Optimization of digging and loading equipment and hauling for overburden production with quality capacity methods and queuing methods in east pit, August 2017 period PT. Artamulia Tata Pratama, site Tanjung Belit, Bungo, Jambi

M Gusman, Y Asri and I Prengki

Mining Engineering Department, Faculty of Engineering, Universitas Negeri Padang, Prof Hamka Street, Padang 25131, Indonesia

Abstract. In the mining process, the availability of dump truck equipment and loading equipment will determine the sustainability of production which has an impact on productivity and efficiency. The purpose of this study is to optimize production on stripping the overburden using the queuing method, match factor. The location of the study was conducted at PT. Artamulia Tata Pratama, Tanjung Belit, site Bungo, Jambi in August 2017 – September 2017. The loading equipment used is the PC 1250 Komatsu Excavator and the Komatsu HD 465-7 dump truck. The simulation results of the number of dump trucks needed based on production capacity is 17 units while based on queuing theory there are 17 units. Where the actual dump trucks used were 19 units.

1. Introduction

In overburden stripping activities, PT. Artamulia Tata Pratama uses excavator backhoe and dump trucks to move material from the loading point to waste dump with an overburden production target of 26,000,000 bcm/year, while the production target for July is 2,099,901 bcm/month. However, the actual data obtained in July's production is 1,858,215 bcm/month. This data is clearly less than what PT has planned. Artamulia Tata Pratama in July 2017.

As a result of these conditions the company was only able to move overburden of 53,514 BCM/day from the production target of 68,543 BCM/day. For this reason, efforts need to be made to reduce the time constraints that exist and also by increasing or reducing the number of loading and unloading equipment and transportation equipment that are operating, so that efficiency will increase and work harmony will also be achieved which will increase production. The mechanical tools observed were Komatsu HD 465-7 and PC-1250 Excavator dumptruck, this is the background of the author in conducting research on "Optimization Of Digging And Loading Equipment And Hauling For Overburden Production With Quality Capacity Methods And Queuing Methods In East Pit, August 2017 Period Pt. Artamulia Tata Pratama, Site Tanjung Belit, Bungo, Jambi".

In the mining process, equipment factors are very important factors in ensuring the continuity of production. One of the simulation methods that can be used to optimize the production of the main dumptruck loaders is to use the optimal production capacity method of the excavator and the ability of
the dumptruck. With the queuing theory, the amount of dumptruck can be determined to get optimal production according to the production target.

2. Literature Review

2.1 Mining Activities

Mining activities that are applied are open-pit systems, this type is usually applied to coal deposits which have a thick layer and are carried out by bench [10].

2.1.1 Selection of Mechanical Equipment. Analysis of mechanical equipment is an important step that must be taken before calculating the productivity of mechanical equipment, especially digging-loading equipment. And transportation equipment and hydraulic excavators and dump trucks [1].

2.1.1.1 Swell Factor. Swell "is the development of the volume of a material excavated from its place of material in the field if it is dug up to be developed [2.3]. The development factor can also be known from the ratio of loose material density to the density of the material material. The volume of material that affects the calculation of the displacement is stated in bank cubic meters, loose cubic meters, and compact cubic meters (CCM). The equation for calculating the amount of swell factor and % swell is of two types, that is:

Calculation based on volume

\[
\text{Swell factor} = \frac{\text{bank volume}}{\text{loose volume}} \frac{\text{bank weight}}{\text{weight in bank}} \times 100\% \\
\%
\text{s}
\text{w}
\text{e}
\text{l}
\text{l} = \frac{\text{loose weight}}{\text{bank weight}} x 100\%
\]

Calculation based on density

\[
\text{Swell factor} = \frac{\text{loose weight}}{\text{weight in bank}} \frac{\text{density in bank}}{\text{loose density}} \\
\%
\text{s}
\text{w}
\text{e}
\text{l}
\text{l} = \frac{\text{density in bank}}{\text{loose density}} x 100\%
\]

2.1.2 Utilization and Capability of Load Digging Equipment.

2.1.2.1 Hydraulic Excavator. Hydraulic excavators are one of the mechanical equipment that uses hydraulic pressure to move the bucket so that it can dig and load material [4].

2.1.3 Effectiveness of Mechanical Equipment. Mechanical equipment in general is not 100% and will always operate optimally. There are times when there are several influences, both from the equipment itself, as well as from external factors such as the weather, besides, for each mechanical equipment there is time catagorization.

2.2 Queue Theory

Queueing theory can be used in statistically analyzing the costs of dump trucks and loading equipment needed for a number of trucks so that the optimum number of trucks can be determined. Besides this queuing theory can also provide an overview of optimum production that can be achieved with the least cost. The queuing theory application can take an example of a loading device used to service several trucks, where the truck will transport the destination location cargo, spill it, and return to the loading place for further loading [5]. In the opinion of P. Siagian (2006: 390) in Sugiarto. Et al. (2012). Queue is a waiting line from units that need services from one or more service facilities [6].

2.2.1 Service discipline. Service discipline is a rule where customers are served, the type of queue rule consists of [7.8]:

a. First In First Out (FIFO). Basic rules for first-come, first-out or first-come ones to be served (first come first served). This rule is commonly used in mechanical soil transfer.
b. Last In First Out (LIFO). The service rules that are based on the last incoming customer come out.
c. **Service In Random Order (SIRO).** **Service rules in random rules.**  
d. **Priority Disciplines (PRI).** **Service rules based on priority.**

Grouping of service facilities according to the amount available [11.15].

- Single channel single phase
- Single channel multiple phase
- Multiple channel single phase
- Multiple channel multiple phase

2.2.2 Characteristics of service equilibrium systems. The fixed state probability of M stage and N truck is as follows:

\[(N+M-1)! \\ (M-1)!N! \]

The probability of a round queue state if there are 4 stages with N trucks can be calculated by the formula:

\[ P(n_1, n_2, n_3, n_4) = \frac{\mu_1^{(N-n_1)}}{\mu_1!\mu_2!\mu_3!\mu_4!n_1n_2n_3n_4} \]

The probability that a working phase is:

\[ Pr(stap i work) = \eta_i = 1 - \sum P(n_1, n_2, n_{i-1}, 0, n_{i+1}, n_M) \]

The number of customers expected to wait in the queue:

\[ L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \frac{p^2}{1-p} \]

The total of trucks that can be served at each stage are:

\[ \theta_1 = \eta_1 \times \mu_1 \]

The total of trucks waiting in the queue at stage i is:

\[ L_{qi} = \sum n_i P(n_1, n_2, ..., n_M) - \sum P(n_1, n_2, ..., n_M) \]

The duration of a truck queued at stage 1 is:

\[ W_{qi} = \frac{L_{qi}}{\theta} \]

The total cycle time of one truck unit to complete stage M is:

\[ CT = \sum_{i=1}^{M} (W_{qi} + \frac{1}{\mu_i}) \]

### 3. Research Method

This research was conducted in August 2017 until September 2017. The research locations at PT. Artamulia Tata Pratama. Site Tanjung Beit, Bungo, Jambi.

#### 3.1 Types of research

In this study using a type of quantitative research. That is because in the study later it will use data in the form of numbers. Quantitative methods are research methods that are based on the philosophy of positivism, used to research population or samples which are generally done randomly. Data collection uses research instruments, data analysis is quantitative or statistical in order to test predetermined hypotheses [9].

#### 3.2 Data processing stage

The data collection phase begins by taking primary data in the form of data cycle time for loading equipment and transportation equipment.

#### 3.3 Data Processing Phase

Data processing is done by calculating the cycle time of loading and hauling equipment, the production of loading equipment and transportation equipment, match factors, optimizing the number of dump trucks based on production capacity, optimizing the number of dump trucks using queuing theory, the number of dump trucks capable of being serviced by excavators, determining queuing model, optimization of production of loading equipment and transportation equipment.
4. Results and Discussion

4.1 The composition of the equipment

Table 1. Average cycle time of dumptruck in seconds.

| No. Unit | Sporting Time | Loading Time | Hauling Time | Maneuver | Dumping Time | Returning Time | Delay time |
|----------|---------------|--------------|--------------|-----------|---------------|----------------|------------|
| AR 33    | 48            | 228          | 459          | 35        | 46            | 284            | 162        |
| AR 34    | 34            | 102          | 187          | 47        | 37            | 149            | 202        |
| AR 07    | 34            | 105          | 142          | 29        | 33            | 138            | 164        |
| AR 30    | 36            | 124          | 213          | 48        | 35            | 171            | 224        |

Table 2. Time of Work Barriers to Load and Hauling Equipment

| OBSTACLES | Excavator PC 1250 (minutes / days) | Dump Truck HD 465-7 (minutes / days) |
|-----------|------------------------------------|--------------------------------------|
| obstacles that can be suppressed | | |
| Late shift | 30 | 30 |
| Stop working early | 20 | 25 |
| Rest too long | 15 | 20 |
| Operator requirements | 10 | 15 |
| Total | 75 | 90 |
| Barriers that cannot be suppressed | | |
| Rain and drying of the road | 180 | 180 |
| Break down | 25 | 200 |
| Daily check by Operator | 15 | 15 |
| Front improvements | 10 | 10 |
| Fuel refill | 20 |
| Total | 230 | 425 |
| Total Obstacles | 305 | 515 |

4.2 Production excavator and dumptruck per unit

Table 3. Calculation of Dumptruck and Excavator Production

| No. Unit | Cycle time DT (Menit) | Jumlah DT (Unit) | Cycle time excavator (Menit) | Kapasitas bucket (BCM) | Faktor isian bucket | Faktor efisiensi excavator | Faktor efisiensi DT | Produksi excavator | Produksi dump truck |
|----------|-----------------------|------------------|-----------------------------|------------------------|---------------------|---------------------------|---------------------|--------------------|---------------------|
| ATP 04   | 16.25                 | 5                | 0.5                         | 6.7                    | 0.80                | 0.74                      | 0.59                | 3.39               | 418.63              |
| ATP 08   | 8.41                  | 4                | 0.48                        | 6.7                    | 0.80                | 0.74                      | 0.59                | 3.39               | 498.57              |
| ATP 07   | 8                     | 5                | 0.48                        | 6.7                    | 0.80                | 0.74                      | 0.59                | 3.39               | 498.57              |
| ATP 09   | 9.36                  | 5                | 0.51                        | 6.7                    | 0.80                | 0.74                      | 0.59                | 3.39               | 466.63              |

Table 4. Match Factor and queuing time on fleet

| Fleet   | Match Factor | queue time |
|---------|--------------|------------|
| Fleet 1 | 1.06         | 2.5 minutes|
| Fleet 2 | 1.14         | 1.92 minutes|
| Fleet 3 | 1.5          | 2.4 minutes|
| Fleet 4 | 1.36         | 2.55 minutes|
Table 5. Total of units, unit production, and match factors based on the production capacity method.

| No. | Unit Excavator | Jamelah Excavator (Unit) | Jamelah Dump Track Annual (Unit) | Cycle Time Excavator (Minit) | Cycle Time Dump Track (Minit) | Jamelah Pneumatic (Bucket) | Matching Factor | Jamelah Dump Track Simulator (Unit) |
|-----|----------------|---------------------------|---------------------------------|-----------------------------|-------------------------------|---------------------------|----------------|-------------------------------------|
| ATP 04 | 1              | 5                          | 0.5                             | 16.36                       | 7                             | 1.06          | 5                               |
| ATP 05 | 1              | 4                          | 0.48                            | 8.41                        | 5                             | 1.14          | 4                               |
| ATP 08 | 1              | 5                          | 0.48                            | 8                           | 5                             | 1.5           | 4                               |
| ATP 07 | 1              | 5                          | 0.51                            | 9.36                        | 5                             | 1.36          | 4                               |
| Total | 4              | 19                         |                                 |                             |                               |               |                                 |

4.3 Optimization of Dumptruck Amount with Queue Theory

Table 6. Probability of PC queue 1250 (ATP 08) with 4 units of dump trucks HD 465-7 (AR 34)

| State Number | System state | Coefficient | probability of the situation |
|--------------|--------------|-------------|------------------------------|
| n1 | n2 | n3 | n4 | | 2.21184E-03 | 7.95004E-04 |
| 2 | 0 | 0 | 4 | 0 | 2.24813E-04 | 8.08047E-05 |
| 3 | 0 | 0 | 4 | 0 | 3.08747E-03 | 1.10973E-03 |
| 4 | 4 | 0 | 0 | 0 | 1.00000E+00 | 3.59431E-01 |
| 5 | 0 | 0 | 1 | 3 | 2.25698E-03 | 0.000811229 |
| 6 | 0 | 1 | 0 | 3 | 9.61670E-03 | 0.003456541 |
| 7 | 1 | 0 | 0 | 3 | 1.84320E-02 | 0.006625037 |
| 8 | 0 | 1 | 3 | 0 | 9.57897E-04 | 0.000344398 |
| 9 | 1 | 0 | 3 | 0 | 1.83597E-03 | 0.000659905 |
| 10 | 0 | 0 | 3 | 1 | 8.81265E-04 | 0.000316754 |
| 11 | 1 | 3 | 0 | 0 | 2.36706E-02 | 0.008507948 |
| 12 | 0 | 3 | 1 | 0 | 2.89844E-03 | 0.001041789 |
| 13 | 0 | 3 | 0 | 1 | 1.13619E-02 | 0.004083815 |
| 14 | 3 | 1 | 0 | 0 | 5.21739E-01 | 0.187529343 |
| 15 | 3 | 0 | 1 | 0 | 1.22449E-01 | 0.04401989 |
| 16 | 3 | 0 | 0 | 1 | 4.80000E-01 | 0.172526996 |
| 17 | 0 | 0 | 2 | 2 | 1.72728E-03 | 0.000620839 |
| 18 | 0 | 2 | 0 | 2 | 1.56794E-02 | 0.005635664 |
| 19 | 2 | 0 | 0 | 2 | 1.15200E-01 | 0.041406479 |
| 20 | 2 | 0 | 2 | 0 | 1.49938E-02 | 0.005389223 |
| 21 | 0 | 2 | 2 | 0 | 2.04074E-03 | 0.000733505 |
| 22 | 2 | 2 | 0 | 0 | 1.36106E-01 | 0.048920698 |
| 23 | 1 | 2 | 2 | 0 | 7.82283E-03 | 0.002811769 |
| 24 | 1 | 0 | 1 | 2 | 1.41061E-02 | 0.005070181 |
| 25 | 0 | 1 | 1 | 2 | 7.35972E-03 | 0.002645312 |
| 26 | 0 | 1 | 2 | 1 | 3.75496E-03 | 1.34965E-03 |
| 27 | 1 | 2 | 1 | 0 | 1.66660E-02 | 5.99029E-03 |
| 28 | 2 | 0 | 1 | 1 | 5.87755E-02 | 2.11258E-02 |
| 29 | 1 | 2 | 0 | 1 | 6.53308E-02 | 2.34819E-02 |
5. Discussion of Research Result

In August 2017 the harmony value of PC 1250 tools (ATP 04, 08, 05 and 07) with each truck in sequence are 1.10, 1.4, 1.5, and 1.36. Based on the production capacity method of PC 1250 (ATP 04) requiring 6 units dump trucks, PC 1250 (ATP 08) requires 4 units of dump trucks, PC 1250 (ATP 05) requires 4 units of dump trucks, and PC 1250 (ATP 07) requires 4 units dump truck. Based on the PC 1250 queue method (ATP 04) requires 5 units of dump truck, PC 1250 (ATP 08) requires 4 units dump trucks, PC 1250 (ATP 05) requires 5 units dump trucks, and PC 1250 (ATP 07) requires 4 units dump trucks.

6. Conclusion

Increased effective working time by reducing obstacles that can be avoided by dump truck operators and excavator operators. There needs to be road widening on certain spots. This is because on certain roads the dump trucks cannot be mixed up with each other and cause one of the dump trucks to be defeated.

Acknowledgments

We thanks to PT. Artamulia Tata Pratama Site Tanjung Belit for the permission to do this research

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