Comparison of Excavators based on Productivity for Land Excavation Work in a Toll Road Project

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Abstract

To accelerate the work of the toll road project located in the area of DKI Jakarta - West Java, it takes accuracy in choosing heavy equipment it is very important because it can affect the productivity of the tool, this time the tool suitable for excavation work is the excavator. the purpose of this study is to compare between the two types of tools in terms of product, work time and operational costs incurred by the project, after being calculated it is determined which excavator is more efficient in terms of cost and time for the locations reviewed. Based on observations on the field and calculations that have been done, the results are obtained for the volume of soil excavation at the location reviewed by 578.34 m3 and for type A excavator's obtained productivity of 171.86 m3/ hour with a working time of 8 days and requires operational costs of Rp. 31,856,000, - and for type B excavators obtained productivity of 109.95m3/ hour with a working time of 12 days and requires operational costs of Rp. 28,184,000, -.

Keywords
Productivity, Soil digging, Excavators, Time estimation, and cost estimation.

1. Introduction
Currently, massive development in the field of property carried out by the government to meet the wishes of the surrounding community. Therefore, contractors are competing for a project planned by the government, therefore effectiveness, efficiency and economy are the attraction in getting a project. In general, every construction project uses manual means such as using human power but using human power alone is not enough because it can reduce the efficiency of time and effectiveness of work therefore in order to minimize time, heavy equipment is needed to help human labor work to be faster (Sigit & Dwitama, 2019). Tool efficiency (in this case is heavy equipment/tools) is the condition of the tool that must be taken into account due to field conditions that are not as planned and certain things such as topography besides that work efficiency also depends on several factors such as operator expertise, maintenance standards and so on which depend on the operation of the tool. The hourly productivity of the tool must be taken into account in planning is the standard productivity of the tool multiplied by work efficiency (Fardila, Wiranto, & Mudianto, 2017).

Heavy equipment has many types, so the selection of heavy equipment must be tailored to the needs in the field. The selection of the right machine can affect productivity and the achievement of job targets. Machine productivity is the ability of a machine to complete a job calculated in units of time and that productivity depends on bucket capacity, bucket factor, cycle time, and production correction factor. Soil excavation work is the activity of digging to obtain materials in the form of soil material from a location, material obtained by digging that is usually done by excavator tools with the depth and limits of bricks that have been agreed by contractors, communities, and local governments and through the process of consideration and calculation of the impact in the community on the work environment. (Fikri, Rahmawati, & Paryati, 2016).

At the end of 2019 there was an outbreak of COVID-19 disease that required the project to adhere to protocols that have been created by the government. Such as a 50% reduction in employees, plus the project must also meet the contract that has been agreed between the contractor and the owner. With the event can cause construction work to be stopped due to the swelling costs incurred by the project, therefore it takes methods that can make the work faster and more effective (Bejasekto, 2020). Selection of the right heavy equipment can affect productivity and the achievement of work targets. Machine productivity is the machine's ability to complete work which is calculated in units of time and that productivity depends on bucket capacity, bucket factors, cycle time, and production correction factors

(Ainurrizki, Choiriyah, & MCA, 2019). In general, productivity is the degree of effectiveness in the use of labor, tools, capital, materials and time. Productivity is the achievement of goals in a more efficient and practical way, productivity can also be said as the number of working hours required for certain expenditures by including materials and capital (Hermawan, 2020).

The use of heavy equipment can actually accelerate the workmanship but in determining the use of heavy equipment cannot be arbitrary, because the use of heavy equipment is very expensive so it is better if choosing the right machine that can make the project work can be faster with pandemic conditions like this, therefore it takes a method to make the work of the project faster by minimizing cost expenditures, therefore in this study is by comparing 2 existing heavy equipment at the location reviewed to determine which *excavator* is better in terms of productivity, work time and cost and can provide wider options in the implementation of the project (Bejasekto, 2020). Costs related to operational costs are the cost of equipment rental, mobilization costs, and operator wages. Heavy equipment equipment also requires fuel to drive the engine, therefore fuel costs are also included in the costs that must be considered. Operational costs are obtained from calculations: the multiplication between each volume and the number of tools used as well as the cost of the work unit (Purworini, 2016).

2. State of The Art

Previous research also covered similar topics and was used in this study, following previous research:

a. Productivity of the heavy equipment used. This previous study used a comparison between the two heavy equipment and used the same formula (Fikri, Rahmawati, & Paryati, 2016).
b. The productivity of heavy equipment is based on the location of the research and also makes an alternative if something unexpected happens such as a delay in work.

3. Research Methodology

In starting the research, the first thing that must be done is to see the formulation of the problem that you want to research after the problem formulation has been understood then the purpose of the research is created. The thing that is done after the goal has been determined then begins the search for literature review, in the literature review that contains about theoretical theories about research this time such as theories about the productivity of heavy equipment, what methods are used, and also standard standards used related to this topic. After that, a survey is conducted in the field to find out the actual conditions at the location that wants to be examined such as the condition of the soil and the condition of the machine to be used after that just starting the collection of data needed to conduct analysis such as analysis of machine productivity and work time and operational costs. It was said that in the field, it is difficult to determine the efficiency of the tool, but based on experience, it can be determined that the efficiency of the tool is close to reality (Aoliya, Wiranto, & Mudianto, 2017). Calculations of each method will be used to meet the applicable standards, after the results from the calculation is obtained and then validated by interviewing field contractors and also validation through previous journals with the same topic after being validated and then can only be drawn conclusions which machine is most effective in terms of productivity and also cost. In this research, the specification for the heavy equipment were taken from the heavy equipment specification book (Komatsu. LTD, 2005). The flow for the research method can be seen on Figure 1.

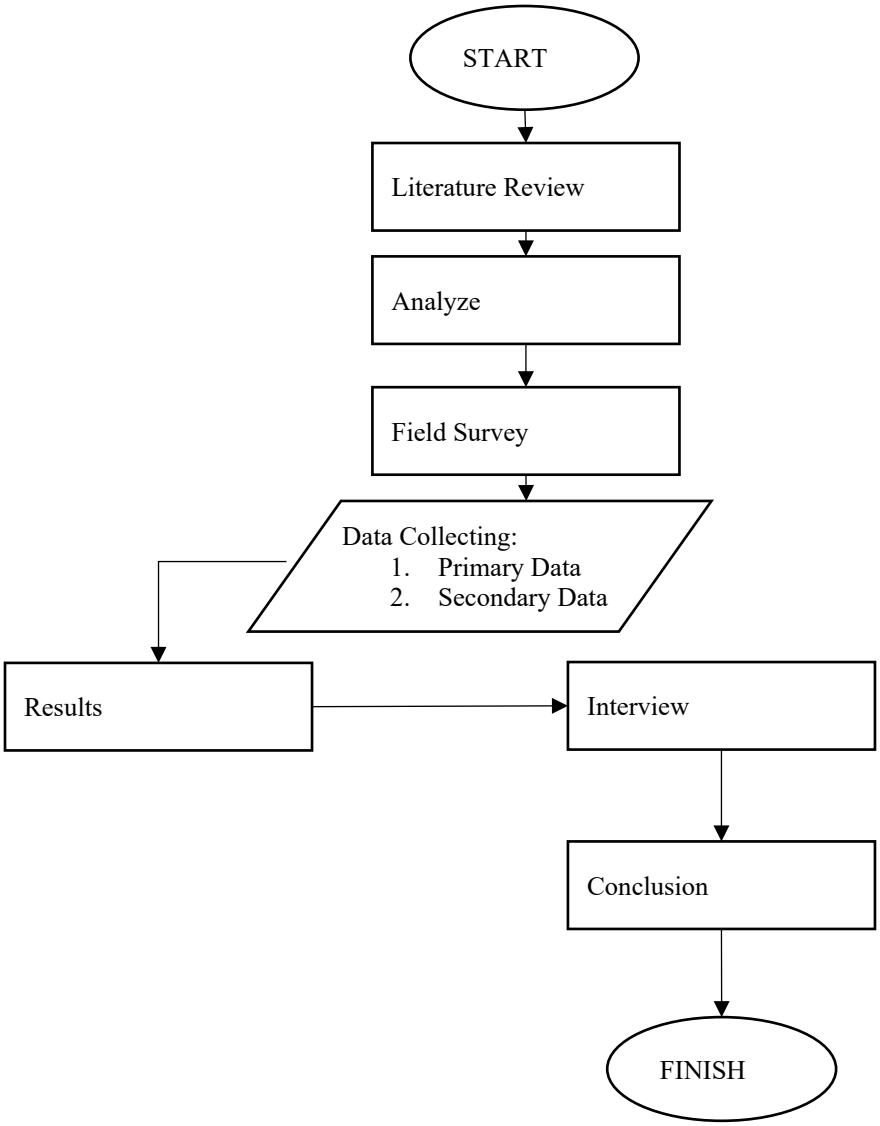

Figure 1. Research Flow Diagram

4. Data and Analysis

This section consists of an analysis of productivity and cost of heavy equipment based on survey data from both heavy equipment reviewed at the excavation site of the Jakarta-West Java toll road project.

4.1 Productivity Calculations

Productivity is the ability of a tool in units of time (m^3/hour). Tool productivity depends on capacity, cycle time and tool efficiency. The work cycle in material transfer is a work that is done repeatedly, the cycle time itself is required consisting of several elements, the time required in the cycle of activity is called cycle time, with the cycle time data and heavy equipment specifications obtained through field surveys and heavy equipment specification, and the costs obtained through unit price analysis.

4.1.1 Excavator

Calculation of excavator productivity using formula (1) (2) (Aoliya, Wiranto, & Mudianto, 2017) , while for specifications between the two tools can be seen in Tables 1 and 2 (Komatsu. LTD, 2005). In the case of the

excavator's efficiency, refer to the regulation by Minister of Public Works and Public Housing of the Indonesian Republic (Indonesian Republic, 2016):

$$Q = \frac{\text{q x 3600 x E}}{\text{cm x Fv}} \quad (1)$$

$$q = q_1 \times K \quad (2)$$

The following notation:
Q = production per cycle (m^3)
CM = *Excavator* Cycle Time
E = Tool Efficiency
q_1 = *Bucket Capacity*
fv = Conversion factor
K = Bucket Factor

Table 1. Specifications of Type A Excavator

Description	**Specifications**
Tool type	Type A
Bucket capacity	1,19 m^3
Work efficiency	0,83
Effective working hours	10 hours
Soil type	Dry

Table 2. Specifications of Type B Excavators

Description	**Specifications**
Tool type	Type B
Bucket capacity	1,3 m^3
Work efficiency	0,75
Effective working hours	10 hours
Soil type	Dry

4.2 Working Time

The time you work on is the length of time it takes to do a job. Each job has a target volume of work that is how much work can be completed by *excavator* heavy equipment within an hour, the target in this case is how many "numbers" that must be the benchmark of work during a unit of time period, such as how much (m^3) per hour, per-week or even per month or can be like for example how many (m^2) per hour, per-week or per-month and so on. In the calculation of work production and work volume is one basic thing to calculate the time of implementation of work using heavy equipment. In formula 3 is a formula used for calculation of work time, among others (Fikri, Rahmawati, & Paryati, 2016):

$$W = V/Q \quad (3)$$

The following notation:
V = Volume of a excavation (m^3)
Q = Excavator production in every hour (m^3/hour)

4.3 Volume

The volume is obtained from calculations and plan drawings from surveys and measurements in the field. The volume calculation must also consider factors that may affect the work. For soil work there are many factors that can affect the work for example such as loose soil, native soil, solid soil and so forth such as calculating the capacity and production of tools, units of volume can vary such as: m, m^2, m^3 and so forth, formula (4) is the formula used to calculate the volume of excavations, namely as follows (Fikri, Rahmawati, & Paryati, 2016):

$$V = P \times L \times T \quad (4)$$

The following notation:
V = Volume (m^3)
P = Length
L = Width

4.4 Calculation of Heavy Equipment Costs

Costs related to operational costs are the cost of leasing the mobilization cost tool, the cost of the operator's wages. Heavy equipment also requires fuel to drive the engine therefore the cost of fuel is also included in the costs that must be considered. Operational costs are derived from the calculation of multiplication between each volume and the number of tools used as well as the hara unit of work. In formulas 5 and 6 is the formula used to calculate the total operational cost of using both tools, the formula used as follows (Fikri, Rahmawati, & Paryati, 2016):

Excavation Cost = Total Cost Per Day x Work Time (5)

Total Excavation Cost = Total Cost of Excavation + Mobilization Cost (6)

To find out the costs needed to dig soil material in the excavation, these data are obtained on the 2020-unit price list in DKI Jakarta province. In tables 3 and 4 are data from both excavator tools, the data is as follows:

Table 3. Unit Price List for Type A Excavator

No.	**Description**	**Price (Rp)**	**Description**
1	Excavator rental fee 10 hours	3,200,000	per-day
2	Cost of Fuel 19 Liters 10 hours	182,400	per-day
3	Operator wage costs	250,000	per-day
4	Operator assistant wage costs	100,000	per-day
Sum (1+2+3+4)		3,732,000	per-day
5	Cost of *mobilizing excavators*	2,000,000	per-day

Table 4. Unit Price List for Type B Excavator

No.	**Description**	**Price (Rp)**	**Description**
	Excavator rental fee 10 hours	1,650,000	per-day
	Cost of Fuel 19 Liters 10 hours	182,400	per-day
	Operator wage costs	250,000	per-day
	Operator assistant wage costs	100,000	per-day
Sum (1+2+3+4)		2,182,000	per-day
	Cost of *mobilizing excavators*	2,000,000	per-day

4.5 Calculation of Excavator Productivity

Here is an example of an excavator productivity calculation for 1 cycle in Table 5 and 6.

Table 5. Calculation of Productivity of Type A Excavator

Data	Code	Quantity	Unit
Bucket Capacity	q_1	1,19	m^3
Tool Efficiency Factor	And	0,83	-
Cycle Time	Cm		
- Digging time	T_1	4,33	second
- Play Time	T_2	3,46	second
- Waste time	T_3	3,06	second
	Cm	14,31	second
Heavy Equipment Productivity	Q	171,86	m^3/hour
Factor Rear	K	0,9	
Conversion Factor	Fv	1,3	

Based on Table 5, the calculation of the type A excavator activity product is 171.86 m3/hour to do pile cap excavation work.

Table 6. Calculation of Productivity of Type B Excavator

Data	Code	Quantity	Unit
Bucket Capacity	q_1	1,13	m^3
Tool Efficiency Factor	And	0,75	-
Cycle Time	Cm	22,1	second
Heavy Equipment Productivity	Q	109,95	m^3/hour
Factor Rear	K	0,9	
Conversion Factor	Fv	1,3	

Based on Table 5, the result of calculations from the productivity of type A excavators is 171,86 m^3/hour to do pile cap excavation work.

From the calculation of productivity above can be compared from the two heavy equipment if done according to effective working time is as follows on Table 7:

Table 7. Comparison between the two excavators

No	Tool Type	Volume	Tool Productivity	Working Time
1	Excavator Type A	578,34 m^3	171,86 m^3/hour	8 days
2	Excavator Type B	578,34 m^3	109,95 m^3/hour	12 days

4.6 Calculation of Excavator Costs in Excavations

From the calculations above it can be known the cost of excavators in excavations as below:

Table 8. Sum Cost for Type A Excavators

No.	Description	Price (Rp)	Description
Sum Cost		3,732,000	per-day
	Cost of *mobilizing excavators*	2,000,000	per-day

So, as seen on Table8, the total cost per day for excavators on excavation work is Rp. 3,732,000, - If in the excavation process takes 8 days, to calculate the cost of digging for 8 days it uses the formula (5) and to calculate the total cost of excavation using the formula (6) the calculation results are as follows:

a. Excavation cost of 8 days = total cost per day x time required
   = Rp. 3,732,000, - x 8 days
   = Rp. 29,856,000, -
b. Total cost of excavation = Total cost of 8 days + mobilization cost
   = Rp. 29,856,000, - + Rp. 2,000,000, -
   = Rp.31,856,000, -

So, the total cost needed for excavation work on *pile cap* for 8 days amounted to Rp. 31,856,000, -

Table 9. Sum Cost for Type B Excavators

No.	Description	Price (Rp)	Description
Sum Cost		2,182,000	per-day
	Cost of *mobilizing excavators*	2,000,000	per-day

So, as seen on Table 9 the total cost per day for excavators on excavation work is Rp. 2,182,000, - If in the excavation process takes 12 days, to calculate the cost of digging for 12 days it uses the formula (5) and to calculate the total cost of excavation using the formula (6).

a. 12-day excavation cost = total cost per day x time required
   = Rp. 2,182,000, - x 12 days
   = Rp.26,184,000, -
b. Total cost of excavation = Total cost of 12 days + mobilization cost
   = Rp.26,184,000, - + Rp.2,000,000, -
   = Rp.28,184,000, -

So, the total cost needed for excavation work on *pile cap* for 12 days amounted to Rp. 28,184,000, -

4.7 Interview Results

According to the field contractor, between excavator type A and B excavators that are suitable for the research site are excavators of type A, because the productivity produced is 56% more than type B excavators, the Type A excavator also minimizes work for 4 days. for the condition of the project which was pursuing the target of Eid al-Fitr in 2020 at that time and 1 more thing that made the contractor choose this type A excavator, namely the efficiency of the type A excavator in good condition while the type B excavator in moderate condition, the efficiency of the tool is also affect the work of a tool, therefore the reason why field contractors prefer the type A excavator.

5. Conclusion and Suggestion

5.1 Conclusion

Based on calculations and analysis conducted on the weight equipment activity between the excavator type A excavator used by the project and the excavator type B excavator recommended in this study, the conclusion obtained from the calculation above is as follows:

a. For the volume of excavation obtained at the location of P6 which is 578.34 m^3;
b. For productivity between the two excavators it was obtained for type A excavators namely obtained by 171.86 m^3/ hour while for type B excavators obtained by 109.95 m^3/hour;

c. For operational costs needed for type A *excavators* costs Rp. 31,856,000, - with a working time of 8 days and for type B excavators has a costs Rp. 28,184,000, - with a working time of 12 days;
d. From the conclusion above it can be concluded that the Type A excavator has a shorter working time and has greater productivity than the Type B excavator but in contrast the Type B has a lower cost usage than the Type A, the productivity comparison between the Type A and Type B on this project is 56% and the price difference between the Type A and Type B on this project is 12%.

5.2 Suggestion

Based on the above conclusions can be taken as follows:

a. In future studies you should take a cycle time of more than 1 day to be able to get an accurate comparison;
b. In future research can take other types of excavators so that more varied results can be obtained;
c. To anticipate the work of soil excavation to be in accordance with the time schedule, it must choose heavy equipment that is in good condition and supported by a professional operator.

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