HEAVY EQUIPMENT EFFICIENCY, PRODUCTIVITY AND COMPATIBILITY OF COAL MINE OVERBURDEN WORK IN EAST KALIMANTAN

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ABSTRACT

A mining activity starts with clearing the land from plants and overburden stripping. The purpose of this study is to analyze the value of work efficiency, productivity, and compatibility of heavy equipment in overburden work. This research employs a descriptive method and includes a case study, then the data were obtained from observations. The research results found that the value of workload efficiency is 74.63% and the value of conveyance is 58.37%; while the productivity of loading equipment is 5,055 BCM/hour and conveyance is 5,189 BCM/hour; furthermore, the match factor level of the equipment is 0.65. However, the match factor level is still below the standard. Thus, further research is required to determine the appropriate strategy to make the equipment's match factor level equal to one.

Key words: work efficiency, productivity, coal, heavy equipment, overburden

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1. INTRODUCTION

Indonesia, which is a developing and archipelagic country, undoubtedly requires a lot of physical and non-physical resources. These are the main capital for the implementation of development sustainability in various sectors, videlicet the economy, energy, industry, infrastructure and so forth. Management and control of resources are greatly essential and strategic for promoting the development of an advanced, independent, prosperous and just nation [1]. Apart from being an archipelago, Indonesia is also a developing country rich in natural resources, such as tin, gold, oil, coal, and others. Coal is one of the natural resources that contribute to a great deal of foreign exchange. Based on Coal Country Meal in 2007, Indonesia is one of the ten largest coal producing countries in the world.

Production equipment in mining operations is vital to support the final production target determined by the company's management. Its utilization is not only concentrated in the process of both open-pit and underground mining but is also needed for mining support processes, which are mine roads maintenance and the structuring of post-mining reclamation areas. A mining activity starts with clearing the land from plants/scrub and overburden stripping; the main purpose of overburden is to remove overburden covering the minerals (coal, gold, etc.) consisting of sandstones and clay stones. The overburden that has been stripped is transferred to the landfill, usually called 'disposal'. It is an area in an open pit operation for disposing materials.

A company in east Kalimantan has carried out coal production activities since 2009. The total production from 2009 – 2013 was as much as 12,307,021 MT and the remaining reserves were 16,547,443 MT. New reserves of 1,424,668 MT were found during the exploration activities in 2009 – 2018 so that the remaining reserves as of January 2019 were 17,972,111 MT. The estimated budget for purchasing coal mining equipment in east Kalimantan with a production of 2,670,000 tons - 3,500,000 tons was Rp. 512,999,050,000,-. From the estimated value, a precise and thorough analysis is required in selecting the combination of heavy equipment utilization, particularly in overburden work. It is expected that the right combination in terms of the type of equipment, capacity, and number will be selected.

From the background previously explained, the formulation of the problem in this study pertains to the value of work efficiency, productivity and work performance of heavy equipment utilized in overburden work. The results of the study are expected to provide an initial rationale for analyzing heavy equipment that will be practically utilized so as to minimize errors occurring in the determination of heavy equipment combination (types, specifications, and quantities) in a project. It will also provide information and knowledge to consultants, contractors, owners and the public in regards to the alternative combination efficiency of heavy equipment utilization. In addition, this study makes the determination of the heavy equipment utilization combination and the evaluation of equipment performance at the time of implementation uncomplicated to an executor or project manager.

2. LITERATURE REVIEW

2.1. Coal Mining in Indonesia

Refer to Darmawan and Irawan [2], climate and weather affect mining activities as they:

a. Affect the performance of mining operations

The high rainfall and rainy days will directly affect the performance of mining operations. A considerable amount of work time is wasted due to rain. The determination of monthly production plans adjusted to the monthly rainfall characteristics deserves attention. This is related to the annual production target to achieve.

b. Affect the design of mine drainage facilities

The mine will be a pit. High rainfall means high discharge and runoff volume entering the pit. If the drainage facilities (settling ponds) are not properly designed and make the in-pit capacity inadequately handle runoff water, the pit will be flooded and mining operation will stop. Therefore, the analysis of the rainfall general state intensity will generate recommendations that will be used as parameters for the drainage system and setting pond design.

Coal sediment mining in the exploration area to be performed with an open pit is divided into the following stages:

a. Clearing the Mine Site (Land Clearing)

The purpose of land clearing is to clear the mine site from plants and shrubs so as not to interfere and to facilitate the stripping work and mining. The plants and shrubs are piled at a certain spot and are used to cover the upper part of the disposal area. This is expected to reduce erosion and produce nutrients in the disposal area.

b. Overburden

The stripping activity in the coal mining business is performed as follows:

- Stripping the Topsoil

Topsoil is a part of the overburden containing nutrients needed by plants and it is handled separately. The topsoil is evenly stripped from the depth of 0.25 m to 0.50 m from the ground to the entire mine site's surface and placed close to the mine opening plan with a maximum spacing of 500 m; after the former mine is backfilled, the topsoil can be deployed to the landfill site.

- Stripping the Covered Soil

Stripping the sandstones and clay stones is performed by pushing the overburden horizontally and loading them into the dump truck with the excavator. Next, they are transported to the landfill. Coal overburden is generally arranged with sandstones and clays; the sandstones generally imparts colors of light grey to grey, are fine to medium-grained, have sub-rounded to sub-angular shapes, consist of loose to compact materials and clay, also are generally reddish-white to light gray colored with medium to high plasticity.

- Land Cover Disposal

The landfill is divided into two types, which are the disposal of out pit dump within 300 m - 1000 m and the disposal of overburden into the mining area (in pit dump) used as a backfill to the former mine.

c. Coal Mining

This work is performed after the excavation stage of the overburden is completed and followed the overburden excavation progress. Coal dismantling is conducted in accordance with the planned production target. In this work, you will use heavy equipment, which is a bulldozer equipped with rakes. After the coal is uncovered, it is collected with a bulldozer using a blade. The total reserves to be demolished are 15,028,263.79 MT.

Based on the shape of the coal seam, contour mining will be performed. The excavation technique is done from the highest to the lowest elevation based on the predetermined mining depth and follows the direction of the coal seams deployment in each mine pit.

2.2. The Use of Heavy Equipment in Coal Mining

According to Nuryanto [3], several things essential to consider in using heavy equipment are as follows:

- The decision of using heavy equipment is based on the scenario stating that the equipment must provide greater income than the costs incurred (including operating/ownership costs); if it is not the case, there is no need to purchase the equipment.
- An engineer must have the knowledge of heavy equipment; he must know the most recent information on the latest equipment development and can decide the appropriate machine suitable for an appropriate implementation method.
- Cost relationship informs that the heavy equipment in the field should be able to increase work capacity and minimize costs incurred.
- There might be problems; and thus, there are a number of matters that must be planned: expenses for the equipment purchase or maintenance, the cost of supervision (periodic), the need for skilled operators and training for other workers, and methods for increasing effectiveness in using the equipment.

There are several types of equipment often used in mining:

- Ground Digger Equipment, such as power shovels and excavators
- Material Loaders, such as Crawler Loaders and Wheel Loaders
- Material Conveyance (Hauler). According to Rostiyanti [4], selecting the type of conveyance depends on the conditions of the field, material volume, time and cost. The vehicle is made specifically for the purpose of transportation adapted to the conditions of the transport itself, such as dump trucks. These are long haul vehicles; thereby, the haul road can be flat, upward and downward sloping.

Several previous studies on the use of heavy equipment in Indonesia included heavy equipment productivity analysis in road projects [5], optimization of heavy equipment in road projects [6], optimization of dump truck use in mining [7], and evaluation of using heavy equipment in dam projects [8]. Notwithstanding, none of the studies have examined the efficiency, productivity, and compatibility of overall heavy equipment utilization particularly in coal mining overburden work.

3. RESEARCH METHOD

This research employs a descriptive method. According to the type of problem investigated, this research includes a case study. Case study research is an in-depth study of individuals, a group, an organization, an activity program, and others in a certain period. The purpose of the case study is to describe the detailed illustration of the background, nature, and characteristics typical of the case, which will be a general idea.

The data were collected in the form of:

Primary data

Data directly obtained from observations in the field, such as the circulating time of mechanical equipment, effective working time, real theoretical production of mechanical equipment, equipment requirements, the number of digging equipment bucket filling and loading to the conveyance, soil excavation volume, the distance between excavation sites and disposal locations, as well as travel time for dump trucks.

Secondary Data

Data obtained from existing research results, including location maps, topographical conditions of the research area, tool specifications, as well as rainfall data, and so forth.

Subsequently, the data obtained is analyzed based on the process as follows:

- Calculating the geometry of the haul road for loading and conveyance equipment.
- Calculating the cycle time of loading and conveyance equipment.
- Improving the work efficiency of loading and conveyance equipment both in theoretical and real theoretical ways which increase the work efficiency of loading and conveyance equipment in a real theoretical way to obtain better productivity results.
- Calculating the productivity of loading and conveyance equipment both in theoretical and real theoretical ways which increase the work efficiency of loading and conveyance equipment in a theoretical way to obtain better productivity results.
- Calculating the need for equipment in theoretical and real theoretical ways.
- Calculating the compatibility between the number of conveyance as well as the loading and unloading equipment by viewing the number of conveyance and digging equipment in the field.

4. RESULTS AND DISCUSSION

The production of mechanical equipment is affected by physical and mechanical conditions as well as by the conditions in which the equipment is used. To achieve the specified production target, a production capability assessment of the loading and conveyance equipment is needed. The assessment is conducted through observations and research on the conditions in the field and the factors affecting the equipment's capability [9]. This knowledge is expected to provide the best effort in achieving production goals.

Field conditions can affect the performance of loading and conveyance equipment. Mechanical equipment can work optimally in a field with good conditions; a haul road that is not dusty in the dry season or not muddy in the rainy season, for instance. In contrast, mechanical equipment cannot work optimally in a field with poor conditions; if the road is dusty, it will interfere with the sight of the dump truck operator. To deal with this problem, the haul roads are watered periodically using a water truck. If the road is bumpy and muddy due to vehicle loads and rain, the road maintenance is done using a motor grader.

4.1. The Condition of the Mining Front

Based on the specifications of the largest truck hauler (Komatsu HD 465) and the results of calculations, the minimum bend radius that can be traversed by the truck is 8.6 meters. The width of the truck is 4.75 m and the required loading point area is = 2 x 8.6 + 4.75 = 21.95 m. Based on the observation revealing that the loading point width in the field is 35.67 meters, there is no need for widening because the conveyance can easily maneuver.

4.2. Load Pattern

The loading pattern used in the field is based on the excavation level between the loading equipment and the conveyance using a top loading pattern, in which the excavator does the loading by placing itself on top of the ladder or the truck is placed under the loading equipment. The loading pattern based on the number of truck placements is single back up, that is, the truck positions itself to be loaded in one place, while the next truck waits for the first truck to be fully loaded. After the first truck leaves, the second truck positions itself and so on. This loading pattern is applied considering the long cycle time and the number of conveyances which results in a low level of the loading and conveyance equipment compatibility.

4.3. The Width of Haul Road

Determining the minimum haul road for straight and bending roads is based on the rule of thumb proposed by the AASHTO (American Association of State Highway and Transportation Officials) Manual Rural Highway Design. With the process of calculating the minimum haul road width for straight roads, it was found that the haul road width needed for the 2 transport lines using the Komatsu HD 465-7 dump truck on a straight road is 17 meters (calculating the minimum haul road width for straight roads); while according to observations, the road width in the mining area is 24 meters. Furthermore, based on the calculation on the bending road, the haul road width is 21.34 meters. Nevertheless, in regards to observations and conditions at the site, the minimum required width is 25 meters. For this reason, there is no need for widening the road. Loading patterns used in the field are based on the level of excavation between the loading equipment.

4.4. Slope (Grade)

The slope of the haul road is one of the factors affecting the conveyance capability to work in mining activities from pit overburden to the disposal area in dealing with inclines. The slope of transport road between pits to disposal area is 12.8%. According to the Komatsu HD 465-7 dump truck technical specifications data, it is revealed that:

- - Weight charged: 98, 800 Kg ~ 98.8 tons
- - Empty weight: 42,800 Kg
- - Horsepower: 715 HP

In order to move the truck, the required number of rim pulls must be the same as the available rim pull. This will occur if the haul (a%) of the haul road is 14.9%. From the observations on the map, the location of the mining haul road has a slope of ± 12.8%, in which the Komatsu HD 465-7 dump truck climbing ability is 14.9% (pertaining to the results of the required rim pull calculation), thus the conveyance can still work well at the location of the mining site. For that reason, there is no need to reduce the slope of the road because the Komatsu HD 465-7 dump truck can work well at the mining site.

4.5. Bend Radius

According to observations in the location, the haul road at the mine has a bend radius of 17.3 meters. The bend radius allowed for the Komatsu HD 465-7 dump truck is 8.6 meters. The radius of the existing bend is arguably safe because the operator does not need to reduce speed when the conveyance turns.

4.6. Material carrying capacity

The material carrying capacity is a material's ability to support equipment above it. Equipment placed above the material will provide ground pressure. Resistance given material is called material carrying capacity. In accordance with the specifications of the conveyance, the following data are obtained:
For Komatsu HD 465-7

- - Empty weight = 42,800 kg (94,360 lb)
- - Load Weight = 97,875 kg (215,780 lb)
- - Load weight for each front wheel 32%: 2 = 34,525 lb
- - Load weight for each rear wheel 68%: 4 = 36,682.5 lb
- - Tire pressure = 68.15 psi

Based on calculations, the load received for each front wheel is 455.94 in^{2c}, while the load received for each rear wheel is 484.44 in^{2c}. The load received by the road surface (lb/ft^2) = 10,903.7 lb/ft^2.

At the mining site, the road construction connecting the mining front location to the landfill is the original structure of the existing material, because the nature of the mine road is only temporary. Thereby, there is no special construction for road carrying capacity. The carrying capacity of the mine road based on the material used, which is hard dry consolidate clay, is 10,000 lb/ft^2. Currently, the load received by the road surface is 10,903.7 lb/ft^2 (the calculation of load received by the road surface); there is an overload of 903.7 lb/ft^2 so that the road surface is often bumpy. For this condition, the use of motor graders is very essential; the road's routine and periodic maintenance can help optimize the work of conveyance.

4.7. Cycle Time

Calculating the cycle time of mechanical equipment is conducted by paying attention to the pattern of mechanical equipment motion during its activities. The cycle time for loading equipment is the amount of time spent in a series of work starting from taking the digging position until it returns empty for re-digging.

4.8. Loading and conveyance equipment Work Efficiency

Work efficiency is a comparison between effective hours of work available. Effective working hours are the number of working hours actually used for production activities. In regulating work activities, the mining contractor has set a working time schedule, which is the workday schedule from Monday to Sunday, 2 (two) work shifts per day with a total working time of 24 hours per day on average. On Friday, the afternoon break starts from 11 – 1 p.m so the working hours are reduced to 23 hours. The average effective working hour is 20.7 hours/day or 1,242 minutes/day.

According to observations, there are a number of hindrances that can be dealt with, but not on the loading and conveyance equipment, they are:

Hindrances that can be dealt with:

- Being late at the start of a shift
- Getting off the work early
- Resting for too long
- Requiring operators

Hindrances that cannot be dealt with:

- Rain and dry roads
- Equipment breakdown
- The operator daily inspection
- Front Repair
- Fuel refill

Based on the calculation, the results are obtained as follows:

Loading Equipment Work Efficiency

Productive work time is an available working time in one day minus the amount of unproductive time. Loading equipment productive working time is 927 minutes. Thus, the work efficiency of loading equipment can be calculated in the following:

Eff = (Productive working time / Available working time) x 100%

= (927 / 1,242) x 100%

= 74.63%

Conveyance Equipment Work Efficiency

Productive work time is an available working time in one day minus the amount of unproductive time. The productive working time of the conveyance is 725 minutes. Thus, the working efficiency of conveyance equipment can be calculated in the following:

Eff = (Productive working time / Available working time) x 100%

= (725 / 1,242) x 100%

= 58.37%

4.9. The Productivity of Loading and Conveyance Equipment

Loading and conveyance equipment production is the achievable amount of production in the reality of the loading and conveyance equipment work based on the current achievable conditions. Productivity capabilities can be discovered by calculating the production capability of existing mechanical equipment. Greater equipment production means better equipment production.

a) The calculation for loading equipment production is:

Qm = Nm x (60/CTm) x Cm x F x sf x E (BCM/hour)

Qm = 10 x (60/0.38) x 6.7 x 0.8 x 0.81 x 74.63%

= 5,055 BCM/hour

b) The calculation for the production of conveyance is:

Qm = Na x (60/CTm) x Cm x sf x E (BCM/hour)

Qm = 25 x (60/7.5) x 55 x 0.81 x 58.37%

= 5,189 BCM/hour

4.10. Loading and Conveyance Equipment Working Compatibility

Match factor is the working compatibility between loading and conveyance equipment. The compatibility of work price for each work set of mechanical equipment used is determined based on the cycle time data and the number of mechanical equipment used in each set of work.

MF = Na x CtL

Nm x CTa

The combination of work between loading and conveyance equipment in mining is:

Na = 25 units

Nm = 10 units

CTm = 0.38 minutes

CtL = 1.96 minutes

CTa = 7.52 minutes

MF = (25 x 1.96) / (10 x 7.5) = 0.65

MF <1, this indicates that loading equipment works less than 100% while conveyance works 100%; this is due to the production of loading equipment which is greater than the production of conveyance. It means that the conveyance equipment is busy transporting while the loading equipment is waiting for its arrival; so, there is a waiting time for the loading equipment, and the calculation is as follows:

Wtm = Nm x CTa - (CTm x n) (minutes)

Na x CTa

= ((10 x 7.52) / 25) - (0.38 x 25)

= 6.61 minutes

Based on calculations from field data, the match factor level of the equipment for 10 (ten) Komatsu PC1250SP-7 excavator units with 25 (twenty-five) units of Komatsu HD465-7 dump truck conveyance is 0.65, with the loading equipment cycle time of 6.61 minutes.

5. CONCLUSION

From the results of the analysis, it can be concluded that the value of work efficiency, productivity and work performance of heavy equipment used in overburden work are as follow:

- The current work efficiency for loading equipment is 74.63% and the work efficiency for conveyance equipment is 58.37%.
- The current equipment productivity in overburden work with 10 units of Komatsu PC 1250 SP-7 excavator loaders is 5,055 BCM/hour and 25 units of Komatsu HD 465-7 dump truck are 5,189 BCM/hour.
- The match factor level for the 10 Komatsu PC1250SP-7 excavator units with 25 Komatsu HD465-7 dump trucks is 0.65, with a cycle time of 6.61 minutes.

The level of MF (Match Factor) obtained is still below 1 (one), so further research can be conducted to find suitable alternative strategies for MF to be nearly 1 (one). Some possible alternatives are the addition of conveyance and loading equipment or additional time for each equipment.

REFERENCES

[1] Ruddy Harjanto, Subandiyah Azis and Sutanto Hidayat, The Accelerating of Duration and Change of Cost on Construction Project Implementation. *International Journal of Civil Engineering and Technology*, 10(01), 2019, pp 825-832.

[2] Darmawan and Irawan. 2009. Reklamasi Lahan Bekas Tambang Batubara PT Berau Coal, Kaltim. Prosiding Workshop IPTEK Penyelamatan Hutan Melalui Rehabilitasi Lahan Bekas Tambang Batubara. Balai Besar Penelitian Dipterokarpa. Samarinda.

[3] Nuryanto, Bambang. 2000. Alat-alat Berat Pemindahan Tanah Mekanis. Diklat Alat Berat.

[4] Rostiyanti, Susy Fatena. 2008. Alat Berat Untuk Proyek Konstruksi. Rineka Cipta. Jakarta.

[5] Andriyanto, Arif Agus. 2012 Perhitungan Produktivitas Alat Berat Pada Pelaksanaan Pekerjaan Pembangunan Jalan Batu Cermin (Sempaja) Kota Samarinda. Jurnal Teknik Sipil. Sekolah Pasca Sarjana Universitas 17 Agustus 1945 Samarinda.

[6] Retno, Deddy Purnomo. 2013. Analisa Optimalisasi Penggunaan Alat Berat Pada Kegiatan Pembangunan Jalan Wilayah III Kecamatan Perhentian Raja dan Kampar Kiri Hilir Kabupaten Kampar. Jurnal Saintis Volume 13 Nomor 2, Oktober 2013, Program Studi Teknik Sipil Universitas Islam Riau.

[7] Prasmoro, Alloysius Vendhi. 2014. Optimasi Produksi Dump Truck Volvo FM 440 Dengan Metode Kapasitas Produksi dan Teori Antrian di Lokasi Pertambangan Batubara (Studi Pada Salah Satu Kontraktor Pertambangan Area Samarinda, Kalimantan Timur) Jurnal OE, Volume VI, Maret No. 1 2014 Program Studi Magister Teknik Industri. Universitas Mercu Buana.

[8] Riyanto, Joko. 2016. Evaluasi Kombinasi Alat Berat Menggunakan Indikator Waktu dan Biaya Pada Pelaksanaan (Study Kasus Pekerjaan Galian Tanah di Bendungan Tugu Kabupaten Trenggalek). Tesis Program Pascasarjana Teknik Sipil. Institut Teknologi Nasional Malang.

[9] Asiyanto. 2008. Manajemen Alat Berat Untuk Konstruksi. PT. Pradnya Paramita. Jakarta.

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