



## Productivity Analysis of Excavator and Dump Truck Heavy Equipment on Digging and Loading Works Flood Control Afvoer Watudakon Mojokerto

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<b>Abstract</b> Heavy equipment is a vital resource in a project, but renting heavy equipment is a costly undertaking. Besides that, a project always has constraints that allow the project completion time to exceed the specified time, and delays will also cause costs incurred to increase. So from the calculation of the productivity of heavy equipment, it is necessary so that the tool can work optimally. From the analysis results, it was found that the productivity of excavators was 154.185 m <sup>3</sup> /Hour. For dump trucks, it was 37.99 m <sup>3</sup> /Hour, then calculating the duration of work. For heavy equipment excavators, it took 454 Hours, and for dump trucks, it took 263 O'clock. For the cost of renting heavy equipment from the calculation of the analysis of the cost of renting heavy equipment for excavators, a value of Rp.1,985,200/Day is obtained, while for dump trucks, it is Rp.2,578,000/Day.	<b>Article history:</b> <i>Submitted 03-01-2023</i> <i>Revise on 03-01-2023</i> <i>Published on 28-05-2023</i>  <b>Keyword:</b> <i>Dump Truck, Excavator, Flood Control, Productivity</i>  <i>DOI: <a href="http://dx.doi.org/10.26418/jtsft">http://dx.doi.org/10.26418/jtsft</a></i>
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### 1. Introduction

In the implementation of a construction project, there are almost always constraints that have been calculated or constraints that have yet to be calculated, considering that these constraints can cause a project to experience delays and the project does not run smoothly. Hence, a project always has the possibility that the project's completion time will exceed the specified time; the delay will also cause the costs incurred to increase.

Likewise, with the Afvoer Watudakon Mojokerto Flood Control Development project, where there are obstacles to ongoing excavation work, tools must be fixed, and terrain conditions must be more supportive. Therefore an active management role is needed, especially productivity calculations, to determine steps for fundamental changes to avoid or reduce the constraints.

Calculating heavy equipment productivity is needed so the tool can work optimally and work items can be completed on time and save costs. The use of heavy equipment in the implementation needs to be taken into account so that the equipment works optimally; optimal conditions are ideal conditions where a project can achieve a minimum cost with a target

implementation time achieved. One of the calculations of heavy equipment productivity can be done using the formula method of several other studies. The heavy equipment in this study was the Hyundai HX210S Excavator and the Hino HD 130 Dump Truck.

The purpose of this study was to analyze the productivity of heavy equipment Excavators and Dump Trucks using observation methods and formula calculations from several studies, journals, and books, which then calculate the rental costs and the duration of the combination of tools on excavation work items in the Afvoer Watudakon Flood Control Development project in Sooko District, Mojokerto Regency.

### 2. Materials and Methods

#### 2.1 Theoretical Frame Work

The purpose of this study is to analyze the productivity of heavy equipment excavators and dump trucks using observation methods and formula calculations from several studies, journals, and books, which then calculate the rental costs and the duration of the combination of tools on excavation work items in the Afvoer Watudakon Flood Control Development project in Sooko district, Mojokerto Regency.

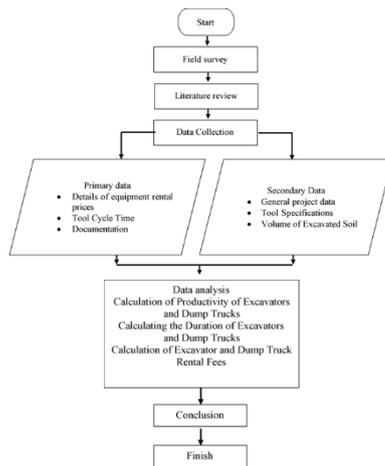


Figure 1. Flowchart

## 2.2 Research Location

The research location is on the Watudakon River, Tempuran Village, Sooko Mojokerto District. Mojokerto Regency is one of the regencies in East Java Province, where the total area is 969,360 km<sup>2</sup> or around 2,09% of the scope of East Java Province.

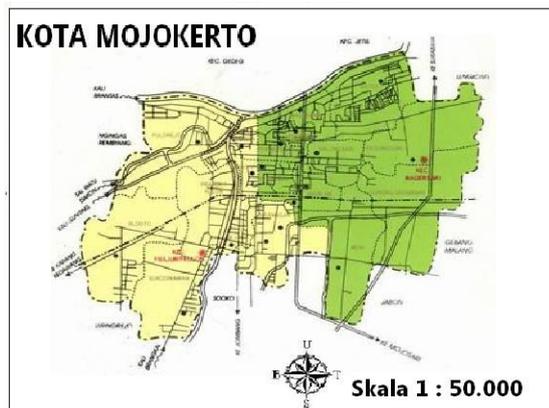


Figure 2. Mojokerto Regency

## 2.3 Data

This stage is the stage of collecting data that functions to obtain data that will be used as research material, which is necessary to acquire the required data. This stage is also the field observation stage, by directly observing activities in the field and obtaining the data that will be needed for writing purposes. The data in this study consisted of primary and secondary data, and the primary data contained details of equipment rental prices, the cycle time of the observation tool carried out using the Multi Stopwatch application on a smartphone, and documentation. Meanwhile, secondary data contains specifications and types of excavators and dump trucks, general project data, and volume of excavation work.

## 2.4 Analysis Method

The method used to collect data is through field observation or direct observation. This

approach is employed to gather data that will be utilized as research material. The analytical method employs formula calculations derived from various literature and books. These calculations are performed using Excel software. Equations can be inserted in this section and should be typed using the equation editor.

### 2.4.1 Excavator Productivity

An excavator is a tool for digging with a predetermined depth. Excavator productivity is affected by several factors, namely:

1. The condition of the machine and heavy equipment must be checked periodically because the engine is the main component of the excavator so that the tool can move. Whether the machine's state is good or bad will impact the instrument's productivity.
2. Lifting capacity or bucket, a bucket is a tool shaped like a basket that functions to dredge—the larger the ability of the bucket, the more volume of soil that can be excavated.
3. Working conditions, field conditions, and soil types are also factors that can influence. Operator skill and dump distance can also affect productivity.

Excavator Productivity (Q<sub>1</sub>) can be calculated using the formula below based on Indonesia PUPR Ministerial Regulation Number 1 of 2022.

$$Q_1 = \frac{V \times F_{aEXC} \times F_b \times 60}{T_{s1} \times F_v}$$

V is excavator bucket capacity, F<sub>aEXC</sub> is heavy equipment efficiency factor, F<sub>v</sub> is excavation depth conversion factor, F<sub>b</sub> is bucket factor and T<sub>s1</sub> is cycle time for excavator.

### 2.4.2 Dump Truck Productivity

Trucks are essential tools used for transportation. Their ability to move quickly and carry a large capacity makes them an effective means of conveyance with relatively low operating costs. In the Afvoer Flood Control project in Mojokerto, Dump Trucks are utilized to remove excavated soil. The productivity of Dump Trucks (Q<sub>2</sub>) can be calculated using a formula based on Indonesia PUPR Ministerial Regulation Number 1 of 2022.

$$Q_2 = \frac{V \times F_a \times 60}{T_{s2}}$$

V is dump truck vessel capacity, T<sub>s2</sub> is the cycle time for dump truck, and F<sub>a</sub> is heavy equipment efficiency factor

### 2.4.3 Cycle Time

Cycle Time in the material transfer is a repetitive activity that involves various tasks such as digging, loading, moving, unloading materials, and returning to the initial action. This activity can be accomplished using one or more

tools. It is important to note that the cycle time may vary depending on the tool used. Below are the cycle times for excavators and dump trucks.

• Excavator

The cycle time of an excavator ( $T_{s1}$ ) is determined by the sum of the digging time, the time spent when the bucket is filled, the time spent when the bucket is empty, and the dump time. The formula for calculating the excavator cycle time is based on Indonesia's Minister of PUPR Regulation Number 1 of 2022.

$$T_{s1} = T_1 + T_2 + T_3 + T_4$$

$T_1$  is loading time,  $T_2$  is swing fill time,  $T_3$  is spill time, and  $T_4$  is empty swing time.

• Dump Truck

The cycle time of a dump truck is typically determined by adding the loading time, the travel time when the truck is filled, the travel time when the truck is empty, and other relevant times. The calculation of the dump truck cycle time ( $T_{s2}$ ) can be done using the equation formula specified in Indonesia's Minister of PUPR Regulation Number 1 of 2022 as follows:

$$T_{s2} = T_1 + T_2 + T_3 + T_4$$

$$T_1 = \frac{V \times 60}{Q_{exc}}$$

$$T_2 = \frac{L \times 60}{V_f}$$

$$T_3 = \frac{L \times 60}{V_r}$$

$$T_4 = t_1 + t_2$$

$V$  is dump truck vessel capacity,  $Q_{exc}$  is excavator productivity,  $L$  is dump truck mileage,  $V_f$  is average loaded velocity,  $V_r$  is empty average velocity,  $t_1$  is dump time, and  $t_2$  is loading time. Dump time and loading time can be seen in Table 1.

**Table 1.** Dump Time and Loading Time

Operational state	Dump Time ( $t_1$ )	Loading Time ( $t_2$ )
Good	0.50 – 0.70	0.10 – 0.20
Average	1.00 – 1.30	0.25 – 0.35
Bad	1.50 – 2.00	0.40 – 0.50

**2.4.4 The Number of Tools and Duration of Work**

The number of tools used and the duration required can be calculated. The following is the calculation of the number of devices ( $n$ ) used.

$$n = \frac{\text{completion duration(day)}}{\text{working hours}}$$

Meanwhile, the duration of heavy equipment work can be calculated using the formula below.

$$\text{Duration} = \frac{\text{job volume (m}^3\text{)}}{\text{Produktivty (m}^3\text{/jam)}}$$

**2.4.5 Heavy Equipment Rental Fees**

Heavy equipment costs include renting the equipment, the operator's wages, and fuel costs. When calculating rental expenses, the demand for heavy equipment is influenced by the following factors.

1. Equipment Rental Cost

The cost of renting this tool is usually calculated in Hourly fees. Equipment rental costs vary depending on the company where the device is rented.

2. Operator and Fuel Cost

The operator wage ( $L$ ) is calculated according to the salary for one effective working Hour, and the cost depends on the initial work contract. The following is the calculation formula following the Regulation of the Minister of PUPR Indonesia Number 1 of 2022.

$$L = \text{Number of People} \times U_1$$

$U_1$  is operator salary (rupiah/hour)

Meanwhile, in calculating the fuel ( $H$ ) cost for heavy equipment, it is necessary to know the unit price per liter first. Here is the calculation formula following Indonesian PUPR Ministerial Regulation Number 1 of 2022.

$$H = Ch \times Pw \times Ms$$

$Ch$  is the fuel coefficient, 10% for light work, 11% for medium work, and 12% for heavy work.  $PW$  is engine power capacity, and  $Ms$  is diesel price per liter.

3. Total Operating Cost

The total operating cost ( $P$ ) is the total cost of equipment rental calculated by the formula:

$$P = H + L + \text{Rental Price}$$

$H$  is fuel costs.  $L$  is operator salary costs.

**3. Results and Discussion**

This research is conducted at the Afvoer Watudakon Flood Control Development project in Tempuran Village, Sooko District, Mojokerto. The excavation work item has an excavation volume of 70,016.148 m<sup>3</sup>, where this project was built with a function of flood control in the area.

**3.1 Productivity Calculations**

This calculation consists of excavator and dump truck productivity. The specifications of those equipment is shown in Table 2.

**Table 2.** Excavator and Dump Truck Specification

Heavy Equipment	Brand	Capacity
Excavator	Hyundai HX210S (148 horsepower)	0,92 m <sup>3</sup>
Dump Truck	Hino HD130 (130 horsepower)	7 m <sup>3</sup>

• Excavator

The excavator's heavy equipment functions to carry out soil excavation work on river banks and dump some of the excavated soil into a dump truck. From the results of observing the cycle time in Table 3 that has been carried out, the productivity of the heavy excavator equipment is as follows:

$$T_{s1} = T_1 + T_2 + T_3 + T_4$$

$$= 7,73 + 4,47 + 4,47 + 4,47$$

$$= 19,81 \text{ seconds}$$

Based on cycle time, productivity can be obtained, which is 154,185 m<sup>3</sup>/hour in Hour and 1079,293 m<sup>3</sup>/hour in day.

**Table 3.** Observation Result of Excavator Cycle Time

Cycle	Observation			
	Time (second)			
	Digging	Swing fill time	Time to spill	Empty swing time
1	8,99	4,23	4,4	3,88
2	8,14	4,45	3,95	3,04
3	8,58	3,81	3,44	3,44
4	6,72	4,12	4,94	3,63
5	7,86	4,09	3,57	4,07
6	6,03	5,3	3,39	3,87
7	7,8	5,27	3,17	4,45
<b>Average</b>	<b>7,73</b>	<b>4,47</b>	<b>4,47</b>	<b>4,47</b>
<b>Average cycle time</b>	<b>19,81</b>			

• Dump Truck

The excavated soil is loaded using a dump truck, where the volume of excavated soil is 70,016.148 m<sup>3</sup>. From that volume, it is needed 9,17 minutes of cycle time. It is obtained 37,99 m<sup>3</sup>/hour of productivity per hour.

**3.2 Duration of Work Time Analysis**

From the calculation of the productivity of heavy equipment that has been carried out, an analysis will be made regarding the length of time in which the productivity value of the excavator and dump truck is used. The following is a recapitulation of the results of calculating the productivity of excavators and dump trucks.

**Table 4.** Productivity of Heavy Equipment

No	Heavy Equipment	Produktiviti per Hour	Productivity per Day
1	Excavator	154,185	1079,293
2	Dump Truck	37,99	265,993

From the productivity values above, the calculation of the duration of time for each tool is presented in Table 5 and Table 6.

**Table 5.** Excavator Duration

Excavator		
Duration	Hour	454
	Day	65
Units Total	Units	9

**Table 6.** Dump Truck Duration

Dump Truck		
Duration	Hour	263
	Day	38
Units Total	Units	5

From Table 4, the practical working hour for an excavator is 7 hours per day, so the number of excavators needed is nine units. Meanwhile, from Table 6, the practical working hour for dump trucks is 7 hours per day, so the number of dump trucks needed is five units.

**3.3 Rental Costs Analysis**

To meet the need for carrying out work using heavy equipment, the contractor can rent heavy equipment for realization, where the contractor does not need to worry about long-term maintenance costs for the equipment. The duration of heavy equipment rental is based on a weekly or monthly agreement. The hourly equipment rental price is obtained from the project data, where the rental cost for excavators and dump trucks is per hour in Table 7. Rental costs analysis is carried out in Table 8 for dump trucks and excavator.

**Table 7.** Rental Costs

Heavy Equipment	Produktiviti per Hour	Rental Costs per Hour (Rp)
Excavator	154,185	Rp. 150.000
Dump Truck	37,99	Rp. 250.000

**Table 8.** The Results from Rental Costs Analysis

Rental Excavator			Rental Dump Truck		
Brands	Hyundai HX210S	9 Units	Brands	Hino HD130	5 Units
Engine Power	145	Horse Power	Engine Power	130	Horse Power
Rental Costs	Rp. 150.000,00	Hour	Rental Costs	Rp. 250.000,00	Hour
Operators Wages	Rp. 35.000,00	Hour	Operators Wages	Rp. 30.000,00	Hour
Working Hours	7	Hour	Working Hours	7	Hour
Fuel	Rp. 6.800,00	Liter	Fuel	Rp. 6.800,00	Liter
<b>Calculation</b>			<b>Calculation</b>		
Fuel Costs (H)	Rp. 100.640,00	Hour	Fuel Costs (H)	Rp. 88.400,00	Hour
	Rp. 704.480,00	Day		Rp. 618.800,00	Day
Operators Wages (L)	Rp. 35.000,00	Hour	Operators Wages (L)	Rp. 30.000,00	Hour
	Rp. 245.000,00	Day		Rp. 210.000,00	Day
Operating Costs (P)	Rp. 285.640,00	Hour	Operating Costs (P)	Rp. 368.400,00	Hour
Rental Fee Per Day	Rp. 1.999.480,00	Day	Rental Fee Per Day	Rp. 2.578.800,00	Day
Rent Cost with the Total Number of Tools	Rp. 129.966.200,00	65 Day	Rent Cost with the Total Number of Tools	Rp. 97.994.400,00	38 Day

#### 4. Conclusion

Based on the results of the calculations carried out, several conclusions can be drawn. Firstly, the productivity value of the heavy excavator equipment is determined to be 154,185 m<sup>3</sup>/hour, while the dump truck's productivity value is 37.99 m<sup>3</sup>/hour. These calculations are based on a Hyundai HX210S brand excavator and a Hino HD 130 dump truck.

Secondly, it is found that the construction time required for the heavy equipment excavators is 454 hours, whereas the dump trucks take 263 hours to complete the construction task. Lastly, regarding rental fees, the heavy equipment excavator can be rented at a rate of Rp. 1,999,480.00/Day, while the rental cost for a dump truck amounts to Rp. 2,578,000/Day.

#### 5. Acknowledgement

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#### 6. Author's Note

I, at this moment, declare that the article entitled "Productivity Analysis of Excavator and Dump Truck Heavy Equipment on Digging and Loading Works Flood Control Afvoer Watudakon Mojokerto" is an original work and has been defended in the examination to obtain a Bachelor's degree in Civil Engineering at the Civil Engineering Study Program, Faculty of Engineering, Universitas 17 Agustus 1945 Surabaya.

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