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Evaluation of the Match Factor between Excavation Equipment and Hauling Equipment at CV Bintari Jaya Abadi

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Abstract: CV Bintari Jaya Abadi is a company engaged in andesite stone mining. The actual productivity of the excavator at the CV Bintari Jaya Abadi quarry in January 2024 was recorded at 9,494.8111 BCM, while the hauling equipment achieved 9,362.83824 BCM, with a match factor of 0.68. This resulted in the current andesite mining target not being achieved, where the targeted andesite rock removal at CV Bintari Jaya Abadi is 11,538 BCM per month. The research method used involved the calculation and quantitative analysis of the factors affecting the match factor between loading and hauling equipment in andesite mining activities at CV Bintari Jaya Abadi. Improvement efforts aimed at achieving optimal productivity and operational compatibility were carried out by optimizing the cycle times of both the loading and hauling equipment. As a result, the productivity of the loading equipment increased by 34.71% to 12,790.0415 BCM/month, and the productivity of the hauling equipment increased by 76.34% to 16,509.7606 BCM/month, successfully meeting and even exceeding the target set by CV Bintari Jaya Abadi of 11,538 BCM/month, with a match factor of 0.94.

Keywords: *Cycle Time; Delay Time; Match Factor; Production; Work Efficiency*

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I. INTRODUCTION

Mining is one of the key elements supporting the Indonesian national economy. The positive impacts of mining activities can be directly felt by residents living near mining areas, such as improvements in infrastructure and the local economy. Moreover, mining plays a crucial role in supporting human life. Indonesia is home to numerous companies operating in the mining sector, one of which is CV Bintari Jaya Abadi. CV Bintari Jaya Abadi is an andesite stone mining company. However, in its mining operations, there is a waiting time (delay time) experienced by the loading equipment due to delays from the hauling equipment. This delay time varies between 2 to 6 minutes per hauling cycle. An evaluation of the match factor is necessary to reduce delay time and to assess the optimal number of loading and hauling equipment, aiming to increase production without raising operational costs (Anggara et al., 2024). The match factor involves the availability and capacity compatibility between loading and hauling equipment, the ability of hauling units to transport and distribute andesite rock efficiently, and the capability of the loading equipment to load the rock into the haulers with speed and precision. By understanding the match factor between loading and hauling equipment, operational arrangements and productivity in andesite mining can be improved, leading to the achievement of predetermined production targets. Therefore, the author conducted a study entitled "Evaluation of the Match Factor Between Loading and Hauling Equipment at CV Bintari Jaya Abadi."

II. LITERATURE REVIEW

➢ *Factors Influencing the Productivity of Mechanical Equipment:*

- *Front Loading Conditions:*

Front-loading conditions are one of the factors affecting the productivity of excavating-loading and haulage equipment. The more ideal the front-loading setup, the easier it becomes for haulage machinery to prepare for maneuvering or loading, which in turn reduces cycle time.

- *Loading Patterns in Front Loading:*

Cara The method of loading material by the loading equipment into the haulage equipment is determined by the positional relationship between the loader, the material, and the transport vehicle specifically whether it's top loading or bottom loading.

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- *Cycle Time of Excavation–Loading and Hauling Equipment:*

Cycle time is the total time required by a machine to complete one full operational cycle. Each piece of equipment comprises different cycle-time components, and the overall cycle duration depends on both the number of these components and the time consumed by each.

- *Bucket fill factor:*

It is a factor that compares the actual volume of material scooped by a bucket to its theoretical (rated) bucket volume.

- *Swell Factor:*

Swell Factor is the ratio comparing the volume of material in its loose (excavated) state to its volume in the natural (in-situ) state.

- *Equipment Availability:*

Availability of excavation–loading and hauling equipment in mining.

- *Operational Efficiency:*

Operational efficiency is an evaluation of how a task is carried out, or a comparison between the time used to perform the work and the time available.

➢ *Productivity of excavationloading equipment and hauling equipment:*

Productivity is a measure of effectiveness in the production of goods, typically calculated with respect to time. The production is estimated on an hourly basis for both excavation–loading equipment and hauling equipment.

➢ *Match Factor:*

Work synchronization refers to the harmony between loading equipment and hauling equipment.The match factor between excavation loading equipment and hauling equipment is one of the key determinants in achieving production targets. In other words, the production output of the digging-loading equipment and the hauling equipment represents the total production achieved during a loading and transportation operation.

III. RESEARCH METHODS

The research will be carried out in several stages, including literature review, field observation, data collection and validation, as well as data processing and analysis.

➢ *Literature Review:*

The literature review is used to strengthen the data that will be processed and analyzed during the research. Supporting literature materials are obtained from relevant institutions, theses, journals, previous research, and books, which will serve as references in the analysis of investment in loading and hauling equipment at CV Bintari Jaya Abadi.

➢ *Field Observation:*

Field observation is conducted to closely observe the evaluation of loading and hauling equipment. This observation is carried out by visiting the site of CV Bintari Jaya Abadi, located in Pelantaran Village, Cempaga Hulu District, East Kotawaringin Regency, Central Kalimantan Province, to document field conditions, mining area conditions, and the loading and hauling equipment used to support the research.

➢ *Data Collection and Validation:*

Data collection is conducted at CV Bintari Jaya Abadi with the aim of obtaining accurate data in accordance with the research objectives. This stage involves gathering the necessary data for the research. The data collected includes both primary and secondary data.

- *Primary data:*

Primary data is the source of research data obtained directly from the research site. This data consists of direct field observations and measurements related to the study being conducted. The primary data to be collected includes the following:

✓ Cycle time data of loading and hauling equipment, such as:

- Loading equipment, including observations of digging time, loaded swing time, dumping time, and empty swing time.
- Hauling equipment, including maneuvering time, loading time, travel time, dumping time, and return (empty) time.

✓ Factors influencing the performance of mechanical equipment, such as fill factor, swell factor, front loading conditions, and the loading pattern used.

- *Secondary Data:*

Secondary data is the source of research data obtained through other parties. It serves as complementary data and is gathered from documents and literature studies, including journals, previous research, and past theses. In other words, researchers collect secondary data by visiting libraries, research centers, archives, or reading books relevant to the research. The secondary data to be collected in support of the primary data includes the following:

✓ Company profile.
✓ Work schedule at CV Bintari Jaya Abadi.
✓ Company data on the specifications of loading and hauling equipment used at CV Bintari Jaya Abadi.
✓ Company data on the Andesite production target set by CV Bintari Jaya Abadi.
✓ Rainfall data.
✓ Swell factor and bucket fill factor data.

➢ *Data Processing:*

The collected data is then processed and calculated. This stage includes the following steps:

- Calculation of Effective Working Time of Loading and Hauling Equipment.
- Calculation of Cycle Time for Loading and Hauling Equipment.
- Calculation of Bucket Fill Factor.
- Calculation of Swell Factor.
- Calculation of Equipment Availability.
- Calculation of Work Efficiency.
- Calculation of Loading Equipment Productivity.

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- Calculation of Hauling Equipment Productivity.
- Calculation of Match Factor.

➢ *Data Analysis:*

The analysis stage in this research will include the following steps:

- Analyzing the actual conditions in the field as well as the factors that affect equipment productivity during overburden removal.
- Analyzing the collected data, both primary and secondary. From this data, the actual cycle time in the field both for loading and hauling equipment will be obtained. Based on these cycle times, the productivity values will be calculated and compared with the company's production targets.
- Once the cycle time, productivity, match factor, and the factors influencing productivity in the field have been identified, the researcher will calculate the ideal match factor to be applied in the field.
- Decision-making stage Based on the data collected, tabulated, and described, conclusions will be drawn to determine the factors that influence cycle time and propose improvements to the match factor in order to optimize equipment usage, increase the productivity of loading and hauling equipment, and reduce waiting time.

IV. THE RESULT OF RESEARCH AND DISCUSSION

➢ *Actual Equipment Cycle Time:*

The cycle time measured is the cycle time of excavation loading and hauling equipment used in andesite mining during January 2024.

Table 1 Cycle Time Excavator Komatsu PC 200

Digging (Minute)	Fill Swing (Minute)	Spilled (Minute)	Empty Swing (Minute)	Cycle time (Minute)
0.13	0.08	0.05	0.08	0.34

Table 2 Cycle Time Dump Truck Hino FM 260TI

Maneuver Empty (Minute)	Load (Minute)	Hauling (Minute)	Maneuver Spilled (Minute)	Spilled (Minute)	Return Empty (Minute)	Cycle time (Minute)
0.47	2.40	1.35	0.43	1.06	1.29	7.00

➢ *Bucket fill factor:*

The bucket fill factor value for the Komatsu PC 200 excavator loading tool, based on observations and calculations, is 114%.

➢ *Swell Factor:*

Based on observations and calculations, the swell factor for andesite rock material was found to be 0.83. Swell factor is influenced by the material's density. The material density and swell factor values cannot be changed, as these are inherent properties of the material.

➢ *Equipment Availability:*

Based on data processing analysis, the mechanical equipment availability factor showing the readiness for operation of the mechanical equipment was obtained in the following table.

Table 3 Mechanical Equipment Availability

Equipment	MA (%)	PA (%)	UA (%)	EU (%)
Excavator Komatsu PC 200	91	93	81	75
Dump Truck Hino FM 260TI	99	99	90	80

➢ *Operational Efficiency:*

Mechanical equipment work efficiency is obtained by comparing productive working time with available time. Productive working time is derived by subtracting downtime from available time, resulting in a working efficiency of 58% for the loading excavation equipment and 70% for the hauling equipment.

➢ *Productivity of Komatsu PC200 Excavator:*

Based on field observations in January 2024, the productivity of the Komatsu PC200 excavator at CV Bintari Jaya Abadi in January 2024 can be calculated as follows.

Known data:

Ctm = 0.34 minutes

Kb = 1 m^3

Bff = 114%

Eff = 58%

Sf = 83%

So :

Pm = 60/Ctm×Kb× Bff × Eff × Sf
= 60/0.34×1× 1.14 × 0.58 × 0.83
= 96.8463 BCM/Hour

Productivity per day = Hourly productivity × productive working time

Productivity per day = 96.8463 BCM/Hour × 5.16 Hours/day

Productivity per day = 499.7269 BCM/day

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Productivity per month = 499.7269 BCM/day × 19 day

Productivity per month = 9,494.8111 BCM/month

➢ *Productivity of Hino FM 260 TI Dump Truck:*

Based on field observations in January 2024, the productivity of the Hino FM 260 TI Dump Truck at CV Bintari Jaya Abadi in January 2024 can be calculated as follows.

Known data:

Cta = 7 minutes

n = 7

Kb = 1 m^3

Bff = 114%

Eff = 70%

Sf = 83%

So :

Pm = 60/Cta×Kb× Bff × Eff × Sf
= 60/7×7×1× 1.14 × 0.7 × 0.83
= 39.7404 BCM/Hour

Productivity per day = Hourly productivity × productive working time

Productivity per day = 39.7404 BCM/Hour × 6.2 Hours/day

Productivity per day = 246.39048 BCM/day

Productivity of conveyance = Number of conveyances × Productivity per unit/day

Productivity of transportation equipment = 2 × 246.39048 BCM/day

Productivity of transportation equipment = 492.78096 BCM/day

Productivity per month = 492.78096 BCM/day × 19 day

Productivity per month = 9,362.83824 BCM/month

➢ *Match Factor:*

Based on field observations in January 2024, the compatibility between the loading equipment (Excavator Komatsu PC 200) and the hauling equipment (Hino FM 260 TI Dump Truck) can be determined using the following Match Factor formula:

Cycle time of loading equipment (Ctm) = 0.34 minutes

Number of loading units (Nm) = 1 unit

Cycle time of hauling equipment (Cta) = 7.00 minutes

Number of available hauling units (Na) = 2 Units

Number of bucket loads (n) = 7 Buckets

MF = (Na × Ctm × n)/(Nm × Cta)

MF = (2 × 0.34 × 7)/(1 × 7)

MF = 0.68

The synchronization between the loading equipment (Excavator) and the hauling equipment (Dump Truck) in the andesite mining operation results in a Match Factor of 0.68. For 1 unit of Excavator with 2 Dump Trucks, the Match Factor value is less than 1, which can be interpreted as follows:

- The production capacity of the loading equipment is greater than that of the hauling equipment.
- The loading equipment will have to wait for the hauling equipment, resulting in waiting time for the loader.
- The waiting time of the loading equipment (Wtm) can be calculated using the following formula:

Wtm = (Nm × Cta)/Na- Ctm

Wtm = (1 × 7)/2- 0.34

Wtm = 3.16 minutes

➢ *Factors that result in tool incompatibility and productivity not being achieved:*

- *Front Loading Conditions:*

Front loading conditions are one of the factors influencing the productivity of both excavation-loading and hauling equipment. An ideal front width (at least 20 m, according to company policy) facilitates truck maneuvering and loading, and helps reduce cycle time. At CV Bintari Jaya Abadi, the front-loading width reaches up to 23 m, although it sometimes narrows to 18 m. Given that the dump trucks used have a turning radius of 8.8 m, they can easily perform maneuvering operations. Since CV Bintari Jaya Abadi meets the company's minimum front width policy, the hauling equipment can maneuver and load without difficulty resulting in reduced haul cycle time.

- *Loading Patterns in Front Loading:*

CV Bintari Jaya Abadi employs a top loading method. For truck loading, a single back up pattern is used: the hauling unit positions itself at a single loading point, allowing the truck operator better visibility into the bucket and material placement. Other trucks wait their turn until the first truck is fully loaded. Given the relative elevation between the Komatsu PC 200 excavator and the Hino FM 260 TI dump truck, the excavator is positioned higher. This arrangement enables the excavator operator to more easily align the bucket with the hauling unit, thereby reducing loading cycle time. The loading method

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implemented by the quarry fleet at CV Bintari Jaya Abadi complies with company standards, enabling smooth maneuvering and loading operations.

- *Man Factor:*

Ideally, equipment is expected to operate at full capacity according to its designated working hours. However, in reality, equipment cannot operate at full capacity due to standby time caused by undisciplined operator behavior. This results in equipment being available but not operating. Excavator operators and dump truck drivers often show a lack of discipline at the beginning of their shifts, with delays ranging from 3 to 28 minutes. They also tend to take excessively long breaks and end operations earlier than scheduled. Therefore, direct supervision in the field is necessary, along with strict guidance and corrective action for operators who do not adhere to proper discipline on-site.

- *Machine Factor:*

CV Bintari Jaya Abadi has set a productivity target of 11,538 BCM/month using 1 unit of Komatsu PC 300 excavator and 3 units of Hino FM 260TI dump trucks. The actual productivity in December 2023 with that equipment configuration was 14,638 BCM. Meanwhile, the actual productivity in January 2024 with 1 unit of Komatsu PC 200 excavator and 2 units of Hino FM 260TI dump trucks was 10,427.14 BCM for the excavator and 9,467.52 BCM for the dump trucks.

The specifications of the Komatsu PC 300 and Komatsu PC 200 excavators are clearly different, and the number of hauling units used also varied. Therefore, the productivity target for January 2024 cannot be equated with the productivity target of the previous month.

- *Material Factor:*

Material conditions also have a significant impact. The type of dense material affects the load that must be carried by heavy equipment. High density makes the loading process more difficult, as more effort is required to move the material, and it also affects the efficiency of dump truck usage. The moisture content of the material also influences the loading and hauling process. If the andesite material is too wet, it becomes heavier and tends to clump together, which can complicate the loading process.

- *Environment Factor:*

High rainfall in January 2024 was a major factor contributing to the failure to achieve the andesite production target for that month. According to the data in the Standard Parameter Operation (SPO), the allocated time for rain and clean-up is 1 hour per day, but in reality, it exceeded this limit. Another environmental factor is dust. When the hauling road becomes dusty, the visibility between dump truck drivers is reduced, which leads to lower driving speeds and a decrease in the number of trips (ritase) per hour.

- *Productive Working Time:*

Work efficiency is one of the key factors that affect equipment productivity the more effectively the equipment operates during available time, the higher the production output. Improving work efficiency can be achieved by reducing avoidable work delays such as late arrivals, extended breaks, and early departures.

- *Availability of Dump Truck Units:*

Based on the analysis using the Match Factor formula, the result shows a Match Factor value of 0.68, which means MF < 1, with the working unit consisting of 1 unit of Komatsu PC 200 Excavator and 2 units of Hino FM 260 TI Dump Trucks. This indicates a lack of synchronization between the loading and hauling equipment. It was observed that the hauling units were operating at 100% capacity, while the loading unit was operating at less than 100%, resulting in the excavator experiencing a waiting time of 3.16 minutes for the dump trucks to return from the hopper.

➢ *Improvement Efforts:*

Improvement efforts to achieve optimal productivity and compatibility between loading and hauling equipment in the andesite mining operation at CV Bintari Jaya Abadi include optimizing the cycle time of both the excavator and the hauling units. The average actual cycle time for the Komatsu PC200 excavator is 0.34 minutes. Confidence interval analysis shows that the average cycle time falls within the range of 0.22 minutes to 0.9 minutes. However, a maximum time of 2.34 minutes was observed, indicating delays in the actual cycle time of the Komatsu PC200 excavator.Therefore, reducing digging time during operation is necessary, which can be achieved by optimizing blast fragmentation, so that the digging time meets the required standard. After improving the digging process, the digging time of the Komatsu PC200, which was initially 0.13 minutes, decreased to 0.1 minutes, resulting in a reduced overall cycle time of 0.31 minutes.Optimal fragmentation produces rock fragments that are more uniform and aligned with the capacity of the loading equipment. If the fragmentation is too coarse (contains many boulders), the resulting material volume tends to be larger after blasting, increasing the swell factor. On the other hand, overly fine fragmentation causes the material to become too dense, reducing the swell factor and making the loading and hauling process more difficult. After optimizing the blast fragmentation, the swell factor decreased from 83% to 70%, indicating better fragmentation (finer and more uniform), resulting in less expansion of material volume after blasting. This suggests more consistent rock sizes, leading to a more controlled loose volume. The volume to be hauled also decreased (from 183 m^3 to 170 m^3 per 100 m^3 bank), allowing dump trucks and loading equipment to operate more efficiently. The change in the swell factor from 83% to 70% also affected the bucket fill factor. Each bucket now carries slightly less material, even though the total loose volume is lower. To maintain the targeted volume, the number of bucket loads must increase from 7 to 8. As a result, the bucket fill factor decreased from 114% to 100%.In addition to affecting cycle time, swell factor, loading frequency, and bucket fill factor, optimizing the blast fragmentation also improved the work efficiency of the loading equipment, increasing it from 58% to 75%. As a result, the productivity of the loading equipment, which was initially 9,494.8111 BCM/month, increased by 34.71% to 12,790.0415

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BCM/month, reaching and even exceeding the target set by CV Bintari Jaya Abadi, which was 11,538 BCM/month. Meanwhile, the average actual cycle time of the Hino FM 260TI dump truck is 7 minutes. Based on the confidence interval analysis, the average cycle time ranges between 4.48 and 18.48 minutes, with a maximum actual value of 14.34 minutes. This indicates that there are still delays in the hauling cycle time of the dump truck compared to the ideal cycle time. Therefore, improvements to the cycle time of the Hino FM 260TI dump truck are necessary. This can be done by optimizing the loading time through reducing the digging time of the excavator, and by improving the hauling and return times by increasing the speed of the hauling unit. As a result, the loading time increased slightly from 2.40 minutes to 2.48 minutes, the hauling time decreased from 1.35 minutes to 0.46 minutes, and the return (empty) time decreased from 1.29 minutes to 0.39 minutes, bringing the overall cycle time of the Hino FM 260TI dump truck down to 5.29 minutes.This improvement in cycle time positively impacted the work efficiency of the hauling equipment, increasing from 70% to 88%. Consequently, the productivity of the hauling equipment increased by 76.34%, from 9,362.83824 BCM/month to 16,509.7606 BCM/month, exceeding the productivity target set by CV Bintari Jaya Abadi, which was 11,538 BCM/month. In addition to boosting monthly productivity, improvements in the cycle time of both loading and hauling equipment also enhanced equipment compatibility, increasing the Match Factor from 0.68 to 0.94, which is close to the ideal value. This significantly reduced the waiting time for the excavator.

V. CONCLUSION

- The actual productivity of the excavator at the CV Bintari Jaya Abadi quarry in January 2024 was 9,494.8111 BCM, while the hauling equipment achieved 9,362.83824 BCM. This resulted in the andesite mining target at the quarry not yet being achieved, with the monthly andesite rock removal target set at 11,538 BCM.
- The match factor between the loading and hauling equipment in the andesite mining operations at CV Bintari Jaya Abadi was 0.68, indicating a match factor value of less than 1. This means the loading equipment had to wait for the hauling equipment.
- Improvement efforts to achieve better productivity and operational compatibility were carried out by optimizing the cycle time of both the loading and hauling equipment. It was found that improving the cycle time—from 0.34 minutes to 0.31 minutes for the loading equipment, and from 7 minutes to 5.29 minutes for the hauling equipment—significantly enhanced performance. The productivity of the loading equipment increased by 34.71%, from 9,494.8111 BCM/month to 12,790.0415 BCM/month. Meanwhile, the productivity of the hauling equipment increased by 76.34%, from 9,362.83824 BCM/month to 16,509.7606 BCM/month, successfully meeting and even exceeding the target set by CV Bintari Jaya Abadi of 11,538 BCM/month. In addition to increasing the monthly productivity target, the optimization of cycle time also improved the match factor, from 0.68 to 0.94, indicating that waiting time for the excavator was significantly reduced.

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