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Evaluation of Excavator CAT 330 GC and Mitsubishi Fuso 220 PS Fleet Efficiency The Overburden Removal Target in Pit 2 of PT. Kurnia Alam Investama

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ABSTRACT

Overburden removal is a critical determinant of production continuity in open-pit coal mining, yet inefficiencies in equipment utilization frequently hinder the achievement of production targets. At PT Kurnia Alam Investama, a monthly overburden stripping target of 150,000 BCM for February 2025 was established, to be achieved using two equipment fleets with a planned capacity of 75,000 BCM/month per fleet. However, preliminary observations indicate a discrepancy between planned and actual production, highlighting the need for a systematic evaluation of equipment performance and fleet compatibility. This study aims to assess the productivity and operational synchronization of a CAT 330 GC excavator and Mitsubishi Fuso 220 PS 6x4 HD dump trucks through cycle time analysis, productivity estimation, and match factor evaluation. The results show that actual productivity reached 67,150.72 BCM/month for the excavator and 52,407.4 BCM/month for the hauling units, both below the production target. The average cycle times were recorded at 0.343 minutes for the excavator and 5.39 minutes for the dump trucks. The calculated match factor (MF < 1) indicates an imbalance in the loading–hauling system, resulting in excavator idle time due to insufficient truck availability. The findings reveal that equipment condition and operator performance are the dominant factors affecting productivity losses. This study emphasizes the importance of fleet balancing, cycle time optimization, and operational improvements to enhance equipment utilization and achieve production targets efficiently.

Keywords: *Overburden Removal; Equipment Productivity; Cycle Time; Match Factor; Open-Pit Mining.*

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INTRODUCTION

Open-pit coal mining operations are highly dependent on the effectiveness of overburden removal to ensure the continuity of coal production [1]. One of the key factors influencing the success of this operation is the productivity of mechanical equipment, particularly the combination of loading equipment (excavators) and hauling equipment (dump trucks) [2]. An imbalance between the capacity of loading and hauling units can lead to operational bottlenecks, which may result in the failure to achieve planned production targets [3]. In practice, equipment productivity is influenced by various factors, including mining front geometry, work efficiency, cycle time, haul road conditions, as well as operator performance and operational management [4]. Therefore, evaluating equipment performance is a crucial step in identifying constraints and determining appropriate optimization strategies [5,6].

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At Pit 2 of PT. Kurnia Alam Investama, located in Bathin XXIV District, Batang Hari Regency, overburden removal activities are carried out using a Cat 330 GC excavator in combination with Mitsubishi Fuso 220 PS 6x4 HD dump trucks. Based on actual production data, there are indications that the overburden removal target has not been optimally achieved [7]. This condition highlights the need for a comprehensive analysis of the productivity of the equipment used. PT Kurnia Alam Investama, based on the Revised Work Plan and Budget (RAKB) of 2020 and in accordance with the production permit issued by the Energy and Mineral Resources Office of Jambi Province, was assigned an annual coal production target of 200,000 metric tons. Coal production activities officially commenced on September 15, 2020. The mining operation adopts an open-pit (surface mining) system using conventional methods, where the performance of mechanical equipment—particularly loading and hauling units—plays a critical role in determining overall operational efficiency and production sustainability [8,9].

At Pit 2, the planned overburden removal target is 160,000 BCM per month. However, actual production in January 2023 reached only 87,703.60 BCM per month, equivalent to approximately 55% of the planned target. This significant deviation indicates the presence of inefficiencies within the production system. One of the primary contributing factors is the mismatch (lack of synchronization) between the loading equipment (CAT 330 GC excavator) and the hauling equipment (Mitsubishi Fuso 220 PS 6x4 HD dump trucks). From a productivity standpoint, this mismatch is reflected in an unbalanced match factor ($MF \neq 1$), which leads to idle time either on the excavator side or the hauling fleet. Field observations indicate that the excavator frequently experiences waiting time due to insufficient truck availability, thereby reducing its effective utilization [10,11].

In mining operations, the productivity of mechanical equipment can be quantitatively expressed as a function of bucket capacity, fill factor, cycle time, swell factor, and work efficiency. In general terms, excavator productivity can be represented as [12]:

$$Q=\frac{C_b \times FF \times 3600 \times E}{CT} \tag{1}$$

where Q is productivity (BCM/hour), C_b is bucket capacity (m³), FF is fill factor, E is work efficiency, and CT is cycle time (seconds). Similarly, haulage productivity is strongly influenced by truck capacity, haul distance, travel speed, and delays, which collectively define the overall cycle time of the hauling system [13]. Any increase in cycle time or decrease in efficiency directly reduces production output [9].

The failure to achieve the overburden removal target has significant operational and economic implications, as it prolongs the stripping phase and delays coal exposure, ultimately affecting the mine's cash flow and production schedule [14]. The underlying causes of low productivity are multifaceted, including suboptimal work efficiency, ineffective loading patterns, poor equipment compatibility, prolonged cycle times, and other operational constraints such as road conditions and dispatching inefficiencies [15,16].

Therefore, a comprehensive evaluation of the factors influencing mechanical equipment productivity is essential. This includes analyzing key performance indicators such as cycle time distribution, equipment utilization, availability, and match factor. By identifying the dominant constraints and quantifying their impact, targeted optimization strategies—such as fleet

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balancing, cycle time reduction, and operational improvement—can be implemented. Ultimately, this approach is expected to enhance equipment productivity, improve operational efficiency, and ensure that the overburden removal targets are achieved in a sustainable and economically viable manner[17,18].

METHOD

This study was conducted at PT Kurnia Alam Investama, located in Hajran Village, Bathin XXIV District, Batang Hari Regency, Jambi Province. The research was carried out over a period from February 18 to March 30, 2025. To support data acquisition and analysis, several tools and software were utilized, including a laptop, Microsoft Office, ArcGIS 10.8, Google Earth Pro, a stopwatch, writing instruments, and a documentation camera. These tools facilitated both field observations and spatial as well as quantitative data processing [19].

Research Procedure

The research was conducted through a structured sequence of stages to ensure systematic analysis:

1. **Literature Review**
   Relevant theories and previous studies on equipment productivity, cycle time, and match factor were reviewed to establish a theoretical framework.
2. **Field Observation**
   Direct observations were carried out to understand operational conditions, equipment performance, and work patterns.
3. **Data Collection**
   Data were collected through field measurements and company records.
4. **Data Processing and Analysis**
   The collected data were processed using established mining engineering equations and presented in tabular and graphical forms.
5. **Reporting and Evaluation**
   Results were analyzed and discussed to develop recommendations for improving productivity.

The research methodology was structured into several systematic stages, comprising literature review, field observation, data collection, data processing, report preparation, and regular consultation with field supervisors. Data collection involved both primary and secondary data to ensure comprehensive analysis. Primary data were obtained directly from field measurements, particularly focusing on the cycle time of loading and hauling equipment. This involved recording the complete operational cycle of the excavator and dump trucks, starting from the initiation of loading activities to the completion of hauling cycles [20].

Secondary data were collected from company records and relevant documentation to complement and validate the primary data. These included planned overburden removal targets, rainfall data, company history, and working hours. Such supporting data are essential to provide contextual understanding and to strengthen the reliability of field observations.

Following data collection, data processing was carried out to facilitate analysis using established theoretical approaches in mining engineering. The processed data were presented in the form of tables and graphical representations to enhance interpretability. The analytical procedures included the calculation of equipment cycle time, determination of equipment compatibility using the match factor, estimation of excavator and haul truck productivity, and the identification of optimization strategies to improve productivity. These analyses are critical in evaluating operational performance and formulating technical recommendations to ensure that overburden removal targets can be achieved efficiently.

RESULTS AND DISCUSSION

Overburden stripping operations fundamentally rely on two categories of heavy equipment: loading units and hauling units, each performing distinct but interdependent roles within the production cycle. Loading equipment is responsible for the excavation and loading of overburden material from the mining face, while hauling equipment functions to transport the material efficiently from the excavation front to the designated disposal area. The effectiveness of overburden removal is therefore highly dependent on the compatibility and performance balance between these two types of equipment.

At PT Kurnia Alam Investama, overburden removal activities are carried out using two operational fleets. However, this study specifically examines the performance and characteristics of a single fleet to provide a more focused and detailed analysis. Within the observed fleet, the primary loading unit employed is a CAT 330 GC excavator, which is widely recognized for its operational efficiency and suitability for medium-scale overburden excavation. This excavator has a bucket capacity of 2.2 m^3, enabling it to handle substantial volumes of material per loading cycle.

The hauling operation in this fleet is supported by three Mitsubishi Fuso 220 PS 6×4 HD dump trucks. Each truck is equipped with a vessel capacity of 8.5 m^3, allowing for efficient material transport over the haul distance. The use of multiple hauling units in relation to a single excavator is intended to minimize idle time and ensure continuous loading operations, thereby optimizing overall fleet productivity.

Table 1. Number and Capacity of Overburden Stripping Equipment in 1 Fleet

No.	Unit	Capacity Bucket/Vessel	Quantity
1.	Excavator CAT 330 GC	2,2 m3	1
2.	Mitsubishi Fuso 220 PS 6X4 HD	8,5 m3	3

Based on the collected data, the analyzed fleet consists of one CAT 330 GC excavator with a bucket capacity of 2.2 m^3 and three Mitsubishi Fuso 220 PS 6×4 HD dump trucks, each with a vessel capacity of 8.5 m^3. This configuration illustrates the operational balance between loading and hauling units, which is a critical factor in achieving optimal production performance. Proper matching of equipment capacity and quantity is essential to reduce cycle time inefficiencies and enhance the overall effectiveness of overburden stripping operations.

Cycle Time Data

From looking at the field data, the average time it takes for excavators and haulers to complete a cycle is shown in the table below.

Table 2. Average Cycle Time of Excavators

Cycle Time of Excavators CAT 330 GC	
Average Details	(seconds)
Digging (Tg)	6.88
Filled Swing (Ts)	4.36
Dumping (Tt)	4.83
Empty Swing (Tsg)	4.5
Cycle Time	20.57

Cycle Time (Excavator) = Tg+Ts+Tt+Tsg
= 6.88 + 4.36 + 4.83 + 4.5
= 20.57 seconds/ 0.343 minutes

Among these, the digging phase represents the largest portion of the cycle, indicating that material resistance and digging conditions play a significant role in determining excavator performance. Meanwhile, the relatively balanced duration of swing and dumping activities suggests that the operator performance and machine movement are within an efficient range.

Table 3. Average Cycle Time of Transport Equipment

Cycle Time of Mitsubishi Fuso 220 PS 6X4 HD Dump Truck	
Average Details	(seconds)
Loading Manuver (LM)	38.46
Loading (L) (FL)	71.10
Full Hauling (FH)	48.87
Dumping Manuver (DM)	66.51
Dumping (D)	58.26
Empty Hauling (EH)	40.20
Cycle Time	323.40

Cycle time (*Hauler*) = *LM+FL+FH+DM+D+EH*
= 38.46+ 71.10+ 48.87+ 66.51+ 58.26+ 40.20
= 323.40 *seconds*/ 5.39 *minutes*

The most time-consuming components are the loading process and dumping maneuver, which together account for a substantial portion of the total cycle time. This indicates that truck positioning, queuing, and maneuvering efficiency are key factors influencing hauling performance.

When comparing both equipment cycles, a clear disparity is observed between the excavator and dump truck cycle times. The excavator operates with a much shorter and faster cycle, while the hauling equipment requires a considerably longer time to complete one cycle. This imbalance can lead to inefficiencies in the system, particularly in the form of idle time or waiting time for either the excavator or the trucks, depending on fleet composition. Such conditions directly affect the match factor and overall productivity of the operation.

Furthermore, the relatively long maneuvering times in both loading and dumping stages suggest potential areas for operational improvement. Enhancing haul road conditions, optimizing loading area layout, and improving operator coordination could reduce these delays. In addition, synchronization between the excavator and hauling units is essential to ensure continuous material flow and minimize cycle interruptions.

Overall, the cycle time data highlight that while the excavator demonstrates high efficiency in its operational cycle, the hauling system presents opportunities for optimization. A balanced interaction between loading and hauling equipment is necessary to achieve optimal productivity and to ensure that neither unit becomes a bottleneck in the overburden removal process. Continuous evaluation and adjustment of operational parameters are therefore crucial in improving overall mining performance.

Working Hours

Employee working hours at PT.Kurnia Alam Investama operates with one shift each day.The time change begins from

Table 4. Working Hours on Monday, Tuesday, Wednesday, Thursday, Saturday, and Sunday

SHIFT	Work Activities	Working Hours	Length of Work (Hours)
	Started Work	7:00	0
	Productive Work	7:00-12:00	5
	Break	12:00-1:00	1
	Productive Work	1:00-17:00	4
∑	Total Working Hours		10
	Lost Work Hours		1
	Total Productive Work Time		9

Table 5. Working Hours on Friday

SHIFT	Work Activities	Working Hours	Length of Work (Hours)
1	Started Work	07.00	0
	Productive Work	07.00-11.30	4,5
	Break	11.30-13.30	2
∑	Productive Work	13.30-17.00	3,5
	Total Working Hours		10
	Lost Work Hours		2
	Total Time Productive Work		8

Table 6. Evaluated Work Efficiency

Equipment Type	*Excavator* (Minute)	*Dump Truck* (Minute)
Time Available in 1 Shift (7:00-17:00)	540	540
Unavoidable Obstacles		
Equipment Warm-up	10	10
Equipment Relocation	10	5
Fueling	5	5
Total (Minutes)	**25**	**20**
Avoidable Obstacles		
Lately arriving at work	5	5
Early break	0	0
Lately returning to work after a break	5	5
Early work stoppage	0	0
Total (Minutes)	**10**	**10**
Lost Time (Minutes)	**35**	**30**

Equipment Match Factor Evaluation

The evaluation of the *match factor* (MF) based on actual field calculations resulted in a value of 0.76. This value indicates that the loading equipment (excavator) is operating at less than optimal efficiency (below 100%), while the hauling equipment is operating at full capacity (100%). As a consequence, a waiting time occurs on the excavator side, reflecting an imbalance between the loading and hauling units. This condition demonstrates that the compatibility between the digging and transporting equipment in the overburden stripping operation has not yet been achieved. Therefore, a *match factor* evaluation is necessary to improve the synchronization and overall performance of the equipment fleet.

a. Match factor calculation after evaluation

After improvements were made by increasing the number of bucket fills from 4 to 5, the match factor calculation for the excavator and hauler was as follows:

$$MF = \mathrm{Na} \times \frac{\mathrm{CTm} \times \mathrm{n}}{\mathrm{m} \times \mathrm{CTa}}$$

$$MF = 3 \times \frac{0{,}343 \times 5}{1 \times 5{,}39}$$

$$MF = 0{,}95$$

Following the implementation of improvements, specifically by increasing the number of bucket fills from 4 to 5, a recalculation of the *match factor* was conducted. The updated result shows an MF value of 0.95, which is close to the ideal value of 1. This indicates a significantly improved level of compatibility between the excavator and hauling units. Under this condition, waiting time for both pieces of equipment can be minimized, resulting in a more balanced, efficient, and productive overburden stripping operation.

a. Productivity of the CAT 330 GC Excavator Loading Equipment

b.

Table 7. Data on Cycle Time, Work Efficiency, Bucket Capacity, Swell Factor, and Fill Factor of the CAT 330 GC Excavator After Evaluation.

Cycle Time/Ctm (Second)	**Work Efficiency /EK (%)**	**Bucket Capacity /KB (m^3)**	**Swell Factor/SF (%)**	**Fill Factor (%)**
0,343	0,93	2,2	0,85	1,1

$$Qa = \frac{(60 \times KB \times SF \times EK \times FF)}{CTa})$$

$$= \frac{60 \times 2{,}2 \times 0{,}85 \times 0{,}93 \times 1{,}1}{0{,}343}$$

$$= \frac{114{,}7806}{0{,}343}$$

$$= 334{,}64\ BCM/Hour$$

$$= 334{,}64 \frac{BCM}{Hour} \times 8{,}42\ hour\ a\ day$$

$$= 2.817{,}67\ BCM/day$$

$$= 78.894{,}76\ BCM/month$$

The productivity analysis of the CAT 330 GC excavator after evaluation shows a significant improvement in operational performance. Based on the input parameters—cycle time of 0.343 minutes, work efficiency of 93%, bucket capacity of 2.2 m³, swell factor of 0.85, and fill factor of 1.1—the calculated productivity reaches 334.64 BCM per hour. This value reflects a relatively high production rate, indicating that the excavator is operating efficiently under the improved working conditions.

When this hourly productivity is projected over actual working time, the excavator is capable of producing approximately 2,817.67 BCM per day, assuming an effective working time of 8.42 hours per day. On a weekly basis (7 working days), the production increases to 19,723.69

BCM, while the monthly production (28 working days) reaches 78,894.76 BCM. These results demonstrate a consistent and substantial production capacity over extended operational periods.

The increase in productivity can be attributed to improved operational parameters, particularly the optimization of bucket filling and cycle efficiency. The relatively high fill factor (1.1) indicates that the bucket is being filled beyond its nominal capacity, which contributes positively to production output. Additionally, the high work efficiency (93%) suggests minimal delays and effective time utilization during operations.

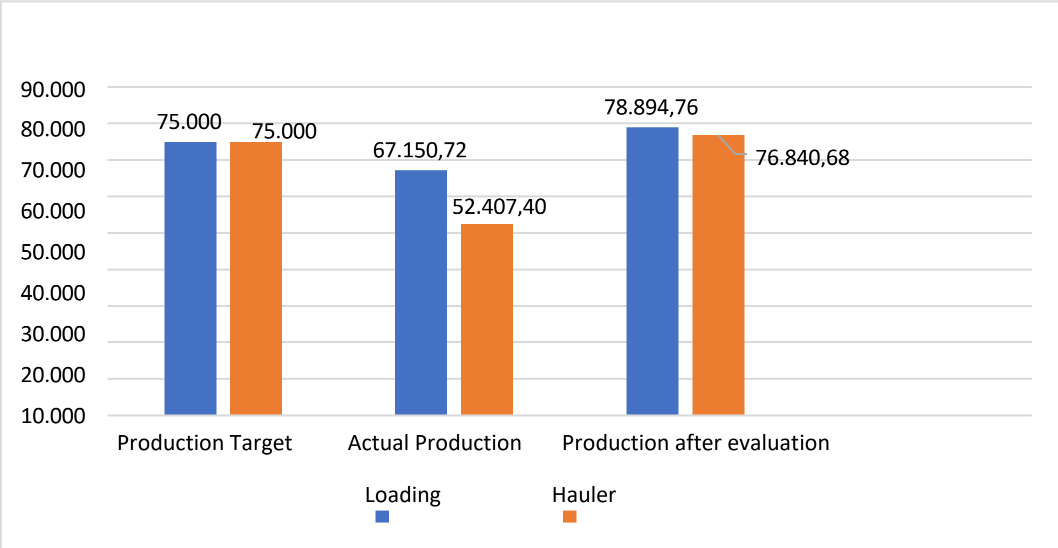

Figure 1. Tool Productivity Graph

Overall, these results indicate that the CAT 330 GC excavator is capable of meeting high production targets in overburden stripping activities. However, it is important to ensure that this increased productivity is balanced with the hauling equipment capacity to avoid potential bottlenecks, as reflected in the match factor evaluation. Continuous monitoring and optimization of operational parameters are therefore essential to maintain efficiency and achieve optimal fleet performance. The following is a graph of equipment productivity in 1 fleet in February 2025.

CONCLUSION

The CAT 330 GC excavator exhibits a relatively short cycle time of 0.343 minutes during overburden removal, while the Mitsubishi FUSO 220 PS 6×4 HD dump truck requires a significantly longer cycle time of 5.39 minutes. In terms of productivity, the excavator achieves 309.45 BCM per hour, equivalent to 67,150.72 BCM per month. Meanwhile, the dump trucks demonstrate a productivity rate of 79.68 BCM per hour, or 52,407.4 BCM on a monthly basis. The calculated match factor (MF) between the loading and hauling units is 0.76, indicating an imbalance in equipment synchronization. An MF value below 1 suggests that the excavator is likely to experience idle time due to waiting for hauling units.
Several operational constraints were identified as contributing factors to the inability to achieve the targeted overburden removal production. These include equipment breakdowns, adverse weather conditions such as rainfall, delays in operator attendance, extended or premature breaks, early termination of work shifts, and suboptimal compatibility between loading and hauling equipment. Further evaluation of the equipment compatibility, particularly under

hauling conditions with an approximate distance of 200 meters, revealed that increasing the number of bucket passes from four to five improved the match factor to 1. This indicates a balanced interaction between the excavator and dump trucks, where both units operate without waiting time, thereby enhancing operational efficiency.

Additionally, efforts to optimize productivity through efficiency analysis resulted in improved performance levels. The productivity of loading equipment increased to 78,894.76 BCM per month, while hauling equipment reached 76,840.68 BCM per month. These findings highlight the importance of proper equipment matching and operational efficiency improvements in achieving optimal overburden removal performance.

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