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Operations Management in Measuring the Operational Effectiveness and Efficiency in Company Engaged in Mining Industry

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ABSTRACT

One of the mining industry companies that implement operations management to carry out the function of monitoring and controlling production by measuring operational effectiveness and efficiency in the use of heavy equipment is PT Surya Kalimantan Sejati. Understanding how operational management theories and techniques are applied to evaluate and attain production operations' efficacy and efficiency is the goal of this study. Through field observations and interviews with relevant business leaders in the company, this study employs the Action Research Method. By evaluating the efficacy and efficiency of production operations with the necessary ideal production level, the outcomes of applying theories and methodologies in the field of operations management work demonstrate suitability for mining activities.

Keywords : Operations Management; Effectiveness; Efficiency; Mining Industry; Heavy Equipment

ABSTRAK

Salah satu perusahaan industri pertambangan yang menerapkan manajemen operasi untuk menjalankan fungsi pengawasan dan pengendalian produksi dengan mengukur efektifitas dan efisiensi operasional penggunaan alat berat adalah PT Surya Kalimantan Sejati. Memahami bagaimana teori dan teknik manajemen operasi diterapkan untuk mengevaluasi dan mencapai efektivitas dan efisiensi operasi produksi adalah tujuan dari penelitian ini. Melalui observasi lapangan dan wawancara dengan para manajer yang terkait di perusahaan, penelitian ini menggunakan Metode Penelitian Tindakan. Dengan mengevaluasi efektivitas dan efisiensi operasi produksi dengan tingkat produksi ideal yang diperlukan, hasil dari penerapan teori dan metodologi di bidang pekerjaan manajemen operasi menunjukkan kesesuaian untuk kegiatan pertambangan.

Kata Kunci : Manajemen Operasi; Efektivitas; Efisiensi; Industri Pertambangan; Alat Berat

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INTRODUCTION

PT Surya Kalimantan Sejati is a company engaged in coal mining, located in Tumbang Kajuei Village, Gunung Mas Regency, Central Kalimantan Province. The operational activities carried out by PT Surya Kalimantan Sejati are producing coal and then selling it to PT SKS Listrik Kalimantan, used as fuel or the main raw material for Steam Power Plants (PLTU). In carrying out production activities, PT Surya Kalimantan Sejati uses the services of mining contractors to carry out coal mining activities so that the role of PT Surya Kalimantan Sejati as a controller and supervisor of operational activities carried out by contractors and also acts as a responsible person for ongoing operational activities to relevant government agencies. PT Surya Kalimantan Sejati production activities start from production planning, production scheduling, production implementation and evaluation of production achievement through measuring the effectiveness and efficiency of operations.

Effectiveness and efficiency are an effort to do the job correctly and optimally which refers to the goals or objectives of a job. The term comes from the words effective and efficient which are used in measuring the achievement of goals or objectives. a job that is done. A job is said to be effective if it is done correctly and a job is said to be efficient if the work is done optimally. In organizational context effectiveness is a level of achievement of success in achievement of targets or objectives while efficiency is the level of optimization in the use of resources or in the use of time in activities. use of resources or in the utilization of time in activities. Measurement of effectiveness can be done with three approaches, namely the input approach, process approach and output approach(Lubis, 2019). While measuring efficiency according to Lubis (2019) "efficiency can be measured as a ratio of output to input". This is because efficiency in organizations only shows the saving or the amount of use of inputs needed to produce outputs (Etzioni & Amitai, 1964, 8 in Lubis, 2019). Through an operations management approach, the achievement of effectiveness and efficiency is measured based on production activities related to the transformation process and the use of resources to produce outputs in order to achieve goals or objectives(Prabowo & Uzd, 2023).

Operations or Operational Management is an approach used to manage the resources owned, through the process of transformation from input to output effectively and efficiently. The production and operation process is an effort to produce products from the utilization of owned resources, such as machine tools and technology (Julyanthry et al, 2020). According to (Efendi et al, 2019)"Production and operations management can also be defined as the activity of organizing and coordinating the use of various resources effectively and efficiently in an effort to make products or increase their usefulness". Operations management includes comprehensive and optimal management by considering labor, goods such as machinery, raw materials, equipment, or products that can be converted into tradable goods or services(Faiq, 2021). Operations or operational management is a method used by companies in their efforts to achieve and measure operational effectiveness and efficiency through the achievement of targets or goals and the ratio of resource use or utilization. In production activities, the operations management approach is used to analyze all activities related to the use of resources to determine the level of output against input.

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Production activities that take place in mining companies such as PT Surya Kalimantan Sejati, generally applies one of the areas of work in operations management to measure and achieve the effectiveness and efficiency of operations management to measure and achieve production effectiveness and efficiency based on goals or objectives and resources used in the production process. The field of work in question is the task of operations management in a company, namely process and capacity design(Dadan Suhendar, 2021). In the mining industry there are many theories and methods that can be used to determine the level of achievement of production effectiveness and efficiency. The problem is that each mining company applies different theories and methods in measuring the achievement of production effectiveness and efficiency, so it is necessary to conduct research to determine the use of theories and methods that are relevant to the production activities of PT Surya Kalimantan Sejati in measuring the achievement of effectiveness and efficiency.

In this study, researchers aim to determine the application of theories and methods in operations or operational management to the measurement and achievement of effectiveness and efficiency in mining production activities. This research focuses on material excavation activities in the OB fleet and coal fleet as well as transportation equipment activities because these activities are the main activities in the production process of PT Surya Kalimantan Sejati. This research does not use cost factors in measuring the achievement of effectiveness and efficiency, because data on costs is the privacy of the company so it is limited by PT Surya Kalimantan Sejati, therefore in this study only uses data on heavy equipment activities (excavators and dump trucks).

RESEARCH METHOD

The method used in this research is the action research method. Action research is one of the research methods that is part of the type of verification research (Syahza Almasdi, 2021). The purpose of action research is to solve problems and develop new skills or methods by applying them in the real world (Aslichati et al, 2022). The approach used by researchers in this study is a qualitative. The data collection technique carried out by researchers in this study is to conduct direct observation or observation carried out at the mining location of PT Surya Kalimantan Sejati and conduct interviews with the Head of the Operations Department of PT Surya Kalimantan Sejati and the supervisors.

The data obtained from the results of data collection is used as material for applying theories and methods in measuring the effectiveness and efficiency of production activities that focus on heavy equipment activities (excavators and dump trucks). Because in mining activities in producing mining products, using machine tools such as heavy equipment as a means of achieving planned goals(Dabbagh & Bagherpour, 2019). In addition, because the main mining activities of PT Surya Kalimantan Sejati are centered on the activities of these tools. Measurement of effectiveness and efficiency is carried out using and target approach through measuring the productivity of heavy equipment (excavators and dump trucks), because the achievement of the effectiveness and efficiency of PT Surya Kalimantan Sejati's production refers to the production target which is the target or production goal of PT Surya Kalimantan Sejati. The target approach is an approach used to measure effectiveness with reference to organizational goals or objectives(Lubis, 2019). In this study, the production target of PT Surya Kalimantan Sejati

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is a reference for measuring production effectiveness while measuring production efficiency using a comparison of actual tool working time with tool working time and a comparison of excavator productivity with the ideal production of excavator tools that should be. In this approach, it considers the factors that affect the performance of heavy equipment in measuring efficiency and effectiveness that generally occur in mining companies(Yusak Mokoagow & Basuki Anondho, 2019). Some theories and methods that are relevant to the application of operations management and applied by PT Surya Kalimantan Sejati to control the production process or operational activities of Company, that is:

Effective Utilization

Effective Utilization or work efficiency is a method that compares working time with the Amount planned time and can be used as an indicator of tool performance assessment in carrying out a production activity(Bilhadi, 2023). The results of calculations using this method are presented in the form of percent values, where the value can be determined by the Formula 1 (Prabowo & Uzd, 2023).

$$\mathbf{Ek} = \frac{\mathbf{W}}{\mathbf{W+S+R}} \mathbf{x\ 100\%} \qquad \mathbf{(1)}$$

Based on Formula 1, where W is tool work duration, S is standby duration, and R is tool repair duration

Bucket Fill Factor

It is a method used to determine the comparison of the actual capacity value of excavated material with the value of the material excavation capacity thoristically expressed as a percentage (Bilhadi, 2023). Formula 2 is what is used to determine the comparison according to (Prabowo & Uzd, 2023).

$$\boldsymbol{Bff} = \frac{\boldsymbol{Va}}{\boldsymbol{Vt}} \boldsymbol{x\ 100\%} \qquad \mathbf{(2)}$$

Based on Formula 2, where Bff is fill factor, Va is actual volume, and Vt is theoretical volume

Swell Factor

Swell is a term that describes the increase in volume of an excavation material from a bank or solid condition at the excavation site to a loose or solid condition. excavated material from bank condition or solid condition at the excavation site to lose or melted condition after excavation (Fahrizal, 2020). condition after being excavated. Swell factor describes the efficient use of the excavator bucket in excavation. Swell factor is also one of the factors that affect the productivity of mechanical equipment or heavy digging equipment just like bucket fill factor. The Swell factor value is expressed as a percentage, where in the research (Prabowo & Uzd, 2023) the Formula 3 used, is:

$$\boldsymbol{Sf} = \left(\frac{\boldsymbol{Bcm}}{\boldsymbol{Lcm}} - \mathbf{1}\right) \mathbf{x\ 100\%} \qquad \mathbf{(3)}$$

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Based on Formula 3, where Sf is swelll factor, Bcm is weight of soil in solid state, and Lcm is weight of soil in the melted state

Queuing Theory

Queuing theory or model is a method used to determine measures of service system performance which include the number of customers in a queue, queuing time, service time per customer, and server utility (Darmawan et al, 2023). queue, service time per customer, and server utility. In this study, queuing theory or queuing models are used with an operations management approach to determine the level of use of diggers, the number of conveyances waiting to be served, the average time of conveyances waiting to be served and the number of conveyances in the system. the theory used in this queuing model is the M/D/S theory. In the M/D/S theory, according to Darmawan (2023) "it is certain that can produce a fixed queue length, then there are 2 different levels, namely the macroscopic level if it is continuous and microscopic if it is discrete" (p.29). The Formula 4 used, namely:

$$\textbf{Tool usage rate } (p) = \frac{\lambda}{s\mu}$$

$$\textbf{Number of haulers waiting } (Lq) = \frac{Va}{2\,(1-p)}$$

$$\textbf{Average time haulage is waiting } (Wq) = \frac{Lq}{\lambda} \quad (4)$$

Based on Formula 3, where Bff is Fill factor, Va is Actual volume, and Vt is Theoretical volume.

Excavator and Dump Truck Productivity

This method is used to determine the performance of heavy equipment used as an indicator of the effectiveness of digging and transporting equipment, where the value of the calculation results of this method will be used as one of the indicators for measuring production effectiveness. To calculate the productivity of an excavator, it is calculated by dividing the loading cycle which includes factors such as work efficiency, swell factor, backet fill factor, and time conversion by the cycle time and is presented in units of tons per hour(Bettens et al., 2022). Meanwhile, to calculate the productivity of the dump truck is to calculate the amount of excavation per excavator bucket that is put into the tub in the dump truck and multiply it by the excavator bucket capacity by considering work efficiency, swell factor, fill factor, and time conversion of 3600 or 60 which is then divided by the cycle time value of the conveyance (Wijaya et al., 2019). The Formula 5 and 6 used to calculate the productivity of excavators and dump trucks is as follows:

Excavator Productivity

$$Pe = \frac{Bc.Ek.Bff.Sf.k}{Te} \quad (5)$$

Productivity of Dump Truck

$$Pd = \frac{n.Bc.Ek.Bff.Sf.k}{Td} \quad (6)$$

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Based on Formula 5 and 6, where Pe is excavator productivity and pd as a productivity of dump truck, n for theoretical volume, Bc is theoretical bucket capacity and Bff as a bucket fill factor, Ek is for work efficiency and K as a time conversion, Te is cycle time excavator and Td as a cycle time dump truck.

These theories and methods are a form of application of one of the fields of operations management work applied by PT Surya Kalimantan Sejati to determine the achievement of production carried out through the productivity of excavators and dump trucks.

RESULTS AND DISCUSSION

Based on the research conducted, on the application of theories and methods that are as a form of application of one of the fields of operations management work, the results of the application of the theory and method show suitability and compatibility with mining activities. and methods show the suitability and suitability of the mining activities of PT Surya Kalimantan Sejati through measuring the effectiveness and efficiency of production operations. PT Surya Kalimantan Sejati through measuring the effectiveness and efficiency of production operations. The results of the application of the theory through the target approach show the effectiveness of production activities carried out by PT Surya Kalimantan Sejati through measuring the effectiveness and efficiency of production operations. production activities carried out by PT Surya Kalimantan Sejati is at 108% for coal production and coal overburden (OB) production. coal production and coal overburden (OB) production based on excavator productivity. As for the effectiveness based on dump truck productivity, it shows a figure of 122% for the OB fleet and 106% for the coal fleet. The effectiveness can be seen in the following Table 1.

Table 1. Production Effectiveness of PT Surya Kalimantan Sejati

Productivity Tools	Target (per day)	Result (Per day)	Achievments (%)
Excavator Fleet OB	4.000 ton	4.301 ton	108%
Excavator Coal Fleet	3.333 ton	3.588 ton	108%
Dump truck Fleet OB	4.000 ton	4.870 ton	122%
Dump truck Coal Fleet	3.333 ton	3.539 ton	106%

Source: Data Mining PT. Surya Kalimantan Sejati, 2023

The production results listed in the Table 1 are the summed values of all excavators and dump trucks operated by the contractor PT Surya Kalimantan Sejati. The results of field calculations show that in 1 OB fleet for 20 hours can dig 1,433.78 tons/day for excavator productivity and dump trucks can transport 1,623.443 tons/day consisting of 5 dump trucks in each existing fleet. While 1 coal fleet, excavator productivity can dig 897 tons/day and 884.7735 tons/day for dump truck productivity consisting of 6 dump trucks in each existing fleet. The hourly productivity value is then multiplied by the number of existing fleets to produce an overall productivity value each day.

The efficiency measurement results are shown from the percentage value of the comparison between actual working hours and working hours that should be calculated.

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actual working hours and working hours are calculated by the effective utilization method, as shown in the calculations in the following Table 2.

Table 2. Table of Working Hours in 1 Day

Work efficiency of excavator PC 500 fleet OB						
Amount Hours	W	S				R
		Oper shift	Break	Maintenance	Amount	
24	20 hours	2 hours	1 hours	1 hours	4 hours	0

Dump truck fleet OB work efficiency						
Amount Hours	W	S				R
		Oper shift	Break	Maintenance	Amount	
24	20 hours	2 hours	1 hours	1 hours	4 hours	0

Work efficiency of excavator PC 400 coal fleet						
Amount Hours	W	S				R
		Oper shift	Break	Maintenance	Amount	
24	20 hours	2 hours	1 hours	1 hours	4 hours	0

Work efficiency of coal fleet dump trucks						
Amount Hours	W	S				R
		Oper shift	Break	Maintenance	Amount	
24	20 hours	2 hours	1 hours	1 hours	4 hours	0

Calculation of equipment work efficiency is done by calculating with Formula 1, as well as data obtained from field observations:

Work Efficiency of Excavator PC 500 Fleet OB

$$Ek = \frac{W}{W+S+R} x\ 100\% = \frac{20}{20+4+0} x\ 100\% = 0.83$$

Dump Truck Fleet OB Work Efficiency

$$Ek = \frac{W}{W+S+R} x\ 100\% = \frac{20}{20+4+0} x\ 100\% = 0.83$$

Work Efficiency of Excavator PC 400 Coal Fleet

$$Ek = \frac{W}{W+S+R} x\ 100\% = \frac{20}{20+4+0} x\ 100\% = 0.83$$

Work Efficiency of Coal Fleet Dump Trucks

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$$Ek = \frac{W}{W+S+R}\ x\ 100\% = \frac{20}{20+4+0}\ x\ 100\% = 0.83$$

The data listed in the table above is obtained from field observations and using this data, a calculation of work efficiency is carried out which shows a value of 83% of the supposed working hours. This value shows the optimization of working time that is less effective or inefficient because the efficiency value required by PT Surya Kalimantan Sejati is 90% based on information from the Head of the Operations Department through interviews conducted by researchers. The value of work efficiency is one of the factors considered to calculate the productivity of excavators and dump trucks. In addition to work efficiency, other factors that affect the determination of productivity can be seen in the following Table 3.

Table 3. Factors Affecting Excavator and Dump Truck Productivity

Productivity of OB fleet PC 500 excavators						
Amount fleet	**Bc**	**Ek**	**Bff**	**Sf**	**k**	**Te**
5	3,5 ton	0,83	0,96	0,21	3600 second	50 second

Productivity of coal fleet PC 400 excavators						
Amount fleet	**Bc**	**Ek**	**Bff**	**Sf**	**k**	**Te**
5	3,2 ton	0,83	1	0,21	3600 second	60 second

OB fleet dump truck productivity								
Amount fleet	**Jum DT**	**n**	**Bc**	**Ek**	**Bff**	**Sf**	**k**	**Td**
5	4	4	3,5 ton	0,83	0,96	0,21	3600 second	800 second

Coal fleet dump truck productivity								
Amount fleet	**Jum DT**	**n**	**Bc**	**Ek**	**Bff**	**Sf**	**k**	**Td**
5	5	9	3,2 ton	0,83	1	0,21	3600 second	2600 second

Some of the data listed in the Table 2, such as Bc (excavator bucket capacity) and Td (dump truck cycle time) were obtained by researchers from interviews conducted with the Head of the Operations Department of PT Surya Kalimantan true and supervisors. In addition to these data, some of the data obtained from interviews are data on the hardness level of mining excavation materials which include OB and coal materials and data on the ideal production of excavator equipment. Data such as Bff (bucket fill factor), Sf (swell factor) k (time conversion), Te (excavator cycle time), number of fleets, number of DT (dump trucks) and productivity of excavators and dump trucks are obtained from direct observations and calculations in the field using Formula 2 which is as follows:

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Bucket Fill Factor

Bucket fill factor excavator PC 500 fleet OB

$$Bff = \frac{Va}{Vt}\ x\ 100\% = \frac{3,4}{3,5}\ x\ 100\% = 0,96$$

Bucket fill factor excavator PC 400 coal fleet

$$Bff = \frac{Va}{Vt}\ x\ 100\% = \frac{3,2}{3,2}\ x\ 100\% = 1,00$$

Sweel Factor

Sweel factor OB

$$Sf = \left(\frac{Bcm}{Lcm} - 1\right)\ x\ 100\% = \left(\frac{1.700}{1.405} - 1\right)\ x\ 100\% = 0,21$$

Coal sweel factor

$$Sf = \left(\frac{Bcm}{Lcm} - 1\right)\ x\ 100\% = \left(\frac{1.340}{1.405} - 1\right)\ x\ 100\% = 0,16$$

Cycle Time Excavator (Queuing Theory)

$$Tool\ usage\ rate\ (p) = \frac{\lambda}{s\mu} = \frac{60}{1\ x\ 60} = 1$$

$$Number\ of\ haulers\ waiting\ (Lq) = \frac{Va}{2\ (1-p)} = \frac{1x1}{2\ (1-1)} = 1$$

$$Average\ time\ haulage\ is\ waiting\ (Wq) = \frac{Lq}{\lambda} = \frac{1}{60} = 0,0167\ hours\ or\ 60\ second$$

Excavator and Dump Truck Productivity

Productivity of excavator PC 500 OB fleet

$$Pe = \frac{Bc.Ek.Bff.Sf.k}{Te} = \frac{3,5x0,83x0,96x0,21x3.600}{50} = 71,689\frac{ton}{hours}$$

$$= 71,689\ x\ 4\ (total\ fleet)$$
$$= 215,067\ ton/\ hours$$
$$= 215,067\ x\ 20$$
$$= 4.301\ ton/hours$$

Excavator productivity PC 400 coal fleet

$$Pe = \frac{Bc.Ek.Bff.Sf.k}{Te} = \frac{3,2x0,83x1x0,21x3.600}{60} = 44,850\ ton/hours$$

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$= 44,850\ x\ 4\ (total\ fleet)$
$= 179,4\ ton/hours$
$= 44,850\ x\ 20$
$= 179,4\ ton/hours$

OB fleet dump truck productivity

$$Pe = \frac{Bc.Ek.Bff.Sf.k}{Te} = \frac{4x3,5x0,83x0,96x3.600}{800} = 16,234\ ton/hours$$
$= (16,234\ x\ 5)x\ 3$
$= 243,51\ ton/hours$
$= 243,51\ x\ 20$
$= 4.870\ ton/hours$

Coal fleet dump truck productivity

$$Pe = \frac{n.Bc.Ek.Bff.Sf.k}{Te} = \frac{9x3,2x0,83x1x0,21x3.600}{2.600} = 6,6725\ Bcm/hours \text{ x } 1,105$$
=7,737 ton/hours
$= (6,6725\ x\ 6)x4$
$= 177\ ton/hours$
$= 177\ x\ 20k$
$= 3.539\ ton/days$

Based on the productivity of the excavator and compared to the ideal production of the tool that should be, the production efficiency value can be known which describes the effectiveness of the production carried out, as in the following Table 4.

Table 4. Efficiency Excavator

Comparison Tools	Productivity (/hours)	Ideal Production (/hours)	Eficiency (%)
Excavator Fleet OB	71,689 ton	70 ton	102%
Excavator Fleet Coal	44,850 ton	44 ton	102%

The application of theories and methods in the field of operations management work adjusts the type of heavy equipment activities (excavators and dump trucks) that exist at PT Surya Kalimantan Sejati in achieving the objectives of the operations carried out. Measurement of operational effectiveness and efficiency is one indicator of the achievement of the objectives of the production operations carried out by the contractor PT Surya Kalimantan Sejati through the supervision of the Operations Department of PT Surya Kalimantan Sejati so that the application of these theories and methods is very relevant to the efforts to supervise and control the operations of PT Surya Kalimantan Sejati.

CONCLUSION

Based on the research conducted, it can be concluded that in the application of theories and methods relevant to the field of operations management work in mining companies such as PT Surya Kalimantan sajati, in measuring the achievement of effectiveness and efficiency of operations, it is necessary to consider factors that affect the

productivity of equipment in production activities. As the results of this study show the effectiveness of the use of excavators PC 500 and PC 400 from the set production targets and effectiveness for dump trucks in the OB fleet and coal fleet. The work efficiency of heavy equipment such as excavators and dump trucks are still less than the required work efficiency level while the efficiency of excavator PC 500 and PC 400 shows the ideal production level required by PT Surya Kalimantan Sejati. The results of the target approach show the achievement of good effectiveness while through the process approach the achievement of effectiveness is still considered not good. Factors that are very influential in measuring the productivity of equipment such as excavators and dump trucks are the factors of Effective Utilization or work efficiency, Bucket Fill Factor, Sweel Factor, and Cycle Time.

RECOMMENDATION

It is necessary to conduct further research on the theory and methods of measuring operational effectiveness and efficiency by considering operational cost factors, obstacle factors and match factors in order to obtain maximum research results. in addition, there is a need for general deepening of the methods used in this study because these methods are only specifically explored by researchers from the fields of mining engineering and civil engineering.

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