

Planning for Stripping Equipment Needs for Conveyance Overburden using the Simplex Method at PT. Mega Bara Universe, Tanjung Agung, Muara Enim, South Sumatra

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Abstract:- PT. Mega Bara Semesta is one of the companies engaged in the field of coal mining business services in Tanjung Agung, Muara Enim PT. Mega Bara Semesta has the same production target every year with an overburden production target of 166,000 BCM/month. The purpose of this study was to determine the planned needs of the transportation equipment and the factors that influence the productivity of the transportation equipment to achieve the stripping target. The productivity of the Caterpillar 340D2L excavator loader is 224 BCM/hour. While the productivity of the Scania P380 dumptruck is 28 BCM/hour. Calculation of the number of transportation equipment needs that have been planned based on the linear programming method at the PT. Mega Bara Semesta said that the Scania P 380 dumptruck needed 16 units and the Caterpillar 340 excavator needed 2 units. Tool productivity is influenced by the following factors, namely material factors, work efficiency, and tool cycle time.

Keyword:- Overburden, Linear Programming, Productivity.

I. INTRODUCTION

PT. Mega Bara Semesta which is engaged in the coal mining services business in Tanjung Agung, Muara Enim in the open pit system (*surface mining*) used by PT. Mega Bara Semesta in mining activities by using a network of loading tools (*excavator*) and conveyance (*dump truck*) to transfer material from loading *point* to the disposal area during the overburden stripping activity (*overburden*). By having a constant monthly production target of 166,000 BCM/month and 1,992,000 BCM/year for peeling overburden which must be fulfilled.

The simplex method is one of the methods used in solving problems in optimizing production and production costs. With the simplex method which is part of the analysis *Linear Programming* in solving optimization problems to get the needs of the transportation equipment used by the company and to optimize production costs.

This study aims to calculate work compatibility (*match factor*) loading and conveying equipment, calculating the optimal production resulting from the stripping activity

overburden based on *Linear Programming* Simplex method, calculating the optimal means of conveyance in production overburden based on the Simplex method, and calculate the minimum production costs that can be generated on production overburden based on the Simplex method.

II. RESEARCH METHODS

The type of research used in this research is quantitative. According to Sugiyono (2018) quantitative research is based research positivist (concrete data), research data in the form of numbers that will be measured using statistics as a calculation test tool, related to the problem under study to produce a conclusion. The research method used is descriptive. Descriptive research explaining the investigation of circumstances, conditions or other matters, which are then translated into research reports. In this study, there are phenomena in the form of forms, characteristics, activities, changes, relationships, similarities and differences between one phenomenon and another (Arikunto, 2013). This research was conducted in January - March 2022 for 3 months at the open pit mine of PT. Mega Bara Semesta (MBS).

➤ Data Retrieval

The research data uses primary data and secondary data which are then developed according to the research objectives. Primary data is data obtained by taking it directly in the field. The primary data needed in this research is *data cycle time* and the number of digging equipment. Retrieval of these data can be seen in equations (1) and (2) for *data cycle time*, while for data collection on the number of load-and-carry digging equipment it can be calculated directly how many tools work in the field. For secondary data which is data obtained directly from the place of research conducted. The secondary data needed is the company's IUP map, stratigraphy, morphological conditions, rainfall, tool working hours, plans and realization of stripping production *overburden*.

➤ Processing and Analysis of Data

From the data collection that has been done both primary data and secondary data, then proceed to the next stage, namely data processing. Where the stages in data processing in this study are as follows:

- Calculating the compatibility of the tool (*match factor*) which aims to obtain a harmonious working relationship between the loading equipment and the means of conveyance. To calculate the compatibility of the work of the tool with the data used, namely *data cycle time* and the amount of loading equipment and transport equipment.
- Calculate the effectiveness of mechanical devices on each tool with the data used, namely data on effective working time, *repair* and standby on the loading and unloading equipment. In calculating the effectiveness of mechanical devices.
- Calculating the productivity of loading equipment and transportation equipment for the productivity of loading equipment for the productivity of transportation equipment. The data used is data *cycle time*, work efficiency that has been obtained from the calculation of mechanical effectiveness
- Minimize the number of means of conveyance used by using the appropriate method, where the method used in this study is the simplex method.
- After obtaining the required number of conveyances from calculations based on the simplex method. Followed by calculating production costs using transportation equipment production data, hauling cost and loading cost.

The results obtained from the simulation calculations on data processing that have been carried out are the compatibility of the work of tools, the effectiveness of mechanical devices, the productivity of loading and conveyance equipment and minimizing the number of conveyances with production costs incurred.

➤ *Linear Programming*

Linear programming is a mathematical technique that is widely used and designed to help operations managers plan and make decisions needed to allocate resources with mathematical methods, which can be used to assist in solving complicated and complex problems, such as about scheduling and the allocation of production factors contained in the production system, as well as other production and operational issues [1][2]. *Linear programming* used to make decisions that are often faced is the optimal allocation of scarce resources, in the form of money, raw materials, machine capacity, quality of time, space and technology.

Heizer & Render translated by Dwianoegrahwati S. and Indra Almahdy (2006) suggests that the characteristics commonly used in problems *Linear Programming* as follows:

- Problem *Linear Programming* aims to maximize or minimize the quantity (usually in the form of profit or cost). This characteristic is referred to as the objective function (*objective function*) of an issue *Linear Programming*. The main goal of a company in general is to maximize long-term profits.

- There are limitations (*constraints*) or constraints, which limit the degree to which objectives are achieved. To maximize or minimize a quantity (objective function) depends on limited resources (limit).
- There must be several alternative actions that can be taken. For example, if a company produces three different products, management can use Linear Programming to decide how to allocate its limited resources (labor, machines, etc.). If there are no alternatives that can be taken then Linear Programming is not needed.
- Programming must be expressed in terms of inequalities or linear equations.

➤ *Formation of Linear Programming Models*

In making a linear programming model, efforts must be made to meet the following criteria:

- The goal to be achieved is stated in the form of a linear function, called the objective function.
- Resources are available in limited quantities, and limitations must be expressed in terms of linear inequalities.
- There must be alternative solutions, namely solutions/solutions that meet all limitations/obstacles.

➤ *Method – Method Linear Programming*

As for the methods in *linear programming* as follows :

• *Method Graphics*

The Graphical Method can only be applied to solve problems *linear programming* which involves two decision variables (or three variables with a three-dimensional graph. [4] The steps to solving using the graphical method proposed by Handoko (1984) can be detailed as follows:

- ✓ Formulate the problem in mathematical form.
- ✓ Describe equations – equations limitation.
- ✓ Determine the area of "feasibility".
- ✓ Describe the objective function.
- ✓ Finding the optimum point.

• *Method Simplex*

The simplex method is a method that is usually used to solve any problems in linear programming where the combination of variables consists of three or more variables. Methods that are mathematically started from the basic solution *feasible* (*basic feasible solution*) to the basic solution *feasible* others, which are repeated (*iterative*) so that an optimal solution is reached. The simplex method is an advanced method of the graphical method. The graphical method cannot solve management problems that have large enough decision variables, so a more complex method is needed to solve it, namely using the QSB computer program (*Quantitative System for Business*) or using the simplex method.

There are several terms that are very often used in the simplex method, including:

- ✓ Iteration is a calculation stage where the value in the calculation depends on the previous table value.
- ✓ A non-basic variable is a variable whose value is set to zero at any iteration. In general terminology, the number of non-basic variables is always equal to the degrees of freedom in a system of equations.
- ✓ The basis variable is a variable whose value is not zero at any iteration. In the initial solution, the basis variable is a variable *slack* (if the constraint function is an inequality \leq) or an artificial variable (if the constraint function uses an inequality \geq or $=$). In general, the number of basis variables is always equal to the number of limiting functions (without non-negative functions).
- ✓ The solution or right value (NK) is the limiting resource value that is still available. In the initial solution, the right value or solution is equal to the number of existing initial limiting resources, because the activity has not been executed.
- ✓ Variable *slack* is a variable that is added to the constraint mathematical model to convert inequality \leq into equation ($=$). The addition of this variable occurs at the initialization stage. In the initial solution, variable *slack* will serve as the basis variable.
- ✓ The surplus variable is the variable that is subtracted from the constraint mathematical model to convert inequality \geq into equation ($=$). This addition occurs at the initialization stage. In the initial solution, the surplus variable cannot function as a basis variable.
- ✓ An artificial variable is a variable that is added to the constraint mathematical model in the form \geq or $=$ to function as the initial basis variable. The addition of this variable occurs at the initialization stage. This variable must be 0 in the optimal solution, because in reality this variable does not exist. Variables only exist on paper.
- ✓ The pivot column (working column) is the column that contains the input variables. The coefficient in this column will be the right-hand divisor to determine the pivot row (work row).
- ✓ Pivot row (work line) is one of the rows from among the base variables that contain the exit variables.
- ✓ Pivot element is an element located at the intersection of column and pivot row. The pivot element will be the basis for calculations for the next simplex table.
- ✓ The input variable is the variable that is selected to be the basis variable in the next iteration. The input variable is selected one of the non-basic variables in each iteration. This variable in the next iteration will be positive.
- ✓ Outgoing variables are variables that come out of the base variables in the next iteration and are replaced by incoming variables. The outgoing variable is selected from among the basic variables at each iteration. This variable in the next iteration will be zero.

To solve a problem, a model can be used *Linear programming*. The modeling steps are as follows:

- Determine the variables of the problem, for example X_1 , X_2 and so on

- Determine the constraints that must be imposed to meet the constraints of the system being modeled.

$$\sum_{j=1}^n AX \{ \leq \text{atau} - \text{atau} \geq \} B \quad X \geq 0, \quad i = 1, 2, 3, \dots, m$$

Information:

- ✓ m = kinds of resource or facility restrictions available
- ✓ n = types of activities that use resources or the facility
- ✓ i = number of each kind of source or facility available
- ✓ j = number of each kind of activity use resources or facilities available
- ✓ X_j = j th activity (decision variable)
- ✓ A_{ij} = number of sources i needed for produce each unit of activity output j .

- Determine the goal (maximization or minimization) that must be achieved to determine the optimum solution of all feasible values of these variables.

$$Z = C_1X_1 + C_2X_2 + \dots + C_nX_n$$

Information:

- ✓ Z = optimized value
- ✓ C_n = contribution of each output unit of activity n to the value of Z
- ✓ X_n = n th activity (decision variable)

➤ Program *pom* for Windows

Program *POM for Windows* is a computer program used to solve problems in the field of production and operations that are quantitative in nature. Attractive graphic display and ease of operation *POM for Windows* as an alternative application to assist decision making.

Steps to use the application *POM for Windows* as follows :

- Prepare the formula for the problem, for example a linear programming problem will be solved, then the work steps are:
 - ✓ Determine whether the problem is maximum or minimum cases.
 - ✓ How many variables are there.
 - ✓ How many limits are there.
- Enter the problem into the program.
- Check for problems if an input error occurs.
- Perform calculations and see the results with a click SOLVE.
- Display calculation results and save the results.

➤ *Tool Productivity*

From the research that the authors have done at PT. Mega Bara Semesta (MBS), then the results of the author's data get on the productivity calculation as follows:

• *Load Tool Production*

Loading equipment is generally used for the work of loading material onto the conveyance and others. Calculations for the production of loading equipment can be formulated as follows:

$$Prod. Exca = Bucket\ size \times \frac{60}{CT} \times BFF \times PA \times Eff \times SF$$

Information:

- ✓ *Prod. Exca* = Loading equipment production (BCM/jam)
- ✓ *Bucket Size* = Capacity bucket (m²)
- ✓ *C* = Tool turnaround time swing (the)
- ✓ *Bucket Fill Factor (BFF)* = Fill factor (%) *Physical Availability* = Equipment Physical Readiness (%)
- ✓ *Efficiency* = Work Efficiency (%)
- ✓ *SF (Swell Factor)* = Development Factor (%)

• *Production of Conveyance Equipment*

Transport equipment operations include *loading, hauling, dumping, returning*. To calculate the production of the means of conveyance related to the amount of filling from the means of loading. Can be calculated using the following equation:

$$Prod. Truck = n \times \frac{60}{CT} \times (N \times KB \times BFF) \times PA \times Eff \times SF$$

Information :

- ✓ *Prod. Truck* = Production of Conveyance Equipment
- ✓ *N* = number of conveyances
- ✓ *KB* = Capacity *Bucket* (m³)
- ✓ *N* = Bulk amount
- ✓ *BFF* = *Bucket Fill Factor* (%)
- ✓ *CT* = Equip cycle time (sec)
- ✓ *Physical availability*= Equipment Physical Readiness (%)
- ✓ *Efficiency* = Work Efficiency (%)
- ✓ *SF (Swell Factor)* = Development Factor (%)

➤ *Compatibility of Mechanical Equipment Work*

A harmonious working relationship between the loading equipment and the transportation means is obtained by adjusting the productivity of the loading equipment to be in accordance with the productivity of the means of transportation. The compatibility factor for loading and transporting equipment is based on the productivity of the loading equipment and the productivity of the transportation equipment, which is stated in *Match Factor* (MF).

Theoretically, the productivity of the loading equipment must be the same as the productivity of the transportation equipment, so that the comparison between

the transportation equipment and the loading equipment has a value of 1. Calculation *match factor* (MF) can be formulated as follows (Andi, 2003):

$$MF = \frac{In \times CTm}{Nm \times Cta}$$

Information :

- ✓ MF = *Match Factor*
- ✓ *Already* = Number of means of conveyance, unit
- ✓ *CTm* = Loading cycle time, minutes
- ✓ *Nm* = Amount of load, unit
- ✓ *Cta* = Circulation time of the conveyance, minutes

The way to evaluate it is:

MF < 1, meaning that the loading equipment is working less than 100%, while the transportation equipment is working 100% so that there is a waiting time for the loading equipment because it is waiting for the transportation equipment that has not yet arrived.

MF = 1, meaning that the loading and transport equipment works 100%, so there is no waiting time for the two types of equipment.

MF > 1, meaning that the loading equipment works 100%, while the transportation equipment works less than 100%, so there is a waiting time for the transportation equipment.

III. RESULTS

➤ *Research Data*

The choice of mechanical device is highly dependent on the chosen mining method. Equipment selection affects the geometry to be made. The height and width of the work surface ladder is affected by the range and capabilities of the selected mechanical device. The need for mechanical equipment per month adjusts to the coal mining production target set by the company (see Table 1).

Table 1 Data Mechanism Tool List

Tool Type	Activity	Equipment
Dig-Load Tool	Overburden excavation	CAT 340 D2L
Conveyance	Overburden Conveyance	SCANIA P380

➤ *Working Time*

Mine working time is the sum of all available time that can be utilized for productive work. PT. Mega Bara Semesta has a fixed working time of 20 hours divided into two *shift* per day. To make it easier to plan, calculate and assess the performance of mechanical devices, it is necessary to consider the loss of working time to obtain an effective working time of 370 hours/month.

Table 2 Working Time Loss Parameters

Hours Schedule				
Lost Time :	S1	Weathering		
	S2	Rain		1.92 Hours/day
	S3	Clean Up / Slippery		0.96 Hours/day
		Total Delay		
	S1	Meal & Rest		2 Hours/day
	S2	Shift Change		2 Hours/day
	S3	Over Shift		0 Hours/day
	S4	Prayers		1 Hours/day
	S5	Safety Talk		0.2 Hours/day
	S6	Ops Refeul		0.4 Hours/day
	S7	Standby Repair Loading Point		0.5 Hours/day
	S8	Fasting		0 Hours/day
	S9	P2H, Greasing, Refueling		0.3 Hours/day
	S1	Independence Day		
	S2	Idul Fitri		
	S3	Idul Adha		
	S4	Christmas		Hours/day
	S5	New Year Day		Hours/day
	S6	Suspend Production		
	S7	Hari Kemerdekaan		
Break Down Hours	Break Down Hours			3.6 Hours/day
	B0	Engine		
	B1	Waiting Part		0.9 Hours/day
	B2	Waiting Mechanic		1.08 Hours/day
	B3	On Process		0 Hours/day
	B4	Periodical Service		0.54 Hours/day
	B5	External Service		0.36 Hours/day
	B6	Accident		0 Hours/day
B7	Others		0.72 Hours/day	

➤ *Tool Productivity*

Tool productivity can be in the form of production of digging and hauling equipment, the magnitude of the calculation value for the production of digging and hauling equipment in a design will generally be different from the results to be obtained in the actual implementation of mining operations, this difference can be caused by the availability of equipment that is less during mining operations due to equipment damage/breakdown.

Table 3 Tool Productivity Data

Moon	Dig Tool - Load	Conveyance
	CAT 340D2L	Scania P380
	Overburden	
January	225 BCM/jam	30,50 BCM/jam
February	225 BCM/jam	30,50 BCM/jam
March	225 BCM/jam	30,50 BCM/jam

➤ *Need for Digging-Loading and Hauling Equipment*

Determining the need for digging, loading and hauling equipment is based on calculating the productivity of mechanical equipment to meet the company's production targets. The company's production target which is relatively the same causes the amount of mechanical equipment needed to be used each month to be the same, the need for digging and loading equipment and hauling equipment every month.

Table 4 Mechanical Tool Needs for Coating Stripping Overburden

Month	Production Targets Overburden (BCM)	Productiy Load Excavator (BCM)	Total Dig-Load Tool	Productivity Conveyance (ton)	Number of Conveyance	Conveyance CT
January	166.637	224,97	2	30,50	14	48 CT/ unit
February	167.655	224,97	2	30,50	14	50 CT/ unit
March	166.541	224,97	2	30,50	14	50 CT/ unit

IV. DISCUSSION

➤ *Calculation of the Number of Dumptrucks with the Simplex Method*

After obtaining the results from the calculation of productivity on each tool, both loading and conveyance equipment. The next step is to minimize the number of conveyances or what is known as dump truck by using analysis linear programming simplex method. In calculating the amount dump truck with the analysis of the simplex method required production data, costs dump truck and plant productivity.

The steps taken are:

- *Determining Problem Variables*

- ✓ x_1 = Number of DT EX 1
- ✓ x_2 = Number of DT EX 2

- *Setting Boundaries*

- ✓ $x_1 + x_2 + x_3 \leq 14$
- ✓ $p_1 x_1 \geq 224 \quad 30x_1 \geq 224$
- ✓ $p_2 x_2 \geq 224 \quad 30x_2 \geq 224$

Setting Goals (maximization or minimization)

- ✓ $Z_{min} = C_1 X_1 + C_2 X_2$
- ✓ $Z_{min} = X_1 + X_2$

After doing these steps, proceed with solving the problem. In this case, problem solving based on the simplex method can be done using a program *POM for windows* and manual calculations.

- *Program POM for Windows*

Variable issues and boundaries that have been determined followed by the objectives of the problem. Completion is done using the program *POM for Windows* which helps to solve it easily and quickly. Steps to use the Program *POM for Windows* as follows :

- *Buka Program POM for Windows*

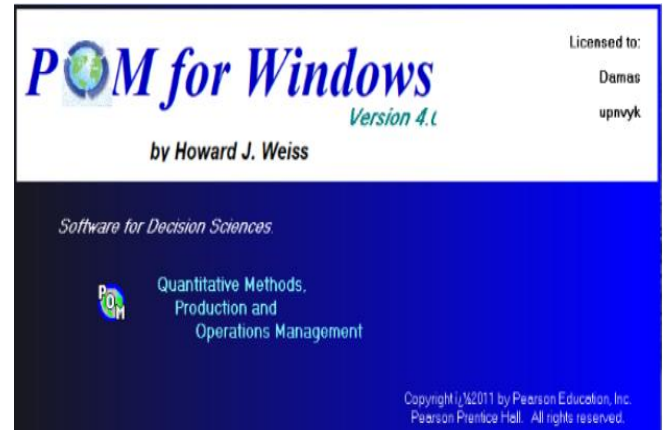


Fig 1 Buka Program POM for Windows

- *Select Linear Programming in the Module*

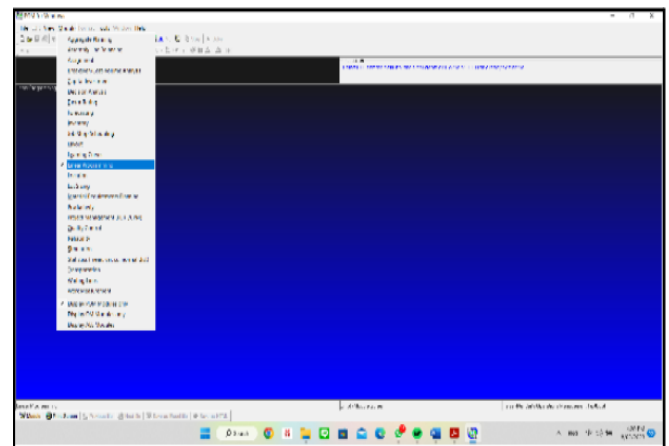


Fig 2 Select Linear Programming in the Module

- *Select File then New*

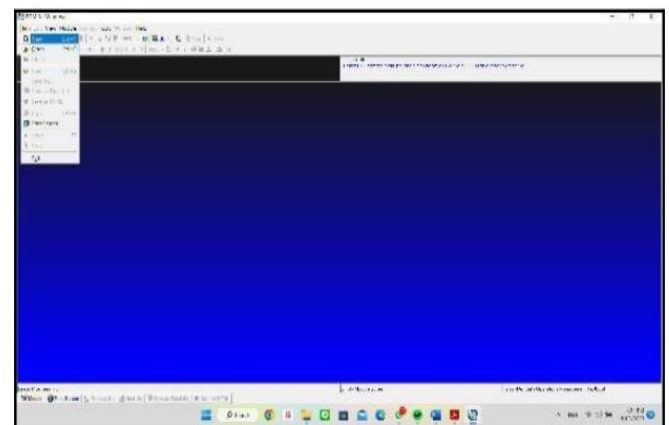


Fig 3 Select File then New

• Create For Linear Programming

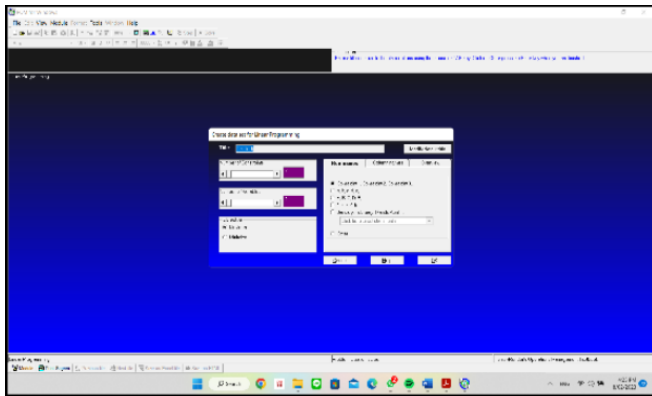


Fig 4 Create for Linear Programming

- As for the data input from the table that has been prepared in the program is as follows

Table 5 The Data that is Input into the Program

	X1	x2		RHS
Minimize	1	1		
Constraint 1	30	0	≥	224
Constraint 2	0	30	≥	224

- After determining the variables, constraints and goals then it will be appear display as shown below:

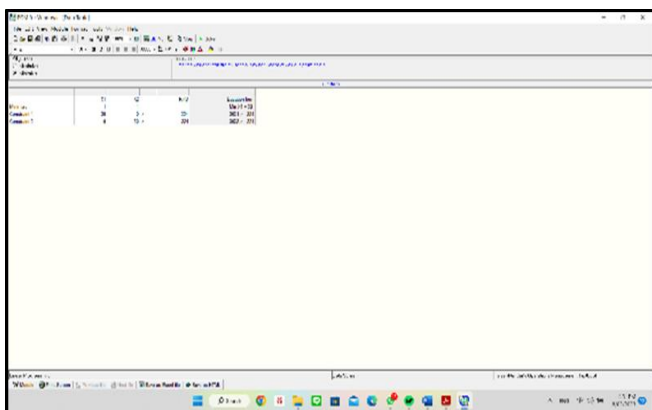


Fig 5 After determining the variables, constraints and goals

- After the data is input, click SOLVE, then the output or solution to the problem will appear as follows:

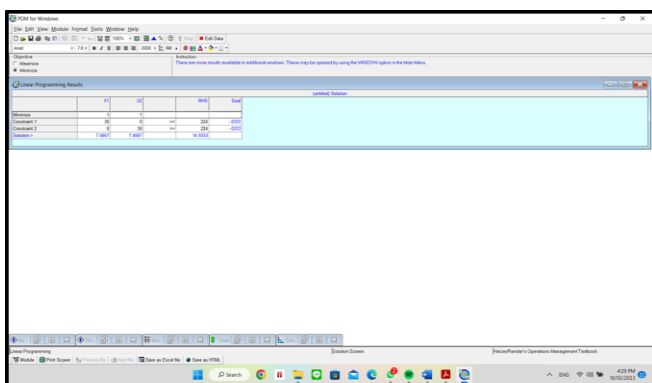


Fig 6 After the data is input, click SOLVE, then the output or solution

- The solution uses the minimalist simplex method with the completion of 3 iteration stages on software POM:

Cj	Basic Variables	1	1	0	0	0	0	Quantity
		X1	X2	artfcl 1	surplus 1	artfcl 2	surplus 2	
Phase 1 - Iteration 1								
1	artfcl 1	30	0	1	-1	0	0	225
1	artfcl 2	0	30	0	0	1	-1	225
	zj	-30	-30	1	1	1	1	450
	cj-zj	30	30	0	-1	0	-1	
Iteration 2								
0	X1	1	0	0.0333	-0.0333	0	0	7.5
1	artfcl 2	0	30	0	0	1	-1	225
	zj	0	-30	2	0	1	1	225
	cj-zj	0	30	-1	0	0	-1	
Iteration 3								
0	X1	1	0	0.0333	-0.0333	0	0	7.5
0	X2	0	1	0	0	0.0333	-0.0333	7.5
	zj	0	0	2	0	2	0	0
	cj-zj	0	0	-1	0	-1	0	

Fig 7 The solution uses the minimalist simplex method with the completion of 3 iteration stages on software POM:

- After solving the problem using the program POM for Windows, the results of the program can be seen in Table 6.

Table 6 Number of Dumptrucks from POM Windows

Unit Excavator	Number of POM Simulation Units	Number of Simulation Units (Rounded)
CAT 340 01	7.467	7
CAT 340 02	7.467	7
Total	14.93	14

➤ Calculation of the Number of Dumptrucks Manually

The need for mining mechanical equipment must be fulfilled to achieve production targets that have been set based on the capabilities of existing tools. So that the need for tools can be calculated by the following formula:

$$\text{Number of Tools} = \frac{\text{Production Targets}}{\text{Tool Production}}$$

In this study for the CAT 340D2L dig-loading tool paired with the DT Scania P380 conveyance for overburden stripping (*overburden*). Whereas for coal mining, the CAT 340D2L dig-loading equipment is used in conjunction with the DT Scania P380 hauling equipment.

- Dig-Load Tool
CAT 340D2L Excavator-Loader

$$\text{Production} = 224.97 \text{ BCM/hour} \times 379.3 \text{ hours/month} = 85,331.12 \text{ BCM/month}$$

$$\text{Production Target} = 166,637 \text{ BCM/month}$$

$$\text{Number of Tools} = \frac{\text{Production Targets}}{\text{Tool Production}} = \frac{166,637 \text{ BCM/month}}{85,331.12 \text{ BCM/month}} = 1.95 \rightarrow 2 \text{ unit}$$

- *Conveyance*

Transport Equipment DT Scania P380

Production = 30.50 BCM/hour x 393.3 hours/month = 11,995.65 BCM/month

Production target = 166,637 BCM/month

$$\text{Number of Tools} = \frac{\text{Production Targets}}{\text{Tool Production}} = \frac{166,637 \text{ BCM/month}}{11,995.65 \text{ BCM/month}} = 13,89 \rightarrow 14 \text{ unit}$$

Overburden stripping and loading (*overburden*) in January 2022, 2 units of CAT 340D2L dig-loading equipment and 14 units of DT Scania P380 transport equipment are needed.

V. CONCLUSION

From the data processing that has been done by the author, several conclusions can be drawn, namely as follows:

Based on Linear Programming Simplex method obtained planning amount dump *truck* the optimum is 14 units with a production target of 166,000 BCM/month.

REFERENCES

- [1]. Bargawa, W.S. 2018. *Mine Planning*. Yogyakarta: Undergraduate study program in Mining Engineering, UPN "Veteran" Yogyakarta
- [2]. Christian, Sugiarto. (2013). Application of Linear Programming to Optimize Production Amounts in Obtaining Maximum Profits at Cv Cipta Unggul
- [3]. Franik, Ewa & Franik, Tadeusz. (2009). Application of Non Linear Programming for Optimizaton of Factors of Production in Mining Industry. Alcon Pharmaceutical Ltd anovartis Company. Fribourg.
- [4]. Hartman, H. 1987, *Introductory Mining Engineering*. The University of Alabama. Tuscaloosa, Alabama.
- [5]. Indonesianto, Y., 2013, Mechanical Land Transfer, Department of Mining Engineering, Yogyakarta Veterans National Development University.
- [6]. Ismail, Hijir. (2018). A Formulation of the Problem of Optimizing the Production of Marble Quarry Mines. *Journal of Mathematics, Statistics and Computing*. 14(2):187-191.
- [7]. Prodjosumarto, Partanto. (1996). *Mechanical Land Transfer*. Bandung: Bandung Institute of Technology.
- [8]. Rochmanhadi. 1982. Capacity and Production of Heavy Equipment. Public Works Department. Jakarta.
- [9]. Suwirmayanti, N. L. G. P. (2018). Production Optimization Applications Using the WEB-Based Simplex Method. *techno. With*, 17(1), 61-69.