution from the initial solution of Rp. 1,887,700,000, - to Rp. 1,849,500,000, - so that the difference in cost reduction is Rp. 38,200,000, - with a minimum cost percentage of 2.02%.**

***Keywords—Projects, Materials, North West Corner Rule, Loop Construction***

## I. Introduction

The success of a construction services sector is highly dependent on optimizing three key elements, namely cost, time and quality. Each element has a vital role and is interrelated with each other. In the current era of engineering technology, delays often occur in project completion. Lack of effective planning in managing resources can have a negative impact on project execution.[1]

The distribution of materials certainly requires a lot of transportation costs, especially in the context of the access road to the Ameroro Dam, which includes the Dam Entrance Road in Segment-1, Segment-2, and Segment-3. This structure is legal and serves as the entrance to the dam, where materials are collected from more than one source of material location. Therefore, careful planning is required to ensure maximum efficiency in the distribution costs incurred. Therefore, alternatives are needed to help minimize these costs.

The transportation algorithm recognizes three kinds of methods to construct the initial table, namely:
a) Northwest Corner Rule Method
b) Least Cost Method
c) VAM or Vogell's Approximation Method

The three methods above each serve to determine the initial distribution allocation that will make all source capacity allocated to all destinations.

After the initial table preparation is complete, the next step is to test the optimality of the table to determine whether the total distribution cost is minimum. Mathematically, this test is done to ensure that the minimum objective function value has been achieved. There are two kinds of table optimality testing and minimum cost transportation algorithm:
a) Modified Distribution Method (MODI)
b) Loop Construction Method

In this research, the initial base solution uses the North West Corner method and the optimal solution uses the Loop Construction method

In the NWCR method, it can be determined from a reference, namely located in the upper left corner, then walking towards the right path. While the least cost method is the opposite, the least cost method has no reference point but focuses on the smallest value first.

The aim of the NCR method was to provide an initial solution in the transportation or distribution model of materials with the aim of minimizing the distribution costs of materials or any similar products. The objectives of the transportation model involve the following:
1. Production planning.

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2. Determine the amount that must be sent from each source based on its capacity to each destination, according to needs, so that total transportation costs can be minimized

The transportation distribution trajectory model from source to destination can be described as follows:

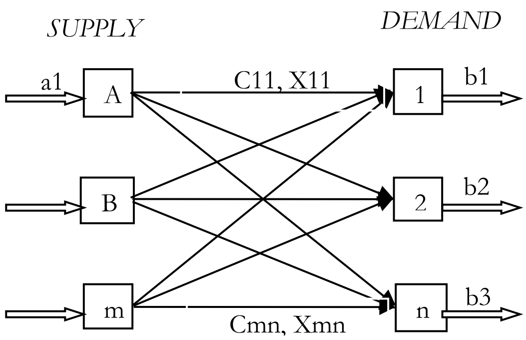


Figure 1. Transport distribution model of a Network

Formulation of a general linear programming model of a transportation problem:

| Z = C1X1 + C2X2 + C3X3 +........CNXN |
|---|

Z = Minimum costs amount (Rp.)
C = Transportation Unit Price between material source and destination (Rp./m³)
X = The amount or quantity transported from source to destination (m³)

## II. Research Methodology

The research location was on the Ameroro dam access road, Konawe Regency, Southeast Sulawesi Province (Package II), namely the Entrance Road to the Dam (Segment-1, L = 3355 m, (Segment-2, L = 2050 m) and the Entrance Road to the Valve House (Segment 3, L = 750 m) and there were three locations Material collection is in Konaweha, Pondidaha and Moramo.

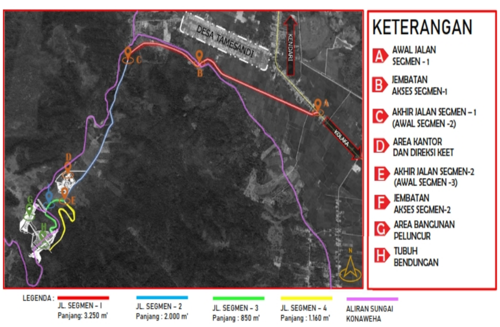


Figure 2. Research sites

The model applied in this research was the transportation model, which focused on minimal cost planning to distribute goods from various material sources to certain destinations, such as Segment 1, Segment 2, and Segment 3.

**1. Northwest Corner Rule Method**

The Northwest Corner Rule method was the method used as the initial solution in determining the material distribution model. The steps can be explained as follows:

a. Start from the top left corner (northwest of the table) and allocate as much as possible without exceeding supply and demand constraints.
b. Delete any rows or columns that can no longer be allocated, then allocate as many as possible to the box next to the undeleted rows or columns. If a column or row is exhausted, move diagonally to the next square.
c. Continue the process until all offers have been allocated and demand requirements have been met.

After all demand requirements are met, the next step was to carry out calculations to determine whether the composition at this stage is optimal using the multipliers method. If the table has not reached the minimum cost for non-basic unit costs, then the process continues with the loop construction method.

**2. Loop Construction Method.**

The steps for testing the Loop Construction method were carried out as follows:

a. Select an unused box to evaluate.
b. Starting from that square, find a closed path that returns to the starting square through the squares in use, with vertical and horizontal movement permitted. Empty or filled boxes can be skipped.
c. Start by marking unused squares with a plus sign (+), placing a plus sign and a minus sign alternately on each square on the closed path just passed.
d. Calculate the improvement index by adding the unit cost in each box that has a plus sign, then subtracting the unit cost in each box that has a minus sign.
e. Repeat steps a through d until the repair index for all unused squares is calculated. If all the calculated indices are minus (-) or equal to zero, the optimal solution is considered achieved. [2]

The condition for achieving minimum costs is if the unit costs for non-basic variables reach a value of (-)

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or zero (0) and the material distribution model is optimal.

A detailed analysis of the implementation cost budget for material sources (SM) around the project location and material needs at the location has been carried out to meet the need for class A aggregate material for LPA work.

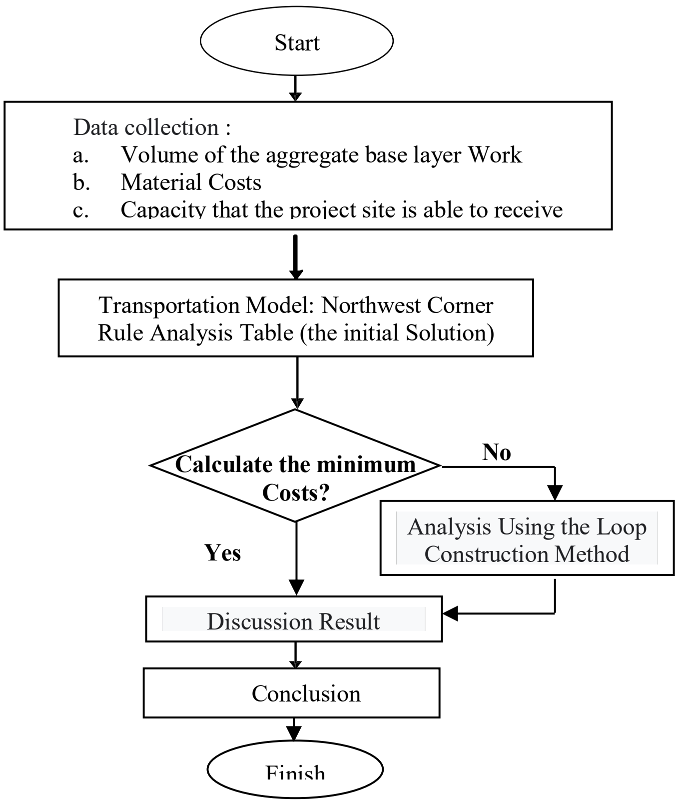


Figure 3. Research Flow Chart

Table 2.1 Material requirements data

| No | Section Name | Requirements ($m^3$) |
|---|---|---|
| 1 | Segment 1 | 3.200 |
| 2 | Segment 2 | 2.000 |
| 3 | Segment 3 | 800 |
| Amount of material requirements | | **6000** |

Tabel 2.2 Material Availability

| No | Material Source | Supply Scenario ($m^3$) |
|---|---|---|
| 1 | Konaweha | 700 |
| 2 | Pondidaha | 2.800 |
| 3 | Moramo | 2.500 |

Tabel 2.3 Scenario Material costs until arriving at the location

| ***Supply – Demand*** | **Seg. 1 (Rp./m3)** | **Seg. 1 (Rp./m3)** | **Seg. 1 (Rp./m3)** |
|---|---|---|---|
| SM 1 | 296.000 | 298.000 | 325.000 |
| SM 2 | 299.000 | 335.000 | 300.000 |
| SM 3 | 317.000 | 325.000 | 350.000 |

## III. Results and Discussion

Survey results and analysis of transportation costs, along with the required volume of class A aggregate material for the top foundation/base course work (thickness = 15 cm), are presented for the Ameroro Dam Construction Work in Konawe Regency, Southeast Sulawesi Province (Package II).

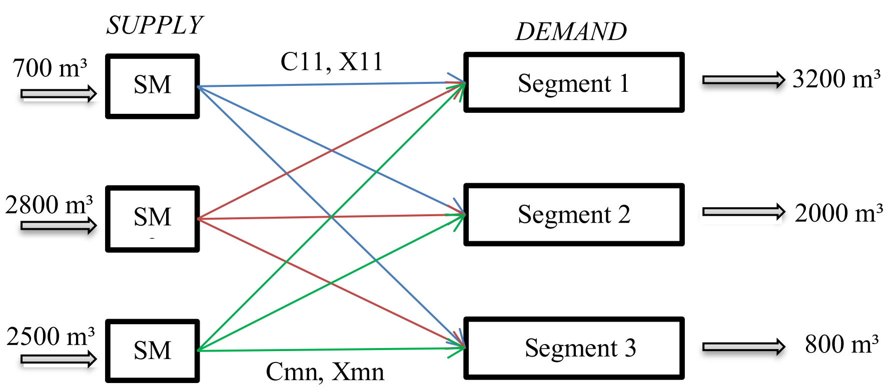


Figure 4. Material Distribution Path Solution Model

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Total Supply = 700 + 2.800 + 2.500
= 6.000 m³

Total Demand = 3.200 + 2.000 + 800 = 6000 m³
Total Supply = Total Demand

Table 3. : Transportation Table by NCR Method

| SUPPLY - DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000 / 700 | 298.000 / NB | 325.000 / NB | **700** |
| SM2 (U2) | 299.000 / 2.500 | 335.000 / 300 | 300.000 / NB | **2.800** |
| SM3 (U3) | 317.000 / NB | 325.000 / 1.700 | 350.000 / 800 | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

The cost units in this condition (in the basic part) are:
Z = (700 x Rp. 296,000) + (2,500 x Rp. 299,000)
+ (300 x Rp. 335,000)+ (1,700 x Rp. 325,000)
+ (800 x Rp. 350,000)
Z = Rp. 207,200,000,- + Rp. 747,500,000,-
+ Rp. 100,500,000,- + Rp. 552,500,000,-
+ Rp. 280,000,000,-
Z = Rp. 1,887,700,000,-
So the cost for the basic part is Rp. 1,887,700,000,-
To find out whether the composition at this stage is minimum, use the Method of Multipliers, namely:
U1 + V1 = Rp. 296,000
U2 + V1 = Rp. 299,000
U2 + V2 = Rp. 335,000
U3 + V2 = Rp. 325.000
U3 + V3 = Rp. 350.000,-
Jika U1 = 0, maka V1 = Rp. 296.000
U2 = Rp. 3.000
V2 = Rp. 332.000
U3 = Rp. -7.000
V3 = Rp. 357.000

Unit costs (Non Basic part) are:
C12 = U1 + V2 – C12
= 0 + Rp. 332.000,- - Rp. 298.000,-
=Rp. 34.000,-
C13 = U1 + V3 – C13
= 0 + Rp. 357.000,- - Rp. 325.000,-
= Rp. 32.000,-
**C23 = U2 + V3 – C23**
**= Rp. 3000,- + Rp. 357.000,- - Rp. 300.000,-**
**= Rp. 60.000,-**
C31 = U3 + V1 – C31
= -Rp. 7000,- + Rp. 296.000,- - Rp. 317.000,-
= -Rp. 28.000,-

With the largest positive value on C23, X23 is the basic variable. To determine the variables to be excluded, one can use the Loop Construction method, which involves forming closed polygons.

The North West Corner Rule method is one of the easiest transportation methods to implement, but the results are, of course, not optimal. In this NWCR method, the source and destination locations are sorted from left to right and from top to bottom in the data matrix map. The method for calculating transportation costs using the NWCR method starts from the top-left side, then moves left or down based on source production capacity (supply) and/or destination request (demand).

The North West Corner method is not effectively used to minimize the costs of transporting materials from multiple sources to various project locations. Therefore, it is supplemented with the final method or loop construction method to search for minimum transportation costs and optimal distribution patterns.

When comparing the North West Corner Rule method with the Least Cost method, which serves as the initial solution for the transportation model, the Least Cost method calculates the cost burden first, aiming to minimize costs through systematic allocation to boxes based on the standard amount of transportation per unit.

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Table 4. Phase I Iteration

| SUPPLY - DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000 / 700 | 298.000 / NB | 325.000 / NB | **700** |
| SM2 (U2) | 299.000 / 2.500 | 335.000 / **-300** | 300.000 / **+NB** | **2.800** |
| SM3 (U3) | 317.000 / NB | 325.000 / **+1.700** | 350.000 / **-800** | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

Based on table 4, the variable that will leave the basic variable and become a non-basic variable is X22 because it has the smallest negative value, namely - 300 $m^3$.

Table 5. Phase I Iteration Results

| SUPPLY - DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000 / 700 | 298.000 / NB | 325.000 / NB | **700** |
| SM2 (U2) | 299.000 / 2.500 | 335.000 / NB | 300.000 / 300 | **2.800** |
| SM3 (U3) | 317.000 / NB | 325.000 / 2000 | 350.000 / 500 | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

The cost units in this condition (in the basic part) are:
Z = (700 x Rp. 296.000,-) + (2.500 x Rp. 299.000,-) + (300 X Rp. 300.000,-) + (2.000 x Rp. 25.000,-) + (500 x Rp. 350.000,-)
Z = Rp. 207.200.000,- + Rp. 747.500.000,- + Rp. 90.000.000,- + Rp. 650.000.000,- + Rp. 175.000.000,-
**Z = Rp. 1.869.700.000,-**
So the cost in the basic part for iteration 1 is **Rp. 1,869,700,000,-**

Next, use the Method Of Multipliers, namely:
U1 + V1 = Rp. 296.000,-
U2 + V1 = Rp. 299.000,-
U2 + V3 = Rp. 300.000,-
U3 + V2 = Rp. 325.000,-
U3 + V3 = Rp. 350.000,-
Jika U1 = 0, maka V1 = Rp. 296.000,-
U2 = Rp. 3.000,-
V3 = Rp. 297.000,-
U3 = Rp. 53.000,-
V2 = Rp. 272.000,-
Unit cost (bagian Non Basik) yaitu :
C12 = U1 + V2 – C12
= 0 + Rp. 272.000,- - Rp. 298.000,-
= - Rp. 26.000,-

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C13 = U1 + V3 – C13
= 0 + Rp. 297.000,- - Rp. 325.000,-
= - Rp. 28.000,-

C22 = U2 + V2 – C22
= Rp. 3.000,- + Rp. 272.000,- - Rp. 335.000,- = -Rp. 60.000,-

**C31 = U3 + V1 – C31**
**= Rp. 53.000,- + Rp. 296.000,- - Rp. 317.000,- = Rp. 3200,-**

**C31** has the largest positive value, then **X31** will be a basic variable. continued with the Loop Construction method

Table 6. Phase 2 Iteration

| SUPPLY - DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000<br>700 | 298.000<br>NB | 325.000<br>NB | **700** |
| SM2 (U2) | 299.000<br>**-2.500** | 335.000<br>NB | 300.000<br>**+300** | **2.800** |
| SM3 (U3) | 317.000<br>**+NB** | 325.000<br>2000 | 350.000<br>**-500** | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

The non-basic variable is X33 because it has the smallest negative value, namely 500 m³.

Table 7. Phase 2 Iteration Results

| SUPPLY - DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000<br>700 | 298.000<br>NB | 325.000<br>NB | **700** |
| SM2 (U2) | 299.000<br>2.000 | 335.000<br>NB | 300.000<br>800 | **2.800** |
| SM3 (U3) | 317.000<br>500 | 325.000<br>2000 | 350.000<br>NB | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

Z = (700 x Rp. 296.000,-) + (2000 x Rp. 299.000,-)
+ (800 x Rp. 300.000,-) + (500 x Rp. 317.000,-)
+ (2.000 x Rp. 325.000,-)
Z = Rp. 207.200.000,- + Rp. 598.000.000,-
+Rp. 240.000.000,- + Rp. 158.500.000,-
+ Rp. 650.000.000,-
**Z = Rp. 1.853.700.000,-**

So the cost in the basic part for iteration 2 is **Rp. 1,853,700,000,-**

U1 + V1 = Rp. 296.000,-
U2 + V1 = Rp. 299.000,-
U2 + V3 = Rp. 300.000,-
U3 + V1 = Rp. 317.000,-
U3 + V2 = Rp. 325.000,-
Jika U1 = 0, maka V1 = Rp. 296.000,-
U2 = Rp. 3.000,-
V3 = Rp. 297.000,-
U3 = Rp. 21.000,-
V2 = Rp. 304.000,-

Unit cost (bagian Non Basik) yaitu :

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**C12 = U1 + V2 – C12**
**= 0 + Rp. 304.000,- - Rp. 298.000,-**
**= Rp. 6.000,-**

C13 = U1 + V3 – C13
= 0 + Rp. 297.000,- - Rp. 325.000,-
= - Rp. 28.000,-

C22 = U2 + V2 – C22
= Rp. 3.000,- + Rp. 304.000,- - Rp. 335.000,-
= -Rp. 28.000,-

C33 = U3 + V3 – C33
= Rp. 21000,- + Rp. 297.000,- - Rp. 350.000,-
= - Rp. 32.000,-

C12 has the largest positive value, then X12 will be a basic variable, Loop Construction method.

Table 8. Phase 3 Iteration

| SUPPLY - DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000<br>**-700** | 298.000<br>**+NB** | 325.000<br>NB | **700** |
| SM2 (U2) | 299.000<br>2.500 | 335.000<br>NB | 300.000<br>800 | **2.800** |
| SM3 (U3) | 317.000<br>**+500** | 325.000<br>**-2000** | 350.000<br>500 | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

X21 because it has the smallest negative value, namely -700 m³.

Tabel 9. Phase 2 Iteration Results

| SUPPLY- DEMAND | SEG.1 (V1) | SEG.2 (V2) | SEG.3 (V3) | *SUPPLY* |
|---|---|---|---|---|
| SM1 (U1) | 296.000<br>NB | 298.000<br>700 | 325.000<br>NB | **700** |
| SM2 (U2) | 299.000<br>2.000 | 335.000<br>NB | 300.000<br>800 | **2.800** |
| SM3 (U3) | 317.000<br>1.200 | 325.000<br>1.300 | 350.000<br>NB | **2.500** |
| ***DEMAND*** | **3.200** | **2.000** | **800** | **6.000** |

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Z = (700 x Rp. 298.000,-) + (2000 x Rp. 299.000,-) + (800 x Rp. 300.000,-) + (1.200 x Rp. 317.000,-) + (1.300 x Rp. 325.000,-)
Z = Rp. 208.600.000,- + Rp. 598.000.000,- + Rp. 240.000.000,- + Rp.380.400.000,- + Rp 422.500.000,-
**Z = Rp. 1.849.500.000,-**
So the cost in the basic part for iteration 3 is **Rp. 1.849.500.000,-**
**Method Of Multipliers:**
U1 + V2 = Rp. 298.000,-
U2 + V1 = Rp. 299.000,-
U2 + V3 = Rp. 300.000,-
U3 + V1 = Rp. 317.000,-
U3 + V2 = Rp. 325.000,-
Jika U1 = 0, maka V2 = Rp. 298.000,-
U3 = Rp.27.000,-
V1 = Rp. 290.000,-
U2 = Rp. 9.000,-
V3 = Rp. 291.000,-
Unit cost (bagian Non Basik) yaitu :
C11 = U1 + V1 – C11
= 0 + Rp. 290.000,- - Rp. 296.000,-
= - Rp. 6.000,-
C13 = U1 + V3 – C13
= 0 + Rp. 291.000,- - Rp. 325.000,-
= - Rp. 34.000,-
C22 = U2 + V2 – C22
= Rp. 9.000,- + Rp. 298.000,- - Rp. 335.000,- = -Rp. 28.000,-
C33 = U3 + V3 – C33
= Rp. 27.000,- + Rp. 291.000,- - Rp. 350.000,- = -Rp. 32.000,-

Because the Unit Cost in the Non-Basic Variable received a Negative value (-), this condition reached the Minimum Cost. If a sensitivity analysis was carried out by varying material distribution costs or material capacity, it minimized material distribution costs. If the volume of each material source and the needs at the project location were different and changed, the minimum value of material distribution costs also changed.

The implementation of the northwest corner rule method on the Ameroro dam access road project (Package II) minimized material distribution costs from three material sources for segment 1, segment 2, and segment 3 access roads from the initial solution of Rp. 1,887,700,000.00,- to Rp. 1,849,500,000.00,- with a cost reduction percentage of 2.02%.

The minimum costs obtained after applying the loop construction method may change if influenced by costs, required material capacity, and material availability at material sources. The application of the North West Corner Rule and Loop Construction methods minimized material distribution costs. These two methods could also be applied to various types of construction projects with other similar products or materials, for example, cement, sand, gravel, manufactured concrete, or other products, especially similar products.

Table. 9 Percentage Cost Reduction

| Iteration Stage | Material Costs |
|---|---|
| Initial Solution | Rp. 1.887.700.000,- |
| Iteration 1 | Rp. 1.869.700.000,- |
| Iteration 2 | Rp. 1.853.700.000,- |
| Iteration 3 | Rp. 1.849.500.000,- |
| *Cost Reduction* | ***Rp. 38.200.000*** |
| *Cost Reduction Percentage* | ***2,02 %*** |

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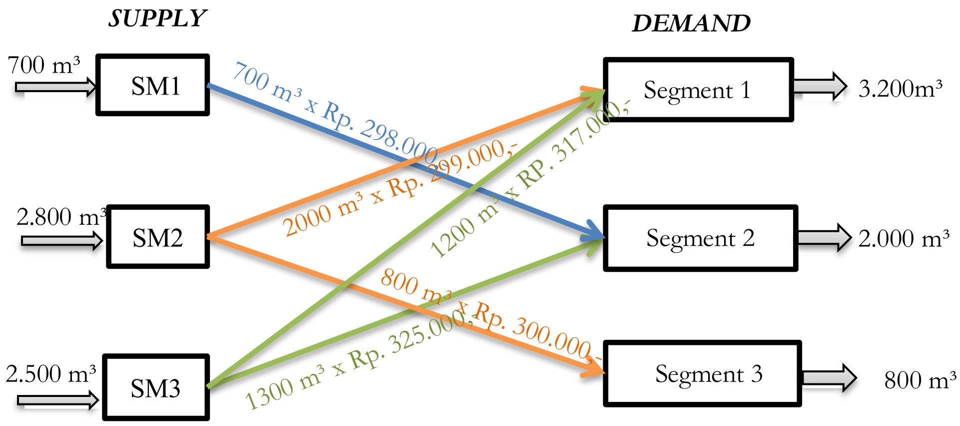


Figure 2. Material Supply Scenario Model (Class A LPA Material Distribution)

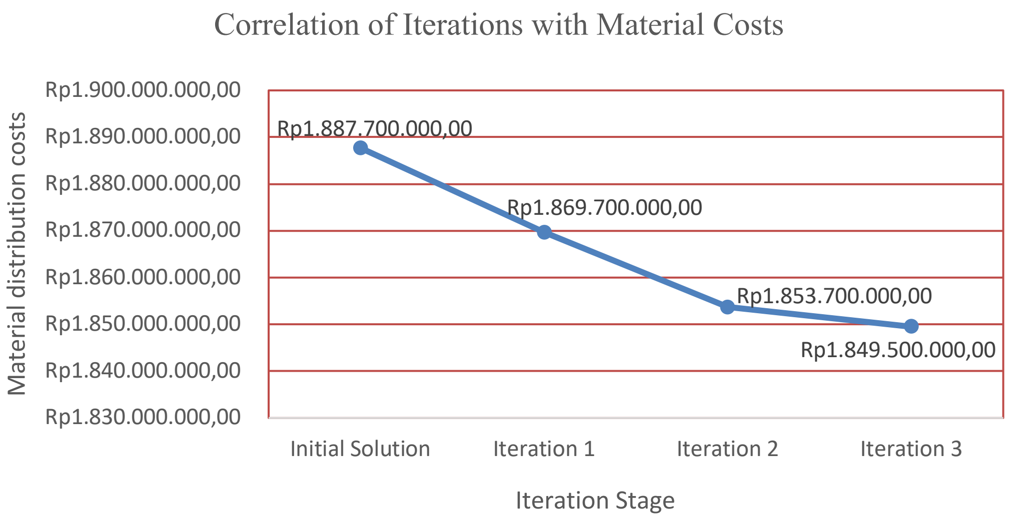


Figure 3. Correlation of the results of the iteration stages with class A aggregate material costs

## Conclusion

Based on the description of the results and discussion, the following conclusions can be drawn:

1. The Class A LPA material distribution process, by implementing the northwest corner rule method on the Ameroro dam access road project (Package II), involves the following:
   - For segment 1, 3200 m3 of material is required, taken from Pondidaha (SM2) and Moramo (SM3).
   - For segment 2, 2000 m3 of material is needed, sourced from Konaweha (SM1) with 700 m3 and Moramo (SM3) with 1,300 m3.
   - For segment 3, 800 m3 of material is necessary, taken entirely from Pondidaha (SM2).
2. The implementation of the northwest corner rule method on the Ameroro dam access road project (Package II) minimizes material distribution costs

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for segment 1, segment 2, and segment 3 access roads. The costs decrease from the initial solution of Rp. 1,887,700,000.00 to Rp. 1,849,500,000.00, resulting in a cost reduction percentage of 2.02%.

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