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Transportation Model to Minimize Distribution Cost of Construction Material

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ABSTRACT

Transportation models for material distribution are a method to organize the transportation process of a product (material) from various sources to provide product (materials) to various destinations (project site). This distribution is done to fulfil request from several destinations that can be filled from several materials sources (Quarry) where each has different needs and availability. The model purpose is to organize transportation process to minimize distribution costs. In simple terms, the model tries to determine a transportation plan of product (material) from a number of sources to several destinations to minimize distribution cost. The methods used in this research is Northwest Corner Rule (NWC) to know at this stage whether the composition already minimum by using Multipliers Method. If it does not reach the minimum charge then continued with loop construction methods. The results shows that application of Transportation model from three material sources to three destination location, i.e. along Jana'-Dongi road, Tana Jaya–Sondra road, and Kalimassang–Sawere road, can minimize the distribution costs of material with an average decline of 3,57% from previous value.

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INTRODUCTION

Construction industry success cannot be separated from optimum implementation of three main components, namely cost, time and quality. Each component plays an important and interdependent role each other. Engineering technology development at this time found that project completion time is often delayed. Lack of proper planning to control resources will adversely affect on project implementation. Planning and scheduling of project are very important and specific. Project management faces some efforts to streamline time and cost.

Construction project consists of several parts of job and also require much material. Material requirement in large amounts cannot be met by one material source. It needs several material sources to meet the material demand. Distances between one material sources with other are different for project. This distance affect on project cost. Farther distance of material sources from project site can increase transportation cost.

Material distribution need transportation costs. Therefore it requires careful planning to makes transportation costs as efficient as possible to the cost planning. Problems that often arise in material distribution process are how material distribution process from source to project location, how to determine the amount to be sent from any source to any destination based on their needs, and how to minimize the distribution cost with application of Transportation models.

Research Purpose:

This paper aims to determine material distribution from the source to project location of Road Construction work of Laston DAK. Determining the amount that must be sent from any source to any destination is based on capacity needed. Obtaining minimum cost for material distribution can implement Transportation models.

Benefit:

This paper is expected to give following: As information for all stakeholders especially construction industry in implementation of project that application of Transportation models can minimize the distribution cost of material from the source to destination. It is also expected to become a point of comparison for future research relevant.

Theoretical review:

Demand to develop in developing countries in order to improve the living standards of its people is higher, considering the advances in all areas that

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should be pursued. Resources available in form of skilled human resources and financial resources are limited. Faced with this situation, a step that is generally taken in addition to sharpen priority is to improve the efficiency and effectiveness of management in order to achieve maximum effectiveness of available resources.

Muljadi Pudjosumarto (Pudjosumarto, 1995) said that project is a series that can be planned in series of activities. They are resources usage (inputs), for example: money and manpower, to get benefit or returns in future. Project activity has starting and ending point. Paul Nugaraha, Isaac Nathan and R. Sutjipto (Nugraha, 1986; Nugraha, 2000) said that project can be defined as an effort within prescribed period with clear goals to achieve formulated results at beginning of construction project.

Understanding Transportation model:

Taha (Taha, 1997) said that Transportation model is a method used to regulate the distribution of a product (goods) from sources to provide the products to destination, as shown in figure 1 below.

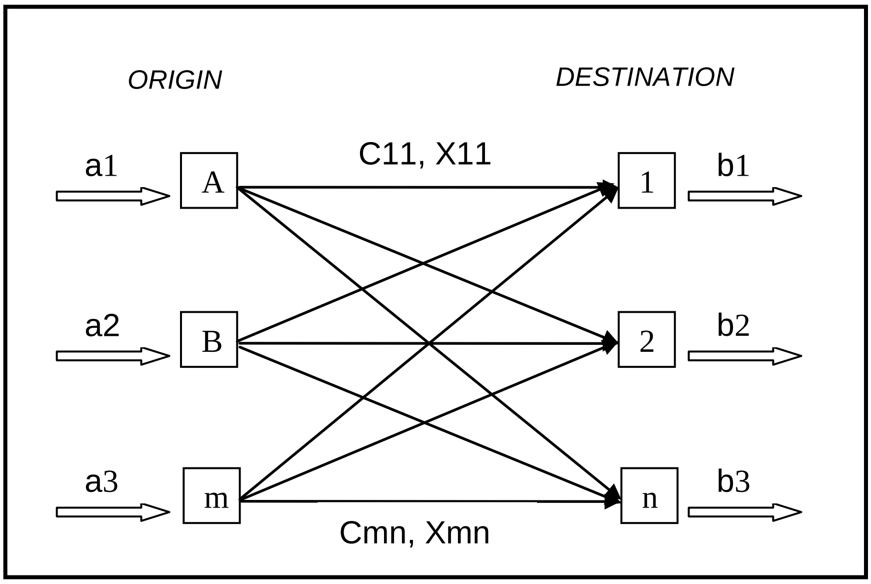

Fig. 1: Distribution Model of Transportation Network.

This distribution is carried in order demand from some location can be fulfilled from several source points; each of them can have a query or a different capacity. Transportation models usage can obtain a goods allocation distribution to minimize total cost. In simplest sense, a transportation model tries to determine a transportation plan of an item from a source to a destination. Data in this model include:

1. Supply level in each source and number of requests in each destination.
2. Transportation costs per unit of goods from any source to any destination

General linear programming model formulation of a transportation problem is follows:

$$Z = C1X1 + C2X2 + C3X3 + \dots\dots\dots CNXN \quad (1)$$

Where: Z = Total minimum cost (USD)
C = transportation unit cost between source and destination (USD)
X = number or quantity transported from source to destination (m^3)

Pangestu Subagyo (Subagyo, 2000) said that "Transportation Method is a method to regulate the distribution of sources that provide the same product, to places that require optimally." These products allocation should be regulated in such a way, because there are differences in cost allocation from one source to different destination, and from some source to a destination is also different.

Moreover, Sri Mulyono (Mulyono, 1999) said that "Generally, transportation problems relate to distribution of a single product from several sources, with a limited offer, toward some destination, with a particular request, transportation costs to a minimum." Because there is only one kind of goods, a destination can meet the demands from one or more sources.

Heizer (Heizer, 2005) said that "Transportation model is a recurrent procedure to solve problem to minimize the cost of products shipment from multiple sources to multiple destinations." We need to know the following things use Transportation models:

(a). Source point and capacity or supply in each period.
(b). Destination point and demand in each period.
(c). Shipment cost for one unit of any source point to any destination point.

Sarjono [8] said that "Transportation model is one management techniques to distribute products from the warehouse to destination." Transportation model is needed by a company to ship the goods in business. Transportation method makes company become more effective and efficient in product distribution activities.

Process of Transportation Model:

Purpose of transportation models are production planning and determination of amount to be sent from any source to any destination based on its capacity to minimize total transportation cost. Siswanto in Sarjono (Sarjono, Haryadi, 2010) said that "Transportation model during the first finding was completed manually by using the algorithm known as transportation algorithm". The algorithm are follows.

First, problem diagnosis is begun with introduction of source, destination, parameters, and variables. Second, all information is poured into transportation matrix. When the entire source capacity is greater than demand, whole purpose of a column (dummy) should be added to accommodate the excess capacity. When the entire source capacity is smaller than entire demand of destination, a line should be added to provide a pseudo capacity that will meet the excess demand. It was clear that excess demand cannot be met.

Third, after transportation matrix is created, it prepared the initial table. Transportation algorithms recognize three methods to prepare initial table, namely: (a). Least Cost Method, (b). North West Corner Method, and (c). VAM or Vogell's Approximation Method. All third method has function to determine the allocation of initial distribution that will make the whole resource capacity can be allocated to all destinations.

Fourth, after the preparation of initial table, the next step is testing the table optimality to determine whether the total distribution costs have minimum. Mathematically, this testing is done to ensure that minimum objective function value has been reached. There are several kinds to test the table optimality and minimum cost of transportation algorithm, namely: a. Method Of Multipliers, Loop Construction, and MODI or Modified Distribution Method

Fifth or the last step is table revision when at fourth step was proved that the table is not optimal or total distribution costs may still be lowered again. Then it uses a loop construction. Therefore, it is clear that the fifth steps will not be done if the fourth step has been proved that tables have been optimal. "

Review of Past 5 Years Research:

Sitaresmi Dyah (Dyah, 2009) on implementation of Greedy Algorithm Method on transportation issues explains that completion of initial solution in transportation problems is to minimize transportation costs with greedy algorithm as main algorithm in problem-solving steps. Completion of initial solution of transportation problems is North West Corner method and Least Cost method. Calculations show that Least Cost method is faster to generate a more optimal solution than North West Corner method because it directly focuses on value with low cost. North West Corner method has advantage in relatively easy handling compared to Least Cost method.

Endang Siswati Prihastuti (Prihastuti, 2010) has studied the transportation cost efficiency with North West Corner method approach and Stepping Stone (Case Study at Bottled Drinking Water Industrial in Lampung). Research results suggested that basically every company needs to maintain stability of its business in order to maintain company viability. This study problem is the high transportation cost incurred by bottled water company from the warehouse to point or market, with amount of Rp. 908.447.500. This research problem is how the effect of North West Corner method followed by Stepping Stone to minimize transportation costs at bottled water company in Lampung. This study purpose was to determine how the minimum cost incurred by bottled water company in production distribution. The hypothesis is that North West Corner method; followed by Stepping Stone method has effect to minimize transportation costs at bottled water company in Lampung.

Study of Agus Pratmoko (Pratmono, 2012) suggested that for each method, minimum distribution cost will converge to same value. the Northwest corner is faster to get initial base solution, but it has a low rate of convergence. Least cost method is slow to get initial base solution, but has a moderate rate of convergence. Vogel's approximation method is slow to get initial base solution, but having high convergence level.

Nurjuliawati Princess Haji (Putri Haji, 2013) stated that Stepping-Stone method can reduces the distribution cost of materials, especially gravel at a total cost Rp.498.562.675,00. Optimum cost was obtained in material distribution planning as follows: For Senduk road projects, it needs 1-2 cm split that equal to 319 m^3 that taken from Tateli Material sources. For Tinoor road projects, total demand of 1-2 cm split is 1275 m^3 that taken from Kema material sources of 694 m3 and Tateli material sources of 581 m3. For Pangu road projects, total demand 1-2 cm split is equal to 425 m3 and supplied from Kema material sources of 156 m3 and Kinilow material sources of 269 m3.

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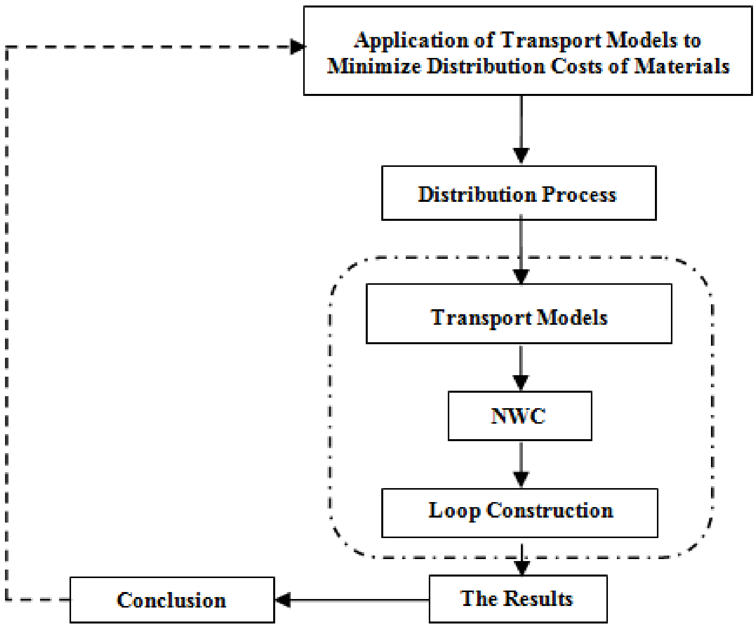

Fig. 2: Conceptual Framework.

Methodology:

Research Approach:

This study uses data collection techniques from field research and library research. Research method is done by taking the data directly at project site. And secondary data was obtained from related companies. Data can be analyzed in according to method used.

Data Collection Technique:

Authors collect the data collection directly through field research. Field research is a research method to find the data needed. In addition, secondary data was collected from information retrieval, literature exploration, scientific papers, magazines, brochures, and so on.

Analysis Method:

Principle of model utilization for this research in according to Said, LB (Said, 2008) is a transportation model. This model determines minimum cost plan to distribute goods from material sources of stone crusher to destinations at Jana'-Dongi, Tana Jaya-Sondra and Sawere-Kalimassang segment. Analytical methods used are follows.

Northwest Corner Rule Method:

Application process of this method is done with steps starting from top left corner (northwest table) and allocate as much as possible at box near column and row. If the rows or columns has fulfilled, it was followed by allocating as much as possible into boxes at next row or column diagonally. Furthermore, same manner was done until all supply has been spent and demand has been fulfilled.

	1	2	3	Supply
A	X11 C11	X12 C12	X13 C13	200
B	X21 C21	X22 C22	X23 C23	450
C	X31 C31	X32 C32	X33 C33	400
Demand	280	410	360	1050

Fig. 3: Initial Solution of North West Corner Rule Method.

Description:
X = transported quantity from source to destination
C = Transportation Unit Price from source to destination

Formulation to determine basic and non basic variables are follow:
Basic variable (Vb) = (m + n) - 1
Non basic variable = (m x n) - Vb

Vb = Variable Basic; m = Number of Lines; n = Number of Columns

Calculation of unit cost for basic variable uses equation (2). Basic variable is column filled by volumes.

After all demand has been fulfilled, then it calculates to know whether the composition at this stage is optimum method of multipliers or not. If the table has not reached the minimum cost for the unit cost, non basic equation (3) is used and followed by a loop construction method.

Loop Construction:

This method in according to Zainuddin Z (Zainudin, 2011) is one application of Transportation models that can be used to obtain optimal solution table with minimum total cost and used as a method to determine initial solution.

In this method, first step is to evaluate the blank cells to determine whether these cells can lower the total cost. If it is found, we will allocate as much as possible into these cells.

Heizer (Heizer, 2005) said that "Step Loop Construction testing method is performed as follows: Searching unused boxes, then starting from this box, it searched a closed path back to start box through boxes currently being used (which allowed only vertical and horizontal movement). However, it better to skip any blank or filled box. From unused box with plus (+) mark, put alternately plus (+) and minus (-) sign in each box on a closed track passed. Next was calculation the index improvement by: first, adding the unit cost found on every box that contains the plus sign, and then followed by reducing the unit cost of each box contains a minus sign. Repeat all the steps above until all the indices were improved for all unused boxes counted. If all indices have minus (-) or equal to zero value, then the optimal solution is reached.

Pangestu Subagyo (Subagyo, 1986) said that "Steps for stepping stone method are: Preparation of allocation table, where data must be compiled into a table that shows the relationship between the factory capacity, warehouse needs, and transportation costs. Then allocation process is done by allocating products from factories to warehouses. Furthermore, change the allocation with trial and error. To reduce transportation costs, allocation was changed by trial and error. "

RESULTS AND DISCUSSIONS

Research Result:

IJaya Construction is one private company in construction services at South Sulawesi province. IJaya Construction has been entrusted by Highways Agency Bulukumba to construct Laston DAK Road Development Project (Package-III) with a total budget of Rp.2.715.000.000, - (Two Billion Seven Hundred Fifteen Million Rupiah) which consists of three sections.

The purpose of Transportation model implementation is consistent with Tamin O., Z (Tamin, 2000) to determine the minimum cost of material transportation from three sources (Quarry 1 (SC1) at Matekko Village, Gantarang sub-district, Bulukumba District, Quarry 2 (SC2) and Quarry 3 (SC3) at Padang Loang Village, Ujung Loe Subdistrict, Bulukumba District) to project site of road construction at Jana'-Dongi, Tana Jaya-Sondra, and Kalimassang- Sawere road. To meet class A material for LPA work, it has been analyzed the details of budget implementation of material sources (Quarry) near the project and material needs, data is shown in following table.

Table 1: Material Needs.

No.	Name of Link	Materials (m^3)
	Jana' – Dongi	280
2	Tanah Jaya–Sondra	410
3	Kalimassang–Sawere	360

Table 2: Scenario Material in each Source.

No.	Origin	Scenario Supply (m^3)
1	SC1	200
2	SC2	450
3	SC3	400

Table 3: Material Costs on Location (on site).

O – D	Jana' - Dongi (Rp)	Tana Jaya - Sondra (Rp)	Kalimassang - Sawere (Rp)
SC 1	255000	291000	237000
SC 2	254000	284000	251000
SC 3	252000	288000	270000

Discussion:

Survey results and analysis of transportation costs for material need or capacity (volume) of Class A aggregate for LPA is based on theory of Bronson, R (1996), Taylor, Bernard W III (2001) and Ervianto, Wulfram I (2004) at Laston DAK Road Development Project (Package-III). Solution model can be described as follows:

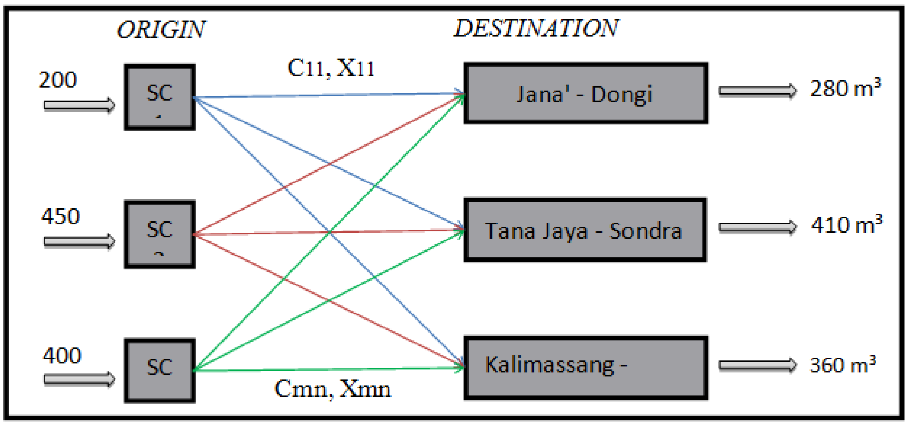

Fig. 4: Solution Model.

Total Supply = 200 + 450 + 400 = 1,050 m³
Total Demand = 280 + 410 + 360 = 1,050 m³
Total Supply = Total Demand = Balance Transportation Model

Further calculation uses equation 2.1. To find initial solution of Transportation model uses Northwest-Corner-Rule method with following steps:

a. Starting at top left corner (northwest table) and allocate as much as possible without departing from supply and demand limit.
b. Remove rows or columns that cannot be allocated anymore, then allocate as much as possible into boxes at next rows or columns, if the column or row has been full, move diagonally to next box.
c. Continue in same manner until all supply has been used and demand has been fulfilled.

Transportation models implementation of Northwest-Corner-Rule can be described as follows:

a. Material needs at Jana'-Dongi road with amounted of 280 m³ must be met first. This can be met by SC1 source of 200 m³ (maximum capability of SC1 source) until SC1 source cannot meet Jana'-Dongi project.
b. Jana'-Dongi road still need material of 280 m³ - 200 m³ = 80 m³. This can be met by SC2 source with ability of 450 m³, and are still able to meet Tana Jaya- Sondra project at 450-80 = 370 m³.
c. Tana Jaya-Sondra road need 410 m³ material where has been met by SC2 source at 370 m³. The residual requirement of 410-370 = 40 m³ is filled by SC3 source with supply ability of 400 m³.
d. Kalimassang-Sawere road need 360 m³ that have been met by SC3 source at 400-40 m³ = 360 m³.

More results as can be seen in following table.

Table 4: Table of Transportation.

O – D	J – D (V1)	TJ – S (V2)	K – S (V3)	SUPPLY
SC1 (U1)	255000	291000	237000	200
	200	NB	NB	
SC2 (U2)	254000	284000	251000	450
	80	370	NB	
SC3 (U3)	252000	288000	270000	400
	NB	40	360	
DEMAND	280	410	360	1050

Controlling the Basic and Non Basic Variables:

• Basic Variable, using equation (2) is obtained = 5
• Basic Variable, using equation (3) is obtained = 4

Variables included in basic variables are U1V1, U2V1, U2V2, U3V2 and U3V3. Variables included in non basic variables are U1V2, U1V3, U2V3 and U3V1. Unit Costs in this condition (basic variable) comes from equation (1) to obtain Z = Rp. 285 120 000,-. To determine whether this composition at minimum or not is used Method of Multipliers

If U1 = 0, then V1 = Rp. 255.000,-,
U2 = - Rp. 1000,- V2 = Rp. 285.000
U3 = Rp. 3000,- V3 = Rp. 267.000,-

Unit cost for non basic variables is :

- C12 = U1 + V2 – C12
= 0 + Rp. 285.000,- - Rp. 291.000,- = - Rp. 6000,-
- C13 = U1 + V3 – C13
= 0 + Rp. 267.000,- - Rp. 237.000,- = Rp. 30.000,-
- C23 = U2 + V3 – C23
= Rp.-1000,- + Rp.267.000, - Rp.251.000,- = Rp.15.000,-
- C31 = U3 + V1 – C31
= Rp. 3000,- + Rp. 255.000, - Rp.252.000,- = Rp. 6000,-

C13 has the largest positive value, then the X13 will become basic variables. Because X13 will change from basic variable to become non basic variable in that solution, then a non basic variable must be converted into basic variable. This is to create balance between supply and demand. To determine the variables that will come out can use Loop Construction methods namely formation of closed polygon.

Table 5: Stage 1 Iteration.

O - D	J – D (V1)	TJ – S (V2)	K – S (V3)	*SUPPLY*
SC1 (U1)	255000 - 200	291000 NB	237000 + X13	200
SC2 (U2)	254000 + 80	284000 - 370	251000 NB	450
SC3 (U3)	252000 NB	288000 + 40	270000 - 360	400
DEMAND	280	410	360	1050

Table 6: Result of Stage 1 Iteration.

O - D	J – D (V1)	TJ – S (V2)	K – S (V3)	*SUPPLY*
SC1 (U1)	255000 NB	291000 NB	237000 200	200
SC2 (U2)	254000 280	284000 170	251000 NB	450
SC3 (U3)	252000 NB	288000 240	270000 160	400
DEMAND	280	410	360	1050

Based on Table 5, basic variables that change to become non basic variable are the X11 because it has the smallest negative value of - 200 m³.

Variables included in basic variables are U1V3, U2V1, U2V2, U3V2 and U3V3. Variables included in non basic variables are U1V1, U1V2, U2V3 and U3V1.

Unit Costs in this condition (basic variable) is from equation (1) namely Z = Rp. 279 120 000, -. To determine the composition at this stage whether the minimum by using Method of Multipliers

C23 has the largest positive value, then it will be a variable x23 basic. Because the x23 will change from a variable non basic be learned the basic variables in solution then there must be issued from the variable basic be non basic, this is for sponsoring the balance between supply with Demand that model remains balanced. To determine the variables that will come out can be used methods Loop Construction i.e. the formation of a closed polygon.

The variables included in variable basic i.e. U1V3, U2V1, U2V2, U2V3 and U3V2. And are included in non basic variables that U1V1, U1V2, U3V1 and U3V3. So the cost of part basic for iteration 2 is Rp. 276 720 000, -. To determine whether the composition at this stage is minimum can use Method of Multipliers

C31 has the largest positive value, then X31 will become basic variables. Because X31 will change from a non basic variable become basic variable, then a non basic variable must be converted into basic variable. This is to create balance between supply and demand. To determine the variables that will come out can use Loop Construction methods namely formation of closed polygon.

Table 7: Iteration Stage 3

O – D	J – D (V1)	TJ – S (V2)	K – S (V3)	*SUPPLY*
SC1 (U1)	255000 NB	291000 NB	237000 200	200
SC2 (U2)	254000 - 280	284000 + 10	251000 160	450
SC3 (U3)	252000 + X31	288000 - 400	270000 NB	400
DEMAND	280	410	360	1050

Table 8: Result of Iteration Stage 3.

O – D	J – D (V1)	TJ – S (V2)	K – S (V3)	*SUPPLY*
SC1 (U1)	255000	291000	237000	200
	NB	NB	200	
SC2 (U2)	254000	284000	251000	450
	NB	290	160	
SC3 (U3)	252000	288000	270000	400
	280	120	NB	
DEMAND	280	410	360	1050

Based on Table 7, basic variables that will change to become non basic variable are X21 because it has the smallest negative value, namely - 280 m³.

Variables included in basic variable are U1V3, U2V2, U2V3, U3V1 U3V2 and. Variables included in nib basic variable are U1V1, U1V2, U2V1 and U3V3.

Unit Costs in this condition (basic variable) is from equation (1) to obtain Z = Rp. 275 040 000,-.

To determine the composition at this stage whether it minimum or not will use Method of Multipliers

Because Unit Cost Variable in Non Basic has been rated negative (-) then the condition has minimum.

Material distribution of process description aggregate class A at work LPA on Crescent Road work DAK project can be described as follows:

Table 9: Percentage of Cost Reduction.

Iteration Stage	Material Costs
First solution	Rp 285.120.000
Iteration 1	Rp 279.120.000
Iteration 2	Rp 276.720.000
Iteration 3	Rp 275.040.000
Cost Reduction	*Rp 10.080.000*
Percentage of Cost Reduction (Average)	*3,57 %*

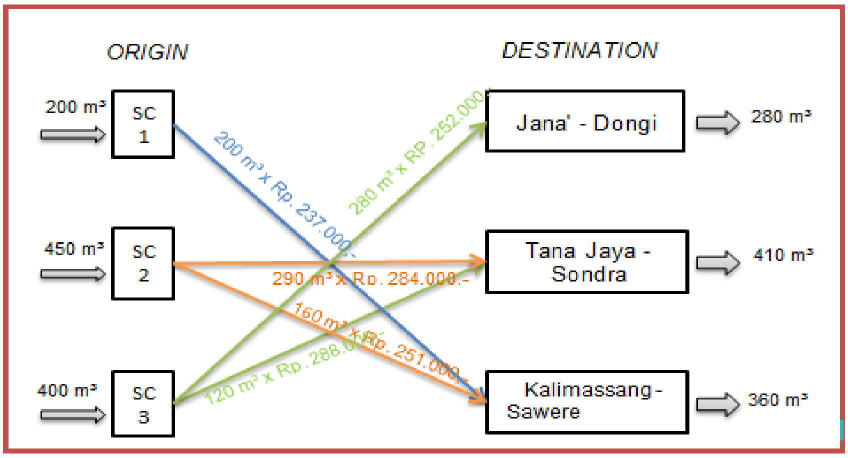

Fig. 5: Solution Model of Minimum Cost Materials Distribution.

That relationship can be described by histogram iteration results with aggregate material costs of class A as follows:

Application of Transportation model for material distribution costs at Highways Agency Bulukumba to construct Laston DAK Road Development Project (Package-III) can be done at Jana'-Dongi, Tana Jaya-Sondra and Kalimassang-Sawere road to minimize cost until Rp .275.040.000, -

Conclusion:

Material distribution at Highways Agency Bulukumba to construct Laston DAK Road Development Project (Package-III) can be done as follows. Jana'-Dongi road require 280 m³ material taken from material sources at Quarry 3. Jaya-Sondra road need 410 m³ materials taken from material sources Quarry 2 and stone crusher 3 respectively 71% and 29%. Kalimassang-Sawere road require 360 m³ materials taken from Quarry 1 and Quarry 2 respectively 56% and 44%.

Transportation models application are very helpful to organize material distribution from source to project site and also can minimize the cost of similar materials needed in construction work items.

Decrease percentage for minimum cost to distribute class A material at Highways Agency Bulukumba to construct Laston DAK Road Development Project (Package-III) for all three roads is average 3.57%.

Transportation models application for future research and case study can uses different samples. Transportation models are not only devoted to material but to any sample type.

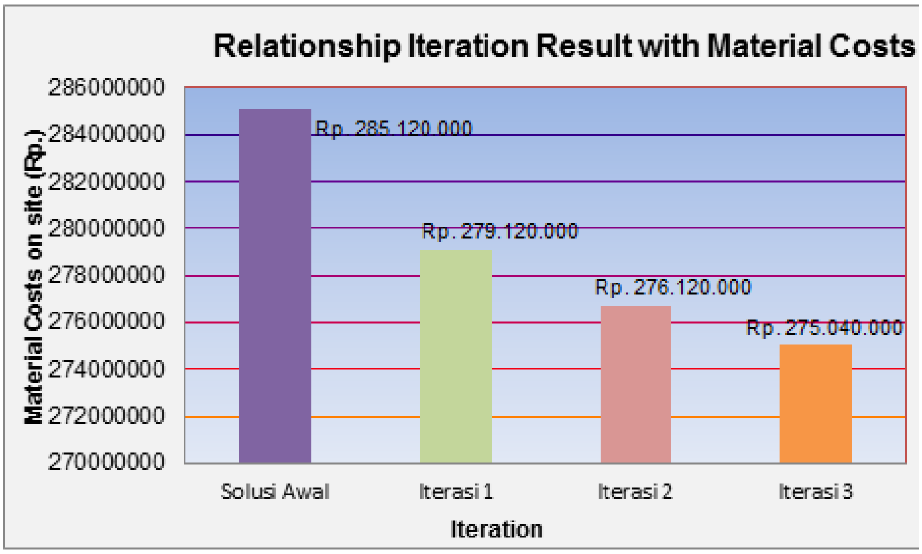

Fig. 6: Relation of iteration results with aggregate material costs for Class A.

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