Evaluation of loading and hauling technology for improving andesite mine performance

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Abstract. This paper evaluates the utilization of loading and hauling technology at andesite mine using cycle time and match factor methods. One mine site operated by PT. Anugerah Karya Agra Sentosa was taken as a case study. PT. Anugerah Karya Agra Sentosa located in Mujahiddin Village, Plampang Sub-district, West Sumbawa Regency is an andesite mining using open pit system with quarry type method. Mechanical equipment that operates is one unit Excavator (Kobelco SK 200) capacity 0.9 m$^3$ and five units Dump Truck (Toyota Dyna 130 HT) with bucket capacity 3.6 m$^3$. The analysis results found that the average cycle time for loading equipment was 0.54 minutes while the average cycle time for hauling equipment was 14.58 minutes. Recalculation for match factor (MF=1) resulted in additional of two hauling equipment from five units to seven units (Dump Truck).

1. Introduction
Mining industry contributes significantly not only to the revenue of a region but also to the communities. On the other side, the mining operation could create an environmental disaster [1, 2]. Therefore, proper management of mine operation is required to minimize the negative impact and increase the positive outcomes. One of mine management that essential to be considered is the fleet management. Heavy equipment plays crucial role in a project including construction and mining projects. The availability of heavy equipment in project site would contribute in accelerating project implementation process and increase project effectivity and efficiency. Therefore, the utilization of heavy equipment should be managed properly to ensure that the project production target is achieved [3, 4].

Two major problems in terms of loading and hauling for mining operations are energy consumption and Greenhouse gases (GHG) emissions [5, 6]. The largest contribution for GHG emissions in iron and ore mining was loading and hauling was noted in [6]. Furthermore, increasing for energy consumption would automatically elevate mine operational cost. The proper design for loading and hauling fleets will also avoid the mine site from the problems associated with operational and investment cost [4].

Therefore, the aims of this study are evaluating cycle time of loading and hauling equipment and calculating match factor of the current equipment. This study also finds the optimum requirement for loading and hauling fleets to increase the project efficiency and sustainability.
2. Methods
This study is using a quantitative method that combines four study stages: literature review, field survey, data analysis, and conclusion. Literature review is aimed to obtain current studies general description on cycle time and match factor of andesite mine. One month field survey was conducted for observing actual cycle time of loading and hauling equipment. The movement of these equipments was recorded by stopwatch. Data obtained from field survey are then analyzed using cycle time and match factor methods. An andesite mine was taken as a case study (see section 2.1).

2.1. Case study
PT. Anugrah Karya Agra Sentosa (PT. AKAS) is a private company with two final products: stone aggregate and Hot Mixture Asphalt. In order to generate these products, PT. AKAS operates Andesite mine located in Brang Ene District, West Sumbawa Regency, West Nusa Tenggara Province and has two main heavy equipment: excavator and dump truck. These two equipments play a significant role in loading and hauling in mining and processing area. Generally, Andesite stone excavated using an excavator and transporting with dump truck to the stockpile prior delivered into crushing (processing) plant.

2.2. Cycle time
Cycle time is total time required by mechanical equipment i.e. excavator and dump truck for finishing one working cycle (start to end task) and ready for the next cycle. Cycle time for loading equipment is described in equation (1) [7].

\[ CT_m = B_t + S_{tf} + D_t + S_{te} \]  

Where \( CT_m \) is cycle time for loading equipment (second), \( B_t \) is time required for digging (second), \( S_{tf} \) is swing time with full bucket (second), \( D_t \) is dumping time (second), \( S_{te} \) is swing time with empty bucket (second). Cycle time for hauling equipment is described in equation (2) [7].

\[ CT_a = ST_l + LT + TT_f + ST_d + DT + TT_e \]  

Where \( CT_a \) is cycle time for hauling (second), \( ST_l \) is positioning time for loaded (second), \( LT \) is loading time (second), \( TT_f \) is transporting time with material (second), \( ST_d \) is positioning time for dumping (second), \( DT \) is dumping time (second), \( TT_e \) is transporting time with empty truck (second).

2.3. Match Factor (MF)
In order to obtain a suitable fleet composition number between loading and hauling equipment, the calculation of match factor is required. According to [8] that MF value equal with one indicated an efficiency operation between loading and hauling equipment. While, If MF value less than one (MF < 1) indicated that loading equipment works 100% effective and loading equipment allocates more time for waiting. The last scenario is when MF value greater than one (MF > 1), this indicated that loading equipment works effectively but waiting time is generated by hauling equipment. MF value can be calculated by using equation (3) [8].

\[ MF = \frac{N \times C_{tm} \times N_a}{C_{ta} \times N_m} \]  

Where: MF is match factor, \( N \) is the number of filling for each hauling equipment, \( N_a \) is the number of hauling equipment (unit), \( N_m \) is number of loading equipment (unit), \( C_{tm} \) is cycle time for loading equipment (minute), \( C_{ta} \) is cycle time for hauling equipment (minute).
3. Result and discussion
There are four mining activities associated with material handling which occurred at PT. AKAS: loosening, collecting, loading, and hauling. These processes involved one unit excavator for loading (Kobelco SK 200 – see figure 1) and five unit dump trucks with 3.6 m³ bucket capacity (see figure 2).

![Figure 1. Loading equipment.](image1)

![Figure 2. Hauling equipment.](image2)

The cycle time data compilation for loading and hauling activities has been generated after one month field survey at the mine site. Average cycle time data are presented in table 1 and table 2.

| Table 1. The average cycle time for loading. |
|---------------------------------------------|
| Variable | Digging (B<sub>t</sub>) | Swing full (S<sub>t</sub>f) | Dumping (D<sub>t</sub>) | Swing empty (S<sub>t</sub>e) | Total (second) |
|----------|-------------------|-----------------|-----------------|-----------------|----------------|
| Cycle time - CT<sub>m</sub>                  | 10.20            | 9.00            | 7.20            | 6.00            | 32.40          |

| Cycle time (second) | 0.54 |

Excavator with 0.9 m³ capacities required 0.54 minute to conduct one cycle for filling in dump truck bucket. Therefore, four cycles (2.16 minutes) were required by excavator to complete filling a dump truck with 3.6 m³ bucket capacity.

| Table 2. The average cycle time for hauling. |
|---------------------------------------------|
| Variable | Loading position (ST<sub>t</sub>) | Loading (LT) | Transporting full (TT<sub>t</sub>) | Dumping position (ST<sub>t</sub>) | Dumping (DT) | Transporting empty (TT<sub>t</sub>) | Total (second) |
|----------|-------------------------------|--------------|-------------------------------|-------------------------------|--------------|-------------------------------|----------------|
| Cycle time - CT<sub>a</sub>                 | 16.80                       | 126.60       | 360.60                        | 18.00                        | 15.60        | 337.20                        | 874.80         |

| Cycle time (second) | 14.58 |

The average cycle time for a dump truck to haulage the andesite stone from mining area to stockpile area was 14.58 minutes. Therefore, total average cycle time for five dump trucks that currently operated by PT. AKAS was 72.9 minutes.

Cycle time required by both heavy equipments and number of equipment operated are two main parameters for calculating MF value. Calculation of MF value using equation (3) resulted that MF value less than one (0.74). MF value shows that dump truck works 100% effective and excavator has...
waiting time for each loading cycle. Improving MF value into one (MF = 1) is then required to increase mine performance. A strategy that can be taken is by adding more dump truck to reduce the excavator waiting time. By using equation (3), the total number of dump truck required to generate MF value equal with one are seven units.

4. Conclusion
This study found that the excavator needs 2.16 minutes to fill in a dump truck (DT) and DT requires 14.58 minutes for transporting material from mining area to stockpile area. The current cycle time which required by both loading and hauling equipment generates MF value less than one. Therefore, in order to improve mine performance, the additional of two dump trucks is required for balancing work load between excavator (loading) and dump truck (hauling).

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