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Analysis of Heavy Equipment Productivity in the Construction of the Surabaya State Polytechnic Integrated Lecture Building Project

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A B S T R A C T

Building construction is intensively carried out in Indonesia. That is because Indonesia is a developing country that needs quite a lot of infrastructure, be it buildings, offices, roads, bridges, or ports, especially at the Surabaya State Shipbuilding Polytechnic which is building an Integrated Lecture Building. The development process certainly does not escape the need for heavy equipment, such as excavators. Heavy equipment is a crucial requirement in building construction projects, this is because heavy equipment is a means of supporting work in the project, for example excavation work. Because excavators are important tools in building construction projects, it is necessary to analyze the productivity of heavy equipment. This study aims to analyze the productivity of excavators so that they can improve operational efficiency, save costs, and determine the duration of work.

1. Introduction

A project is an effort that mobilises available resources, organised to achieve certain essential goals, objectives and expectations and must be completed within a limited period of time in accordance with an agreement [1]. Therefore, the success of a project can be measured by two things, namely the profit achieved and the timely completion of the project [2]. Projects, which can generally be defined as specific activity limited by time, human resources, tools, materials and money, are greatly helped by the existence of tools, where projects with very limited time and accelerated implementation[3]. The implementation of a project is influenced by the availability of resources that will be needed, this availability can affect the effectiveness and efficiency of the implementation of a project, both in terms of cost and time of project implementation[4].

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With the increasing increase in project complexity and the scarcity of resources, it is very necessary to improve the project management system in a good and integrated [5]. In building construction projects, heavy equipment is one of the important items to support the effectiveness of the work. Implementing a construction project means combining various resources to produce the desired end product, in construction projects the need for equipment is between 7 - 15% of the project cost, the construction equipment in question is the tool / equipment needed to carry out construction work mechanically [6].

The use of heavy equipment in building construction projects plays an important role in ensuring that the construction process runs smoothly and efficiently. Heavy equipment is defined as large-sized equipment or machines designed to carry out construction work such as earthworks, road construction, buildings, plantations and others [7]. Heavy types of equipment, such as excavators, cranes, bulldozers, and loaders, are used to facilitate a variety of activities, such as excavation, material removal, and structure installation [8]. However, the effective use of heavy equipment is greatly influenced by its level of productivity, which is directly related to the factors of time, cost, and quality of work. The choice of heavy equipment to be used in the project must be the same as the circumstances and conditions of the project, so that the productivity of heavy equipment is more affected [9].

In practice, construction projects often face challenges related to heavy equipment productivity. Factors such as equipment capacity mismatch with field needs, suboptimal maintenance, fuel delays, and lack of skilled operators can result in a decrease in machine productivity. This has the potential to cause project delays, operational cost overruns, and reduced construction quality. Therefore, the selection of heavy equipment is required to complete a particular project work or section of work. Terrain characteristics and conditions affect machine selection [10]. A comprehensive field analysis and thorough preparation are necessary before starting the project [11]. Terrain characteristics and conditions influence the selection of heavy equipment. Given the importance of heavy equipment contribution to building construction projects, an in-depth productivity analysis is required to identify factors that affect machine performance in the field. In additional, project scheduling by optimizing the performance of heavy equipment is necessary, because heavy equipment is one of the factors that determine the results in a project [12]. Based on looking at the contractor's perspective that using an excavator as a digging tool will make the project can be carried out quickly in accordance with the predetermined schedule, the project can be more economical in terms of cost and quality is increasing [13].

Poductivity is the ratio between the results achieved (output) and all resources used (input) [14]. Productivity is the ability of the tool in units of time (m^3/hour), and machine tools are an important factor in projects, especially large-scale construction projects [15]. To assess machine productivity, each element that relates to other must be analyzed based on the correct standards and analysis steps [16]. Calculations were carried out based on data obtained from the project and calculations were carried out using guidelines from the Minister of PUPR Regulation, Number 8 of 2023 [17].

This study aims to determine the effectiveness of machine utilization based on performance indicators, such as operating time and load capacity. By understanding machine productivity, we can know what to consider when choosing the use of heavy equipment. This includes the place and type of work to be performed, the use, and the type of machine to be used, such as excavation, transport, cleaning, and leveling [18]. The machine that will be used in this research is an excavator.Excavators are heavy equipment commonly used in various projects for digging, lifting and loading without having to move places by using the power take off of the engine owned by the excavator[15]. The selection of an excavator should take into account its capabilities under specific field conditions[19].

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2. Research Method

The descriptive quantitative approach was used in this study, it aimed to analyze the productivity of excavators in earthworks. Quantitative data was collected to describe machine productivity and its influential elements. This research was conducted by observing and measuring the excavator's work cycle at the excavation site directly, after which recording the volume produced by the excavator.

Primary data is used in this research as a result of direct observation in the field. The data recorded is the volume capacity of the bucket, the excavator work cycle, which is the time required for one work cycle, including digging, lifting, moving, and dumping materials, as well as weather conditions during the work process. In addition, there are secondary data as the validity of primary data, namely project documentation and shop drawings. After the observation is complete, the collected data will be analyzed for productivity. The data is analyzed to obtain the duration of work required, and production capacity per hour. The research method is a research procedure and technique, and among one study and another, the processes and techniques can be different.

3. Description and Technical

In the analysis of this research, there are several efficiency factor tables and flowcharts that must be considered. The aim is to make it easier to understand the research method, as well as to provide a visualization of the systematic steps in this research process. Some tables that need to be considered include;

In determining the bucket factor, data is needed that matches what is done in the field [20]. Bucket fill factor is an earthmoving and excavation operation. The term refers to the filling efficiency of the bucket (of a loader, excavator, or similar equipment) during an operation compared to its total capacity.The bucket capacity factor can be determined in Table 1.

Table 1. Bucket Fill Factor

Operating Condition	Field Conditions	Factor
Easily	Plain soil, clay, soft soil Loading of materials from stockpiles or material that has been dredged by another excavator, where no digging force is required and can be loaded into the bucket. Examples: Sand, sandy soil, soil colloidal soils with medium water content.	1,1 - 1,2
Medium	Sandy, dry plain soil Loader of loose soil stockpiles which is harder to dredge and put into buckets but can be loaded almost to the arbor (Full). Examples: Dry sand, soil sandy soil, mixed soil, clay, unscreened gravel, compacted sand that has solidified and so on, or digging and loading gravel directly from the hill original gravel.	1,0 - 1,1
Rather Difficult	Rocky Plain Ground Loading of split rock or stone split rock, hard clay, sand mixed gravel, sandy soils, clayey colloidal soils, clays with high moisture content, these materials such materials Exhausted stockpile / stockpile difficult to fill bucket with these materials. materials.	1,0 - 0,9
Difficult	Large irregularly shaped boulders with many spaces between the piles, blasted stones, large rounded stones, sand mixed with the rounded stones, sandy soil, mixed clay, clay that is shovelled into Large irregularly shaped boulders with many spaces between them, blasted stones, large rounded stones, sand mixed with these rounded stones, sandy soil, clay mixed soil, clay loaded into the bucket.	0,9 - 0,8

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Source : Ravanelli Dei Rizaldi A, Dani H (2024)

An efficiency factor is a measure to describe how effectively a tool, machine, or process works compared to its maximum capacity or ideal conditions. In machine operational construction, efficiency factors are often used to calculate the actual performance of a piece of equipment or process. In addition, to determine the excavator work efficiency factor can be seen in Table 2.

Table 2. Efficiency factor

Operating Condition	Efficiency Factor
Good	0,83
Medium	0,75
Slightly Less	0,67
Less	0,58

Source: Ravanelli Dei Rizaldi A, Dani H (2024)

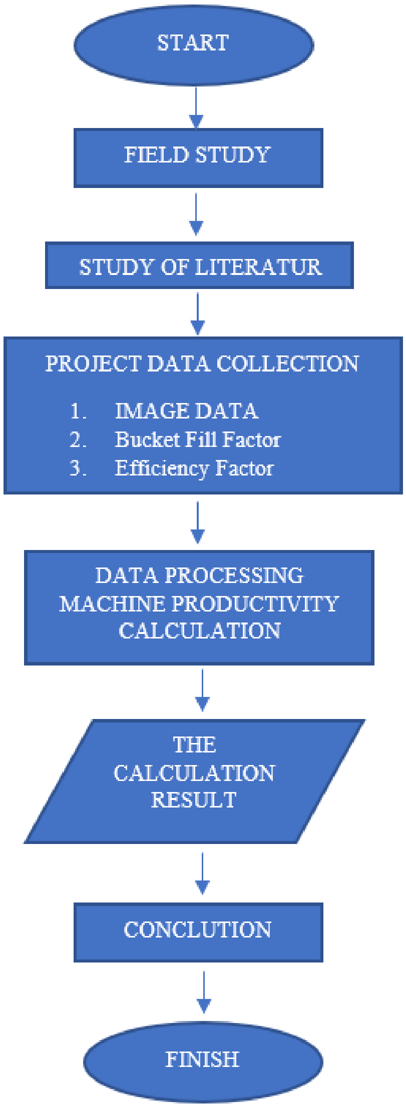

Figure 1. Research Flowchart

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1. Field Study
   Field studies are research methods conducted outside of a laboratory or controlled environment, directly in the project environment where the phenomenon being studied occurs. This method involves collecting primary data through observation.
2. Study Of Literature
   The literature study in this research is to review relevant journals and books so as to get a better understanding of the topic under study.
3. Project Data Collection
   The project data obtained in this study are image data, bucket fill factor, and efficiency factor.
4. Data Processing Machine Productivity Calculation
   Analyze productivity calculations from the data that has been collected.
5. The Calculation Result
   After the productivity calculation is carried out, the next thing that is obtained is the calculation result of the data obtained from the research.
6. Conclusion
   The research conclusion is the final part of the research that summarizes the main results and provides answers to the questions or objectives that have been set in this research.

4. Results and Discussions

The analysis data in this study were obtained in the Surabaya State Shipbuilding Polytechnic integrated lecture building construction project. Excavator Productivity Calculation. This research was conducted at the Sepuluh Nopember Institute of Technology, Chemical Engineering Road, Keputih, Sukolilo, Surabaya, East Java.

Brand : Komatsu

Type : PC78US-6NO

Bucker Capacity (q1) : 0.4 m^3

Bucket Factor (K) : 1,2

Work Efficiency (E) : 0.83

Soil Type : Loamy Soil

Duration of excavation : 5 Seconds

Screening duration : 4 Seconds

Dumping duration : 4 Seconds

Excavation depth : 3,35 m

Producibility per cycle (q) : q1 x K = 0,4 x 1,2 = 0,48 m^3

Cycle duration (Cm) : Excavation duration + Screening duration x 2 + Dumping duration
: 5 + (4 x 2) + 4

: 17 Second

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The calculation of excavator productivity can be calculated using the following formula:

$$P = \frac{q \ x \ 3600 \ x \ E}{Cm}$$

$$P = \frac{0,48 \ x \ 3600 \ x \ 0,83}{17}$$

$$P = 84,36 \ m^3/Hours$$

Excavation productivity / day

= Productivity per hour x working hours

= 84.36 $m^3/Hours$ x 7 hours

= 590.52 $m^3/Hours$

a. Soil Excavation Volume Calculation

Table 3. Excavation Volume Calculation Results

WWTP BUILDING					
Type	Quantity	Length	Width	Height	Total (m^3)
WWTP	1	12.6	6	3.35	253.26
Main Building					
Type	Quantity	Length	Width	Height	Total (m^3)
PC-1	4	1.65	1.65	1.77	19.2753
PC-3	6	2.94	2.94	1.97	102.1674
PC-4	14	3.74	3.74	1.97	385.778
PC-5	4	2.94	4.1	1.97	94.98552
PC-6	1	5.34	3.3	1.97	34.71534
Power House Building					
Type	Quantity	Length	Width	Height	Total (m^3)
Pilce Cap	11	1.5	1.5	1.25	30.9375
Pump House Building					
Type	Quantity	Length	Width	Height	Total (m^3)
Pile Cap	11	1.4	1.4	1.5	32.34

Source : (PPNS) Integrated Lecture Building Project Data

Table 3 is the recapitulation of the calculation of excavation requirements in the construction of an integrated lecture building project.

Example of calculation :

PC-1 (Main Building) : Quantity x Length x Width x Height

: 4 x 1.65 x 1.65 x 1.77

: 19.2753 m^3

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b. Calculation of Excavator Duration to complete the work.

Excavator Productivity : 590.52 m^3 / day

Excavation Work Volume : 953.45 m^3

$$\text{Productivity} : \frac{Excavation\ Work\ Volume}{\text{Excavator Productivity/Day}}$$
$$: \frac{953.45\ \text{m}^3}{590.52\ \text{m}^3/\text{Days}}$$
$$: 1{,}61\ \text{Days}$$
$$: 2\ \text{Days}$$

5. Conclusion and Suggestion

5.1 Conclusion

Based on the results of the analysis of the productivity of the Komatsu PC78US-6NO excavator productivity analysis, it was found that

1) Excavator productivity in a day in excavating as much as 590.52 m^3
2) The duration of time required to carry out excavation work for the Integrated Lecture Building is 2 days.
3) The number of excavators needed in the excavation work of the PPNS Integrated Lecture Building construction project is only 1 unit.
4) Productivity calculations can be used as a reference in selecting the number of heavy equipment units needed and the duration of the work, to make it efficient in carrying out work.

5.1 Suggestion

1) So that this research can be used as a reference in the selection of heavy equipment.
2) This research can be useful for the efficiency of work in the field, especially for the use of heavy equipment.
3) This research can be continued and deepened to improve the efficiency of heavy equipment use.
4) This research is used as a reference so that contractors can improve operator competence, because it is quite influential in heavy equipment productivity.

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