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Work Compatibility of Loading Excavators and Conveying Equipment in The Stripping of Overburden Pc 2000

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ABSTRACT

The productivity of overburden stripping is highly dependent on the productivity and work compatibility of the mechanical tools used. This research was carried out on the work load excavator (Fleet 1825) at Pit Banko Tengah A, PT Bukit Asam (Persero) Tbk. with the aim of analyzing the productivity level of the excavation and loading equipment, determining the work compatibility value (match factor), and evaluating the number of transportation equipment needs. Based on actual observations, obstacles were found in the form of piles of soil (spoil) on the side of the road and undulating transport road surface conditions. Road conditions that do not meet these standards result in narrowing of lanes, a decrease in the average speed of means of transportation, and an increase in cycle time. This study uses a quantitative method with primary data collection which includes cycle time, effective working time, and the number of digging and loading bucket fills. The results of the analysis showed that the actual productivity of the Komatsu PC 2000-8 excavator excavator reached 914.57 BCM/Hour, while the productivity of the Komatsu HD-785 Dump Truck was 164.7 BCM/Hour. The assessment of work compatibility between 1 unit of excavation equipment and 7 units of transport equipment resulted in a Match Factor (MF) value of 1.25. The MF value of > 1 indicates the occurrence of queues and waiting times for transportation equipment in the work area. Based on the evaluation of productivity suitability, it is recommended to reduce the number of transportation equipment from 7 units to 6 units so that the production target runs optimally and efficiently. In addition to optimizing the compatibility of digging loading and transporting equipment, it is recommended to standardize the geometry of the transport road according to regulations to minimize obstacle time.

Keywords: *Overburden Stripping; Equipment Productivity; Match Factor; Excavator–Dump Truck Fleet; Haul Road Geometry.*

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INTRODUCTION

Indonesia is one of the countries with abundant natural resources, where one of its leading strategic energy commodities is coal. On the island of Sumatra, the Enim Basin is known to have very large coal reserves. Coal mining plays a crucial role in modern industry because it provides a cost-efficient energy source, as well as contributing greatly to national development through job creation and fulfillment of industrial raw materials. [1] Along with increasing global energy needs and electrification rates, coal remains one of the main fossil fuels in electrical energy production. [2]

In open pit mining operations, the achievement of production targets is greatly influenced by the productivity of the mechanical tools used, especially at the stage of stripping the overburden layer. [3] The use of suboptimal mining equipment can have a direct impact on the non-achievement of production targets and increased operational costs. Therefore, operational efficiency analysis is absolutely necessary to prevent bottlenecks in the loading and hauling process of overburden rock. [4]

PT Bukit Asam (Persero) Tbk. is a State-Owned Enterprise (BUMN) operating in the Tanjung Enim area, South Sumatra. In the mining operation at the Central Banko Pit A, the overburden stripping activity used a combination of heavy-duty mechanical tools, including Komatsu PC 2000 Excavator (Fleet 1825) as a digging and loading tool and a row of Komatsu HD 785 Dump Trucks as a means of transportation [5]. The smooth operation of this excavation and transport equipment is highly dependent on the condition of the mining road infrastructure. However, based on observations in the field, several operational technical obstacles were found, such as the presence of piles of impurities (spoil) on the side of the main road and undulating road surface conditions on several segments of transportation routes. This less than ideal infrastructure condition results in narrowing of roads, a decrease in the average speed of transportation units, and an increase in cycle time, which ultimately hinders the achievement of daily productivity targets. [6,2]

To minimize the use of ineffective dump trucks and reduce the queue of units at the work front and disposal areas, an in-depth study is needed related to the efficiency of excavation and loading equipment. [7] Therefore, this study aims to analyze the actual productivity level of excavators and transport equipment in Fleet 1825, calculate the work compatibility value (match factor) of excavation and transport equipment, and evaluate the most optimal number of transport equipment needs based on productivity suitability[8,4].

METHOD

This research was carried out in February at the mining site of the Central Banko Pit A, Mining Work Unit of PT Bukit Asam (Persero) Tbk. The equipment used during this study in order to help the smooth obtaining of the required data are Laptops, Microsoft Office Software, Stopwatches, Stationery and Documentation Cameras. The research activities are divided into several stages ranging from literature studies, field observations, data collection, data processing and report preparation, as well as consultation with field supervisors [9] The data taken were in the form of primary and secondary data to support this research.

The data collected in this study is classified into two types, namely primary data and secondary data:

1. Primary Data: Obtained through direct observation at the mining front, which includes cycle time data from excavators and conveyors, effective working time, and the number of loading buckets into conveyors.
2. Secondary Data: Obtained from a literature review and company archives, which includes actual working time data, swell factor (85% for clay material type), bucket fill factor (0.9), tool work efficiency, and technical specifications of operating mechanical tools, namely Komatsu PC 2000-8 Excavator and Komatsu HD-785 Dump Truck.

Data processing is carried out after data collection, aiming to make it easier to conduct analysis, with calculations based on existing theories, which are presented in the form of tables and graphs. The data processing carried out in the study includes:

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1. Calculation of the cycle time of excavators and transport equipment
2. Calculation of the compatibility of the tool (match factor)
3. Calculation of the productivity of excavators and conveyors

The data analysis technique is carried out by processing cycle time, obstacles, and unit specifications data into productivity values [10,11] The calculation is carried out using empirical mathematical equations for mechanical earthmoving tools, with the following stages:

1. Calculating the availability of load-and-carry excavators

   Physical Availability (PA) is a factor that shows the tool's willingness to do the job by calculating lost time, while Utilization Availability (UA) is a factor that shows the tool's work efficiency at the available time where the condition of the tool is not damaged. [12]

   $$PA=\frac{W+S}{W+S+R}\times 100\% \tag{1}$$

   $$UA=\frac{W}{W+S}\times 100\% \tag{2}$$

   Where:
   W : Working hours (Hours)
   S : Standby hours
   R : Repair hours

2. Calculation of the cycle time of the loading excavator

   Cycle time is the time needed for a loading tool to carry out an activity [13]

   $$CTm = Tdg + Tsi + Tdp+Tsk \tag{3}$$

   Where:
   CTm :Total Time Of Excavation Loading Tool
   Tdg : Time Düsseldorf
   Yes : Time Swing Contents
   TDP : Time Dumping
   Tsk : Time Swing Empty

3. Calculation of the cycle time of the transport equipment

   Cycle time is the time needed for a loading tool to carry out an activity [14].

   $$Ct = Tml+Tl+Th+Tmd+Td+Thk \tag{4}$$

   Where:
   Ct : Total time of distribution of means of transport
   Tml : Time Loading Maneuver
   Tl : Time Loading
   Th : Time Hauling
   Tmd : Time Dumping maneuver
   Td : Time Dumping
   Thk : Empty Hauling Time

4. Calculation of Productivity of Digging and Loading Tools

   The productivity of the excavator (Q) is calculated by taking into account the bucket capacity, filling factor, swell factor, work efficiency, and distribution time of the loading tool: [15]

   $$Q= \left(\frac{3600}{Ctm}\right)\times Kb\times Ff\times Sf\times Ek \tag{5}$$

   Where:
   Q : Excavation-loading equipment productivity (BCM/Hour)
   Kb : Bucket Back hoe Capacity (m3)
   Ff : Fill Factor

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E.g. : Tool Work Efficiency (%)
Sf : Swell Factor
Ctm : Cycle Time Loading tool (Seconds)

5. Calculation of Productivity of Means of Transport
Productivity of means of transport (Qa) is calculated based on the number of loads, capacity of tools, and the cycle time of transportation from front to disposal [16,17]

$$Qa = \frac{Na \times Kb \times Ff \times Sf \times Ek \times 60}{Ct} \quad (6)$$

Where:
Qa : Productivity of means of transport (BCM/Hour)
The : The amount of filling in one means of transport
Ct : Cycle time Means of transport (Minutes)
Kb : Capacity Bucket (m3)
Ff : Charging Factor (%)
Sf : Development Factors (Fill Factor %)
E.g. : Work Efficiency (%)

6. Match Factor Calculation
The level of work compatibility between the excavation and the transport equipment (Match Factor) is evaluated to see if there is a waiting time for a unit. The calculation uses the following equation [18,19]

$$MF = \frac{Na \text{ x } (Ctm \text{ x Jumlah Bucket})}{Nm \text{ x } Cta} \quad (7)$$

Where:
MF : Match Factor
Ctm : Cycle Time Loading Tools
Cta : Cycle Time Means of transport
The : number of means of transport
Nm : number of loading tools

RESULTS AND DISCUSSION

Number of Tools

In overburden stripping activities, 2 main types of tools are needed in the process, namely digging tools and transporting tools. Loading excavators are used to excavate overburden materials, and transport tools to transport the material from the front to the disposal area. In the process of stripping the overburden at the Central Banko Pit A (Fleet 1825), the type of excavation tool used is the Komatsu PC 2000-8 Excavator, and the transport tool used is the Komatsu HD-785 Dump Truck.

Table 1. Number and capacity of the tool

Units	Bucket/Vessel Capacity	Quantity
Komatsu PC 2000-8	12 m3	1
Komatsu HD 785-7	60 m3	7

Availability of Dig Load Tool

Decreased productivity can be caused by ineffective use of the available time. This can be seen from the standby time that is still high.

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Table 2. Effective working time and unit resistance

Units	Hours		
	Effective Working Time (W)	**Repair Time (R)**	**Non-operating time (S)**
PC 2000-8	11.18 Hours	0.82 Hours	11.98 Hours
HD-785	9.84 Hours	0.99 Hours	13.16 Hours

From the data above, it can be seen that the standby time (S) takes a lot of time, this is caused by several factors, including rain, slippery, rest and meal, and also safety talk. This is illustrated in the diagram below:

Table 3. Top 5 Obstacles on PC2000-8

Barriers	Time (Hours)
Wait Support	1.25
Slippery	1.32
Rest & Meal	1.37
Safety Talk	2.16
Rain	5.14

Table 4. Top 5 Obstacles on HD-785

Barriers	Time (Hours)
Rain	5.25
Safety Talk	2.55
Wait Support	2.20
Rest & Meal	1.41
Slippery	0.83

Based on the obstacle data above, it can be seen in the pie chart below:

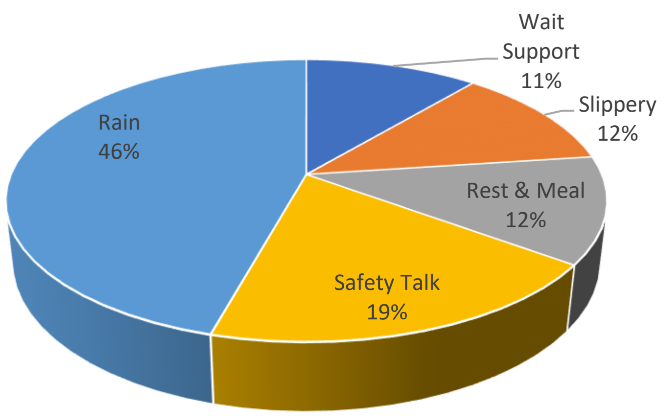

Figure 1. Top 5 Obstacles PC2000-8

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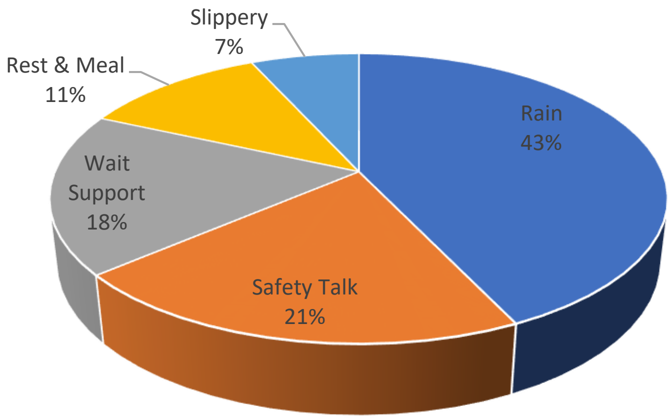

Figure 2. Top 5 Obstacles on HD-785

From the data above, the PA and UA values of each unit will be obtained, including:

Physical Availability (PA)

$$PC2000=\frac{11,18+11,98}{11,18+0,82+11,98}\times100\%$$

PC2000=97 %

So the PA value for PC 2000-8 is 97%

$$HD\ 785=\frac{9,84+13,16}{9,84+0,99+13,16}\times100\%$$

HD 785= 96%

So the PA value for HD-785 is 96%

Utilization Availability (UA)

$$PC\ 2000=\frac{11,18}{11,18+11.98}\times100\%$$

PC 2000=48%

So the UA value for PC 2000-8 is 48%

$$HD\ 785=\frac{9,84}{9,84+13,16}\times100\%$$

PC 2000=43%

So the UA value for HD-785 is 43%

Table 5. PA and UA Values

Units	PA(%)	UA(%)
PC2000-8	97	48
HD-785	96	43

Cycle Time Data

From the results of observations in the field, the average distribution time obtained for digging and loading tools and means of transport can be seen in the table below:

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Table 6. Cycle time Loading Digging Tool

Activities	Average (Seconds)
Digging	14,19
Swing Fill	7,16
Dumping	4,35
Empty Swing	4,84
Cycle Time	**30,54**

Cycle Time (Ctm) $= Tg + Tsi + Tt + Tsk$
$= 14.19 + 7.16 + 4.35 + 4.84$
$= 30.54$ seconds $= 0.5$ minutes

Table 7. Cycle time Means of transport

Activities	Average (seconds)
Loading Maneuver	28,80
Loading	202,73
Hauling Contents	556,03
Dumping Maneuver	39,50
Dumping	31,90
Empty Hauling	444,87
Cycle Time	**1303,83**

Cycle Time (cta) $= Tml + Ti + Ta + Tmd + Td + Tk$
$= 28.80 + 202.73 + 556.03 + 39.50 + 31.90 + 444.87$
$= 1303.83$ seconds $= 21.73$ Minutes

Based on the hauling time of the means of transport, it can be up to 556.03 seconds when it contains cargo, and 444.87 seconds when empty. This is clearly a decrease in productivity, where the dumping distance is approximately 3km.

Work Efficiency Evaluation

Uptime and efficiency are calculated based on the ratio of actual operating time to total scheduled uptime (1 day), after deducting operational bottlenecks.

Table 8. Unit work efficiency

Tool Type	Available Time (Hours)	Working Time (Hours)	Work Efficiency (%)
Excavator PC 2000-8	24	11,18	47
Dump Truck HD 785-7	24	9,84	41

Actual Tool Productivity Calculation

1. Komatsu PC2000-8 Excavator Productivity

Table 9. Productivity parameters of the excavator load

Parameters	Value

Cycle Time (seconds)	30,54
Work Efficiency (%)	47
Bucket Capacity (m³)	12
Swell Factor (%)	85
Fill Factor (%)	90

$$Q = \left(\frac{3600}{Ctm}\right) \times Kb \times Ff \times Sf \times Ek$$
$$= \left(\frac{3600}{30{,}54}\right) \times 12 \times 0{,}9 \times 0{,}85 \times 0{,}47$$
$$= 504{,}5 \text{ BCM/Hour}$$

Based on this productivity, it is clear that it has not been achieved, where the target is 800 BCM/Hour.

2. Productivity of Komatsu HD-785 Dump Truck Haulage

Table 10. Productivity parameters of the hauler

Parameters	Value
Cycle Time (minutes)	21,73
Work Efficiency (%)	41
Bucket Capacity (m³)	12
Swell Factor (%)	85
Fill Factor (%)	90
Number of Units	7

$$Qa = \frac{Na \times Kb \times Ff \times Sf \times Ek \times 60}{Ct}$$
$$= \frac{7 \times 12 \times 0{,}9 \times 0.85 \times 0{,}41 \times 60}{21{,}73}$$
$$= 69 \text{ BCM/Hour}$$

Evaluation of Production Target Achievement

In the actual calculation in the field, the match factor calculation of the digging and loading equipment and means of transport was obtained as follows:

$$MF = \frac{Na \times Ctgm \times n}{Nm \times Cta}$$
$$MF = \frac{7 \times 36{,}4 \times 7}{1 \times 1341{,}05}$$
$$MF = 1.25 \text{ (Queue Hauler)}$$

In the actual calculation, it can be seen that the MF value is 1.25. This shows MF > 1, which means that the loading tools are working optimally, but the transport tools are in a queue, so there is a waiting time for the transport equipment. Therefore, an evaluation of the existing obstacles was carried out. Where on

Table 11 and

Table 12 is the minimum barrier that occurs during the month of February. This aims to improve existing work efficiency.

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Table 11. PC2000-8 minimum barrier

Barriers	Time (Hours)
Shift Change	0.10
Safety Talk	1.00
P2h & P5m	0.03
Rest & Meal	1.37
Pray	0.25
Slippery	0.44
Rain	2.19

Table 12. Minimum resistance HD-785

Barriers	Time (Hours)
Shift Change	0.02
Safety Talk	1
P2h & P5m	0.02
Refuelling	0.001
Rest & Meal	1.41
Pray	0.29
Slippery	0.44
Rain	2.19

So there is a reduction in standby time and an increase in working time based on the minimum barrier as shown in the table below:

Table 13. Working time, minimum resistance and working efficiency PC2000-8

Working Time (Hours)	Breakdown (Hours)	Standby (Hours)	Work Efficiency (%)
17,80	0,82	5,38	74

Table 14. Working time and minimum resistance and working efficiency of HD-785

Working Time (Hours)	Breakdown (Hours)	Standby (Hours)	Work Efficiency (%)
17,62	0,99	5,38	73

So the productivity value of each tool is as follows:

$$Q_{PC2000\text{-}8} = \left(\frac{3600}{Ctm}\right) \times Kb \times Ff \times Sf \times Ek$$

$$= \left(\frac{3600}{30{,}54}\right) \times 12 \times 0.9 \times 0.85 \times 0.74$$

$$= 802{,}5 \text{ BCM/Hour}$$

$$Q_{HD\text{-}785} = \frac{Na \times Kb \times Ff \times Sf \times Ek \times 60}{Ct}$$

$$= \frac{7 \times 12 \times 0.9 \times 0.85 \times 0.73 \times 60}{21{,}73}$$

$$= 123.5 \text{ BCM/Hour}$$

Based on the matching of productivity, the number of suitable units is as follows

$$Na = \frac{\text{Productivity Excavator}}{\text{Productivity Hauler}}$$

$$Na = \frac{802{,}5 \text{ BCM/Hour}}{123{,}5 \text{ BCM/Hour}}$$

Na = 6 units

With the following match factor values:

$$MF = \frac{Na \times Ctgm \times n}{Nm \times Cta}$$

$$MF = \frac{7 \times 36{,}14 \times 6}{1 \times 1341{,}05}$$

MF = 1.07 (Close to 1)

So after evaluating the distribution of productivity, a recommendation was obtained to reduce the units from 7 to 6 units. The reduction of 1 unit of transportation will reduce the Match Factor number closer to 1, so that the compatibility factor of loading tools and transportation tools is more balanced and minimizes queue waiting time (queue hauler).

CONCLUSION

Based on the resistance data, the Phyisical Availability (PA) value of PC 2000-8 is 97% and for HD-785 is 48%, while for PC 2000-8 it is 48% and for HD-785 it is 43%. The average cycle time value of Komatsu PC2000-8 excavator loading tools in overburden stripping activities at Pit Banko Tengah A is 30.54 seconds (0.5 minutes). As for the cycle time of the Komatsu HD-785 Dump Truck with a transport distance of 3 km, it is 1303.83 seconds (21.73 minutes). The actual productivity value of the Komatsu PC2000-8 excavator in overburden stripping activities reached 504.5 BCM/Hour. Meanwhile, the actual productivity value of Komatsu HD-785 Dump Truck transport equipment is 69 BCM/Hour. The match factor (MF) value between the excavator and the operating equipment (1 excavator and 7 means of transport) was obtained as 1.25. With this value, it can be concluded that MF > 1, which means that the loading capacity has been met but there is a waiting time for queues that occur for transportation equipment at the work front. The main factors that cause the high cycle time of transportation equipment and the occurrence of unit queues are the condition of the hauling road that narrows due to the accumulation of spoils on the side of the main road, as well as the condition of the undulating road surface that forces a decrease in unit speed. After evaluating the achievement of the production target by minimizing obstacles, the productivity value of the Komatsu PC2000-8 loading tool is 802.5 BCM/Hour and the productivity of the Komatsu HD-785 conveyor is 123.5 BCM/Hour. The calculation of the number of units is based on the productivity matching formula, it is recommended to reduce the number of means of transportation from 7 units to 6 units. This reduction of 1 unit will make the MF value closer to 1, so that the compatibility factor of the mechanical tool becomes more optimal and minimizes waiting time.

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