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Productivity Evaluation of Digging, Loading, and Hauling Equipment in Limestone Mining, PT Pertama Mina Sutra Perkasa, Jember, Indonesia

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Abstract

The failure to meet the productivity target often occurs in mining operations and is caused by several technical obstacles. PT Pertama Mina Sutra Perkasa set a productivity target of 80 tons/hour for loading and digging equipment and 35 tons/hour for transportation equipment. An analysis of factors that affect productivity needs to be studied in order to find out the causes of not achieving the productivity targets set by the company. This research was conducted on the limestone quarry of PT Pertama Mina Sutra Perkasa (PMSP) located in Grenden Village, Puger District, Jember Regency using quantitative research methods. Research begins with the formulation of problems and then data collection and processing. Data that has been processed and analyzed can then be the basis for determining efforts to improve the productivity of loading and transporting excavations. There are three loadings location not reached the productivity target. Not achieving tool productivity targets due to low work efficiency, suboptimal tool distribution time, and a combination of a less than ideal number of tools. In this study, productivity improvement was carried out by reducing the actual obstacle time in order to increase effective working time and tool efficiency.

1. Introduction

PT Pertama Mina Sutra Perkasa is a company engaged in limestone mining located in Grenden Village, Puger Subdistrict, Jember, East Java Province. This company has 3 different limestone loading points in one mining pit area. Limestone mining at this company uses an open surface mining system using the Quarry method using a Hydraulic Excavator Breaker. PT Pertama Mina Sutra Perkasa in its mining operations uses a Caterpillar 320D excavator for loading equipment and an Isuzu Giga 240 PS for transportation equipment as well as Soosan and Xander as breakers to separate limestone from its parent rock.

PT Pertama Mina Sutra Perkasa has a productivity plan set by the company, namely 80 tons/hour for loading equipment and 35 tons/hour for hauling equipment. The company cannot achieve the productivity target for loading and hauling equipment namely 68 tons/hour and 29.7 tons/hour respectively. Therefore, the author took the initiative to evaluate the factors causing the failure to achieve productivity targets at the 3 loading points to increase and optimize productivity.

2. Methodology

The methodology underpinning this study is rooted in a quantitative framework, aligning with principles commonly associated with applied research [1]. By employing such an approach, the research effectively addresses and quantifies variables of interest, such as cycle time of digging, loading, and hauling equipment, actual resistance time, as well as the weight of the dump truck [2] (see Figure 1).

2.1. Data Collection Techniques

To confirm the validity and relevance of the data, a direct field observation method was applied. On-site inspections were carefully conducted, enabling an in-depth exploration of 3 research locations (loading points / LP). During these visits, principal information was collected concerning the overall circumstances of the mining area, and the mining techniques currently used in the operation [3]. Furthermore, interactions with local engineers and workers were employed to collect supplementary data and further contextual understanding.

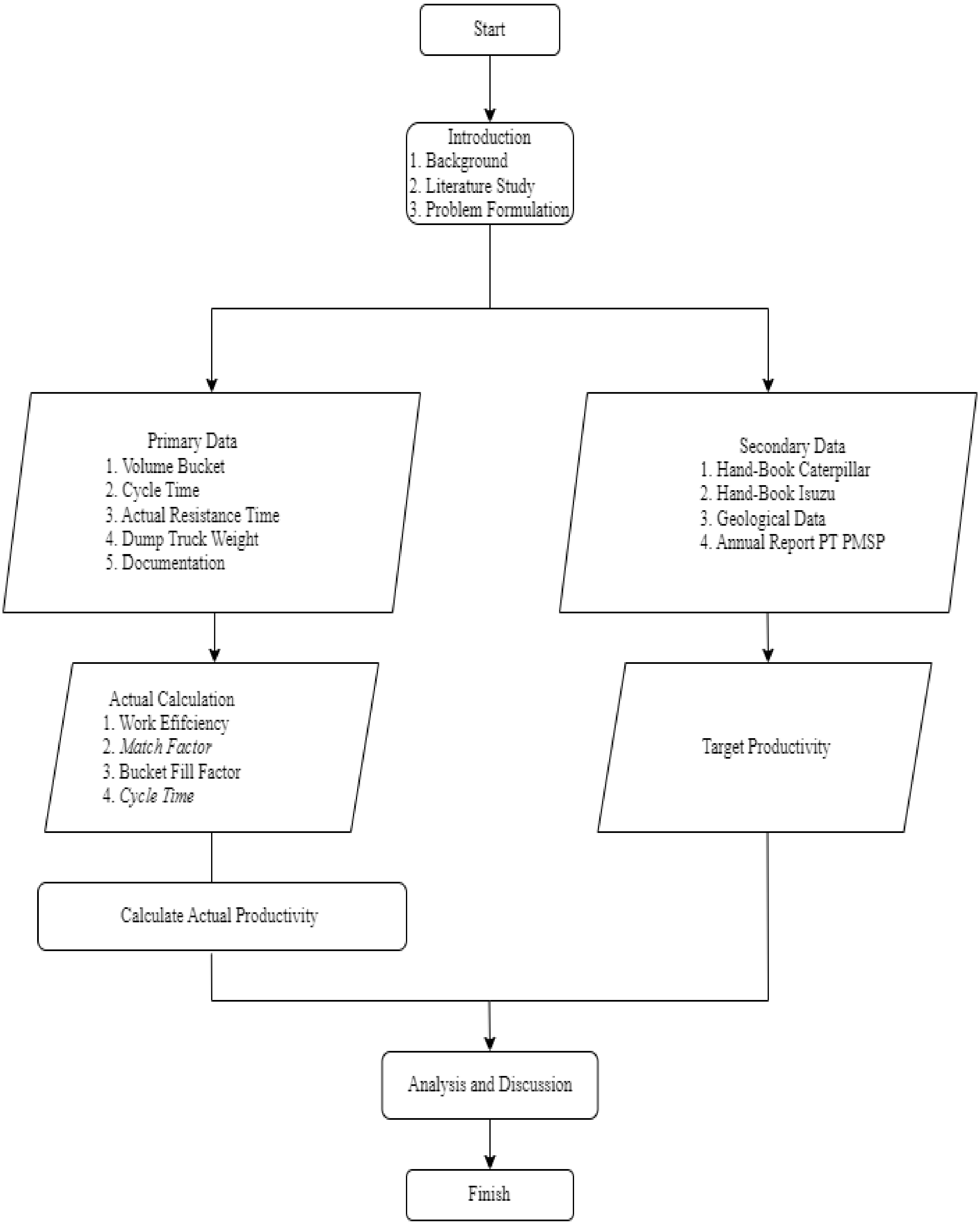

Figure 1. Research Diagram

2.2. Data Processing Approach

Once all the necessary data had been collected, the next state was elaborating on correct mathematical processing. This stage is critical as it incorporates both primary and secondary datasets to generate significant outputs [4]. This extensive processing consisted of various tasks, including calculating the cycle time of the excavator and dump truck, estimating the productivity of the excavator and dump truck, determining the work efficiency, and finally computing the match factor by integrating the swell factor. The combination of both raw observational data with established literature and datasets guarantees precision in the findings. All of the mathematical equations are described below;

Cycle Time Excavator

$$Cte = a + b + c + d \tag{2.1}$$

Cte = total cycle time of excavator (seconds)
a = digging time (seconds)
b = swing time full (seconds)
c = dumping time (seconds)
d = swing time empty (seconds)

Cycle Time Dump Truck

$$Ctd = Lt + Htf + Dt + Hte \tag{2.2}$$

Ctd = total cycle time of dump truck (seconds)
Lt = loading time (seconds)
Htf = haul time full (seconds)
Dt = dumping time (seconds)
The = haul time empty (seconds)

Work Efficiency

$$Ek = We/Wt \times 100\% \tag{2.3}$$

$$We = Wt - (Wtd + Whd) \tag{2.4}$$

Ek = Work Efficiency (%)
We = Effective Working Hour (hour)
Wt = Available Working Hour (hour)

Bucket Fill Factor

$$Bucket\ fill\ factor\ (BFF) = \frac{Observed\ Volume}{Stamdard\ Volume} \times 100\% \tag{2.5}$$

Match Factor

$$MF = \frac{Na(n \times Ctm)}{Nm \times Cta} \times 100\% \tag{2.6}$$

MF = Match Factor
Na = Number of Dump Truck
Cte = Cycle Time of Excavator (seconds)
Nm = Number of Excavator
Ctd = Cycle Time of Dump Truck (seconds)

Productivity of Excavator

$$Q = \frac{3600}{Cte} \times (C \times BFF \times EFF \times SF) \tag{2.7}$$

Q = Productivity of Excavator (m^3/hour)
Cte = Cycle time of Excavator (seconds)
C = Bucket Capacity (m^3)
BFF = Bucket Fill Factor
EFF = Work Efficiency (%)
SF = Swell Factor (%)

Productivity of Dump Truck

$$Q = \frac{3600}{Cte} \times (Cam \times EFF \times SF) \tag{2.8}$$

Q = Productivity of Excavator (m^3/hour)
Cte = Cycle time of Excavator (seconds)
Cam = Vessel Capacity of Dump Truck (m^3)
EFF = Work Efficiency (%)
SF = Swell Factor (%)

Table 1. Unavoidable Delay Time

Unavoidable Delay Time						
Location	Equipment	Start Engine	Fueling	Daily Check-up	Queeing at Loading Point	Queeing at Crusher Point
LP A	Excavator	10	15	10	5	5
	Dump truck	10	15	10	5	5
LP B	Excavator	10	15	10	5	5
	Dump truck	10	15	10	5	5
LP C	Excavator	10	15	10	5	5
	Dump truck	10	15	10	5	5

2.3. Data Analysis Techniques

Having processed the data, the subsequent step was its detailed analysis. This segment was dedicated to critically examining the outcomes from the data processing phase, drawing meaningful interpretations and insights. Key components scrutinized during this phase encompassed the runoff water's discharge rate, discharge attributes of mine water, volume evaluations of open channels, and the comprehensive volume assessment of settling ponds. [9-14] Through such a detailed analysis, a robust understanding of the research objectives was achieved, enabling the formulation of actionable recommendations. A comprehensive visualization detailing the sequential flow and interrelation of the various steps in the research methodology can be found in Figure 1.

3. **Results and Discussions**

3.1 Effective Working Hours

Effective working time is obtained from the available working hours minus the actual time of obstacles that occur in the field. The available working time is 480 minutes (8 hours). Then the obstacles that occur in the field are divided into two types, namely the obstacle time that can be avoided and the obstacle time that cannot be avoided. The obstacle data will be presented in Table 1.

The effective working time of the loading digging equipment at loading points A, B and C is as follows:

a. Effective working time of loading digging equipment at loading points A, B, and C
   We = Wt – (Wtd + Whd) = 480 – 135 = 345 min (A)
   We = Wt – (Wtd + Whd) = 480 – 137 = 343 min (B)
   We = Wt – (Wtd + Whd) = 480 – 135 = 345 min (C)
b. Effective working time of hauling equipment at loading points A, B, and C
   We = Wt – (Wtd + Whd) = 480 – 131 = 349 min (A)
   We = Wt – (Wtd + Whd) = 480 – 134 = 346 min (B)
   We = Wt – (Wtd + Whd) = 480 – 137 = 343 min (C)

Table 2. Avoidable Delay Time

Avoidable Delay Time						
Location	Equipment	Late Start at The Beginning Work	Late Start After Break	Earlier Break	Operator Needs	Earlier End Shift
LP A	Excavator	15	20	10	15	30
	Dump truck	13	20	8	15	30
LP B	Excavator	15	20	12	15	30
	Dump truck	16	20	9	15	30
LP C	Excavator	15	20	10	15	30
	Dump truck	16	20	13	15	30

Table 3. Work Efficiency

Location	Work Efficiency Excavator	Work Efficiency Dump truck
LP A	72%	73%
LP B	71%	72%
LP C	72%	71%

3.2 Work Efficiency

In order to work effectively, work efficiency must be obtained from effective working hours. Work efficiency on loading and unloading equipment at PT Pertama Mina Sutra Perkasa is described in table 3.

3.3 Cycle Time of Excavator

Cycle time of excavator namely one work cycle that can be done by the excavator, with that obtained the total time that can be completed in one work cycle by the digging tool (table 4).

Table 4. Cycle Time of Excavator

Cycle Time Excavator Cat 320 D					
Location	Digging	Swing Load	Dumping	Swing Empty	Cycle Time
A	25	11	7	8	51
B	31	13	8	9	61
C	28	10	8	7	53

3.4 Cycle Time of Dump Truck

Cycle time of dump truck namely one work cycle of the loading equipment that transports the excavated material to its crusher place (table 5).

Table 5. Cycle Time of Dump Truck

Cycle Time Dump Truck Isuzu Giga 240 PS						
Location	Loading	Hauling	Maneuver	Dumping	Returning	Cycle Time (sec)
A	372	744	36	30	552	1734
B	401	772	34	28	541	1776
C	389	764	30	33	530	1746

3.4 Digging Productivity

After obtaining the necessary data, the next step is to calculate the productivity of the loading digging equipment. The productivity of the loading digging equipment that has been determined by the company is 80 tons/hour, whereas in reality, the loading digging equipment that has been obtained is 73 tons/hour, which means that the productivity target has not been achieved.

3.5 Transport Equipment Productivity

After obtaining the necessary data, the next step is to calculate the productivity of the haul excavation equipment. The productivity of the haul-digging equipment that has been determined by the company is 35 tons/hour whereas in reality the haul-digging equipment that has been obtained is 30 tons/hour, which means the productivity target has not been achieved.

3.6 Match Factor

After carrying out actual calculations involving cycle time data and the number of tools at loading points A, B and C, match factor calculations can be generated.

From the calculations above, it can be concluded that the three loading point locations have not reached the ideal match factor number (MF=1) so improvements need to be made to the match factor.

Table 6. Match Factor

Location	Number of dump truck	Number of excavators	Match Factor
LP A	2	1	0,82
LP B	2	1	0,96
LP C	1	1	0,42

4. Conclusion

The unachieved production capacity of the equipment is due to low equipment efficiency and high cycle time. The mine equipment efficiency drops up to 73% and 61 seconds., which is typically below 73%. With significant operational time, loading equipment generally has a maximum operational time of around 61 seconds, while hauling equipment reaches a maximum operational time of about 1776 seconds. The factor hindering productivity achievement is the less than ideal equipment compatibility factor, or match factor below 1.

One optimization strategy to achieve productivity targets is by shortening or eliminating time constraints, which will increase work output. Equipment compatibility factors can approach the optimal value, MF=1, by adding dump trucks and reallocating dump truck functions. Improving the productivity of loading and hauling equipment so that after optimization, the actual average productivity of loading equipment, previously at 68 tons/hour, and hauling equipment at 29.7 tons/hour, becomes 89 tons/hour and 37.2 tons per hour for the equipment used in transit.

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References:

[1] Andi, S. (2019). *Optimalisasi Produksi Alat Muat Dan Alat Angkut Untuk Pemindahan Batubara Pada Operasi Penanganan Batubara 4 Satker Penbara Blok Timur Di Pt. Bukit Asam Tbk, Kabupaten Muara Enim,Sumatera Selatan*.(Skripsi Sarjana, Universitas Pembangunan Nasional 'Veteran' Yogyakarta, 2019).

[2] Amir, F., Fanani, Y., & Sari, A. S. (2021). Analisis Produktivitas Alat Gali Muat Dan Alat Angkut Pada Penambangan Batugamping Pt. Semen Indonesia Tbk, Kabupaten Tuban Jawa Timur. *PROSIDING, Seminar Teknologi Kebumian Dan Kelautan (SEMITAN III)*, *3*(1), 288–296.

[3] Bangun Artha. (2017). Limestone Mining & Lime Production https://bangunarta.co.id/limestone-mining-and-limestone-production, diakses pada 29 Januari 2023 pukul 18.27

[4] Caterpillar. (2017). *Caterpillar Performance Handbook Edition 29th*. Caterpillar Inc., Deerfield, Illinois, U.S.

[5] Fatimah, D., Tono, E. P. S. B. T., & Irvani. (2016). Evaluasi Kinerja Pemindahan Overburden Ditinjau Dari Produktivitas Alat Gali-Muat dan Alat Angkut di Front Kerja 2 TB 2.2 Tempilang Kabupaten Bangka Barat Mitra PT Timah (Persero) Tbk. *Jurnal Mineral*, *1*(1), 1–8.

[6] Ladianto, H. Z., & Ernawati, R. (2019). Evaluasi Produktivitas Alat Muat Dan AlatAngkut Untuk Memenuhi Target Produksi Bulanan Pengupasan Overburden Pada Penambangan Nikel Di Blok B Pt.Paramitha Persada Tama Provinsi Sulawesi Tenggara. *PROSIDING, Seminar Teknologi Kebumian Dan Kelautan I (SEMITAN I)*.

[7] Nasuhi, M., & Tono, T. E. P. S. B. (2017). Optimalisasi dan Produktivitas Alat Gali-Muat dan Alat Angkut pada Tambang Kabupaten Bangka Tengah (Optimization and Productivity of Excavator and Dump Truck in Granite Mining Activity of PT Vitrama Properti at Air Mesu Village, Pangkalan BaruSubdistrict, Central Bangka Regency). In *Maret: Vol. II* (Issue 1).

[8] Undang-Undang Nomor 3 Tahun 2020 tentang Pertambangan Mineral dan Batubara, (2020).

[9] Purba, F., Syahrudin, & Setiawati, S. (2021). Kajian Teknis Produktivitas Alat Gali Muat dan Alat Angkut untuk Mencapai Target Produksi 10.000 M^3/Bulan. Jurnal PWK, Laut, Sipil, Tambang, 8(2),

[10] Pratama, G. R. (2014). Kajian Teknis Produktivitas Alat Gali Muat Dan Alat Angkut Pada

Pemindahan Overburden Pt. Kalimantan Prima Persada Site Mass Asam-Asam Provinsi Kalimantan Selatan. (Skripsi Sarjana, Universitas Lambung Mangkurat, 2014).
[11] Prayoga, D. A. (2020). Kajian Teknis Produksi Alat Gali Muat Dan Alat Angkut Pada Penambangan Batugamping Untuk Mencapai Target Produksi 700.000 Ton/Bulan Di Pt Indocement Tunggal Prakarsa Tbk Site Plant Citeureup, Kabupaten Bogor Jawa Barat. (Skripsi Sarjana, Universitas Pembangunan Nasional 'Veteran' Yogyakarta, 2020).
[12] Qinthara, M. R., Azizi, M. A., Budhya, E. F., & Marwanza, I. (2022). Pengaruh Efisiensi Kerja Terhadap Konsumsi Bahan Bakar Alat Gali Muat Dan Angkut. Indonesian Mining and Energy Journal, 5(1), 24–32.
[13] Ramadhan, Aziz S., Suciyanto, F., Wicaksono, & Ferdy, S. (2021). Batu Gamping. Bandung: ITB
[14] Zulkifli. (2020). Kajian Teknis Produktivitas Alat Gali Muat dan Alat Angkut Batu Andesit Pada PT. Niat Karya di Kecamatan Utan Kabupaten Sumbawa Besar Provinsi Nusa Tenggara Barat. Jurnal Ulul Albab, 24(1), 46–52.
[15] Preduanda, H., & Ansosry. (2019). Evaluasi Kinerja Alat Gali Muat dan Alat Angkut Untuk Mencapai Target Produksi Pada Penambangan Batukapur di Area 242 (Tajarang) PT. Semen Padang. Jurnal Bina Tambang, 4(3), 32–42.
[16] Iranda, E., & Saldy, T. G., (2021). Evaluasi Kinerja Alat Gali Muat Dan Alat Angkut Untuk Mencapai Target Produksi 25.000 Ton/Bulan Pada Penambangan Batu Kapur PT. Bakapindo Di Jorong Durian, Kenagarian Kamang, Kecamatan Kamang Magek, Kabupaten Agam, Sumatera Barat. Jurnal Bina Tambang, 5(5), 257–266.