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Planning of Heavy Equipment Requirement in Excavation and Soil Management Work (Case Study : Medical Building Construction Project Phase 2 of Siti Khodijah Muhammadiyah Hospital Along Branch)

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Abstract

Earthwork on the Medical Building Construction Project Phase 2 of Siti Khodijah Muhammadiyah Hospital Along Branch is one of the main keys to withstand the building's resilience structure. This Building Construction Project has obstacles to the ongoing excavation and Mgrading work, tools that need to be improved, and less supportive terrain conditions. As a result, the completion of work may be delayed leading to cost overruns. Therefore, the need for an active role of management, especially productivity calculations, to determine fundamental change steps so that these obstacles can be avoided or reduced. To analyze the machine's productivity, it must be by the theory of machine productivity related to the subject matter obtained and the appropriate stages of analysis. Thus, machine planning must be carried out carefully and precisely so that the effectiveness of optimal machine use and time can be achieved by calculating the productivity value of the machine. Based on the data analysis, the results of heavy equipment needs were obtained, namely, two units of excavated excavators, five units of dump trucks, and two units of Mgrading excavators. With the total costs incurred to complete the excavation and Mgrading work, namely for excavators Rp. 124,785,550.00 and dump trucks Rp. 11,496,875.00. To complete the excavation and Mgrading work takes 205 hours excavator and 13 hours dump truck.

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1. Introduction

Earthwork on the Medical Building Construction Project Phase 2 of Siti Khodijah Muhammadiyah Hospital Along Branch is one of the primary keys to withstand the building's resilience structure. Earthworks include excavation and backfilling work. Filling work is carried out with the help of heavy equipment. The purpose of using heavy equipment is to make it easier for humans to complete work to achieve the desired results, and the time used is relatively short. The use of heavy equipment in excavation and stockpiling work is essential for the speed and acceleration of construction projects. The value of effectiveness of using heavy equipment such as excavators and dump trucks can be judged by the productivity of the equipment. An excavator is a tool that helps in the work of excavating materials and soil management. The advantage of excavators is that they can move materials to a dump truck more efficiently. Dump Truck is a tool that helps in the work of transporting and moving soil material. Dump Truck is very suitable for transporting materials over long distances.

A machine is said to be productive if the duration and capacity of the device are adjusted to the function and purpose required. The advantage of using heavy equipment is that it takes little time because the work can be completed quickly. Operating costs can be adjusted back to optimized business hours. Errors in using heavy equipment can result in effective and efficient project implementation management. As a result, the completion of work may be delayed leading to cost overruns.

Thus, the Medical Building Construction Project Phase 2 of the Siti Khodijah Muhammadiyah

Hospital Branch As long as there are obstacles to the ongoing excavation and grading work, tools do not work optimally, and terrain conditions are less supportive, therefore the need for an active role of management, especially productivity calculations, to determine fundamental change steps so that these obstacles can be avoided or reduced. Tool productivity depends on the type or type of tool, working method, working terrain conditions, and the time it takes to complete a job. All aspects between the kind of tool, work method, terrain conditions, and time must be related to one another so that an analysis of machine productivity is needed to review the productivity of a machine. To analyse the machine's productivity, it must be by the theory of machine productivity related to the subject matter obtained and the appropriate stages of analysis. (Kalengkongan et al., 2020).

2. Material and Methods

2.1 Theoretical Frame Work

Heavy equipment planning must be carried out carefully and precisely. Hence, the effectiveness of optimal equipment and the time that can be achieved is by productivity analysis value of the heavy equipment. In this case, the author reviews aspects of the productivity of heavy equipment excavators and dump trucks; it can be known the number of heavy equipment needed and how long and cost it takes to complete the work to achieve optimum time and minimum costs.

Heavy equipment is a vital resource in a project, but renting heavy equipment is a costly undertaking (Rafi & Witjaksana, 2023). Before data analysis, firstly it is carried out through these following steps in Figure 1.

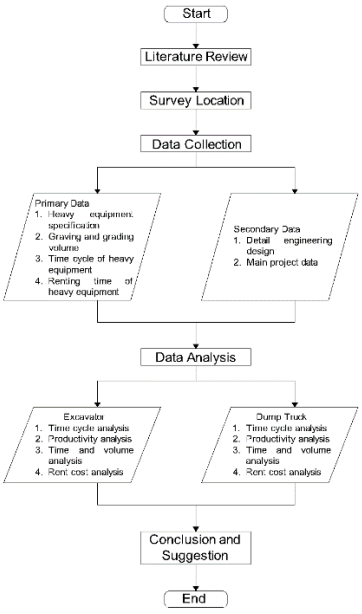

Figure 1. Flowchart

2.2 Research Location

This research is carried out at the Medical Building Construction Project Phase 2 of The Siti Khodijah Muhammadiyah Hospital Along Sidoarjo Branch located on Jalan Pahlawan No. 260.

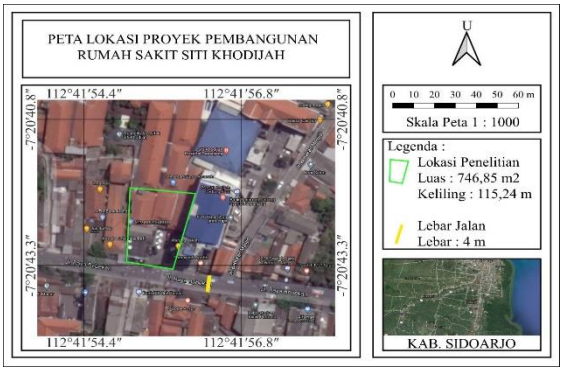

Figure 2. Research Location

2.3 Data

The data on this research consists of primary data and secondary data. Primary data is obtained from field survey activities, interviews, and other media, which are graving and grading volume, heavy equipment specification, heavy equipment cycle time, and heavy equipment rental cost. Secondary data is existing data obtained at an agency or agency and can be used immediately without the need for processing, namely data on heavy equipment from project implementers. The data consists of detail engineering design and project general data.

2.4 Analysis Method

- **Excavator**

Excavator is a equipment for digging the predetermined depth (Rafi & Witjaksana, 2023). The formula of hourly productivity excavator is used from Peraturan Menteri PUPR No. 28 Tahun 2016.

$$Q_1 = \frac{V \times F_a \times F_b \times 60}{T_s 1 \times F_v} \quad (1)$$

V is bucket capacity. F_a is equipment efficiency factor. F_V is depth conversion factor. F_b is bucket factor. T_{s1} is excavator cycle time. The cycle time is found out with the data from the results of observations in the field using formula from Peraturan Menteri PUPR No. 28 Tahun 2016.

$$T_{s1} = T_1 + T_2 + T_3 + T_4 \quad (2)$$

T_{s1} is cycle time. T_1 is dig time. T_2 is fill time. T_3 is wasting time. T_4 is empty rotate time.

- **Dump Truck**

Dump truck is essential equipment for transportation (Rafi & Witjaksana, 2023). This tool is very important to move quickly and carry with large capacity. The ability can make them an effective means of conveyance with relatively low operating cost. The productivity of

this tool is calculated using formula from Peraturan Menteri PUPR No. 28 Tahun 2016.

$$Q_2 = \frac{V \times F_a \times 60}{D \times Ts2} \quad (3)$$

Q_2 is dump truck productivity. V is vessel dump truck capacity. F_a is equipment efficiency factor. T_{s2} is cycle time for dump truck. Cycle time of dump truck has the same formula with excavator.

$$T_{s2} = T_1 + T_2 + T_3 + T_4 \quad (4)$$

$$T_1 = \frac{V \times 60}{Qexc} \quad (5)$$

$$T_2 = \frac{L \times 60}{V_F} \quad (6)$$

$$T_3 = \frac{L \times 60}{V_R} \quad (7)$$

$$T_4 = t_1 + t_2 \quad (8)$$

2.4.1 Time and Number of Tools Requirement

Time efficiency is needed to achieve the right work results according to the plan. Realizing discipline, especially time, requires high loyalty from all parties involved. In determining human resources, paying attention to several factors, including standard operating hours and overtime is necessary.

- Normal operating hours

The working time each day (Monday-Saturday) is set for 7 hours/day with a working wage equal to the standard working wage.

- Overtime operating hours

Overtime time is calculated from the working time that exceeds the standard working time limit (7 hours/day). Overtime work time is carried out outside the regular operating hours for weekdays or an increase in the number of working days per week (week).

The calculation of the time and number of tools needed for a job is as follows:(Sokop et al., 2018)

$$\text{Time Required} = \frac{\text{Job Volume}}{\text{Daily Produktivity}}$$

$$\text{Amount Excavator} = \frac{\text{Time required}}{\text{Execution time}}$$

$$\text{Amount of Dump Truck} = \frac{Excavator \text{ Produktivity}}{Dumptruck \text{ Produktivity}}$$

2.4.2 Heavy Equipment Rental Cost

The way to analyze the unit price of work should be to review all costs that concern or expenses that affect the result, namely:

- Owner Ship or Exact Cost

The cost of ownership is the cost of ownership of the tool that must be considered as long as the instrument in question is operated if the device is owned by itself. This cost must be regarded because the agency will decrease production for a long time; even at a specific time, the tool can no longer produce; this is depreciation.

- Tool Rental Cost

In a construction project, the use of heavy equipment, in addition to using privately owned equipment, can also be leased. In determining the cost of renting the equipment, some provisions have been issued by the Department of Public Works.

The cost of renting heavy equipment is divided into the cost of renting the equipment itself, operator wages, and fuel costs. For the calculation of rental expenses, serious equipment needs can be calculated using the formula from Peraturan Menteri PUPR No. 1 Tahun 2022. Generally the analysis of hourly fuel for heavy equipment uses this following formula.

$$H = C_h \times P_w \times M_s$$

Ch is fuel coefficient. P_w is engine power capacity. M_s is the price of diesel.

The amount of operator wages is calculated based on costs of 1 hour effectively working, which depends on the initial employment contract.

Operator (L) = Number of People × U_1

U_1 is operator wage.

The total operating cost consists of fuel costs, operator wages, and rental price.

P = H + L + rental price

3. Result and Discussion

3.1 Machine Productivity Analysis

- **Excavator for Excavation Work**

Excavators have two functions: to dig the ground and to move the soil to the dump truck, so there is a difference in digging time and exhaust time. The productivity of excavator is calculated by this following data:

Bucket Capacity (V) : 0.32 m^3
Bucket Factor (F_b) : 1.1
Work Efficiency (F_a) : 0.83
Excavated Conversion (F_V) : 0.9
Dig Time (T_1) : 9.04
Fill Time (T_2) : 2.02
Wasting Time (T_3) : 2.05
Average Depth of Excavation : 0.80 m
Maximum Depth Excavation : 1.10 m

US Cyclic Time (TS) $= T_1 + T_2 \times 2 + T_3$
$= 9.04 + 2.02 \times 2 + 2.05$
$= 15.19$

Productivity/hour (Q_1) $= \frac{V \times F_a \times F_b \times 60}{T_s 1 \times F_v}$
$= \frac{0.32 \times 0.83 \times 1.1 \times 60}{15.19 \times 0.9}$
$= 1.15$ m^3/hour

- **Excavator for Moving Soil to Dump Truck**

For calculating the productivity of excavators used to move soil to dump trucks, there is a difference in the last digging time because the excavated soil is easier, namely the excavated soil in the stockpile resulting from the excavator in charge of digging the original soil. The productivity of excavator in moving soil to dump truck is calculated using this following data.

Bucket Capacity (V) : 0.32 m^3
Bucket Factor (F_b) : 1.1
Work Efficiency (F_a) : 0.83
Excavated Conversion (F_V) : 0.9
Dig Time (T_1) : 0.20
Fill Time (T_2) : 0.40
Wasting Time (T_3) : 0.17
Average Depth of Excavation : 0.80 m
Maximum Depth Excavation : 1.10 m

US Cyclic Time (T_S) $= T_1 + T_2 \times 2 + T_3$
$= 0.20 + 0.40 \times 2 + 0.17$
$= 1.17$

Productivity/hour (Q_1) $= \frac{V \times F_a \times F_b \times 60}{T_s 1 \times F_v}$
$= \frac{0.32 \times 0.83 \times 1.1 \times 60}{1.17 \times 0.9}$
$= 14.98$ m^3/hour

- **Dump Truck Productivity**

Dump truck productivity analysis is carried out when the truck loaded by excavator with bucket capacity of 0.32 m^3. The used brand on this work is MITSUBISHI CANTER with the specification below.

Tub Capacity (V) : 8 m^3
Bucket Capacity (q_1) : 0.32 m^3
Excavator Cycle Time : 1.17
Bucket Factor (K) : 1.1
Fill Velocity (V_1) : 30 km/hour
Empty Velocity (V_2) : 40 km/hour
Transport Distance : 5 km = 5000 m
Work Efficiency (F_a) : 0.83
Discharge & Waiting Time (t_1) : 15 minutes
Load Position Taking Time (t_2): 5 minutes

The value of T_1, T_2, T_3, and T_4 is obtained using equation 5, 6, 7, and 8.

$T_1 = 19.43$ minutes
$T_2 = 10$ minutes
$T_3 = 7.5$ minutes
$T_4 = 20$ minutes

$n = \frac{V}{q_1 \times K}$
$= \frac{8}{0.32 \times 1.1}$
$= 22.73$ times ~ 23 times

$C = n \times q_1 \times K$
$= 22.73 \times 0.32 \times 1.1$
$= 8$ m^3

T_{s2} is obtained using equation 4, which is 56.93 minutes. So the productivity is calculated by this formula 3.

$Q_2 = \frac{V \times F_a \times 60}{Ts2}$
$= \frac{8 \times 0.83 \times 60}{56.93}$
$= 6.99$ m^3/jam

- **Excavator Productivity for Landfill Work**

In calculating excavator productivity especially for landfill work, the used data for analysis consists of:

Bucket Capacity (V) : 0.32 m^3
Bucket Factor (F_b) : 1.1
Work Efficiency (F_a) : 0.83
Excavated Conversion (F_V) : 0.9
Dig Time (T_1) : 0.16
Fill Time (T_2) : 0.84
Wasting Time (T_3) : 0.13
Average Depth of Excavation : 0.80 m
Maximum Depth Excavation : 1.10 m

US Cyclic Time (T_S) $= T_1 + T_2 \times 2 + T_3$
$= 0.16 + 0.84 \times 2 + 0.13$
$= 1.97$

With the equation 1, the productivity is obtained. The value is 8.90 m^3/hour.

3.2 Time and Number of Tools Requirement

- **Excavator**

After the excavation work by the excavator is completed, the residual soil collected next to the construction will be transferred to dump truck with the help of an excavator to load the excavated soil. Here is the calculation of the soil transfer to a dump truck with the help of an excavator, which consists of the number of excavator and usage time.

Excavator Uptime $= \frac{\text{Graving Volume}}{Excavator \text{ Productivity}}$
$= \frac{93.18}{1.15}$
$= 81.03$ ~ 81 hours

Excavator uptime to move soil to dump truck is calculated by this following formula:

Excavator Uptime $= \frac{\text{Graving Volume}}{Excavator \text{ Productivity}}$
$= \frac{93.18}{14.98}$
$= 6.22$ ~ 6 hours

Then excavator usage time can be calculated using two those value.

Usage Time = 81 + 6 = 87 hours = 12.46 days

The number of excavator for moving soil to dump truck is calculated depends on working time and usage time of excavator.

$$n = \frac{\text{Complete Duration}}{\text{Working Time}}$$
$$= \frac{12.46}{7}$$
$$= 1.78 \sim 2 \text{ units}$$

With the same formula, the number of excavator for landfill work can be determined.

$$\text{Excavator Uptime} = \frac{\text{Excavation Volume}}{\textit{Excavator}\ \text{Productivity}}$$
$$= \frac{1053.7}{8.9}$$
$$= 118.39 \sim 118 \text{ hours}$$
$$= 16.91 \text{ days}$$
$$n = \frac{\text{Complete Duration}}{\text{Working Time}}$$
$$= \frac{16.91}{7}$$
$$= 2.42 \sim 2 \text{ units}$$

- **Dump Truck**

After obtaining the number of excavator requirement, so the amount of dump truck to transfer soil from excavator must be calculated. The formula is almost same with excavator analysis.

$$\text{Dump Truck Uptime} = \frac{\text{Excavation Volume}}{\text{Dump Truck Productivity}}$$
$$= \frac{93.18}{6.99}$$
$$= 13.33 \text{ hours} \sim 13 \text{ hours}$$
$$n = \frac{\text{Excavator Productivity}}{\text{Dump Truck Productivity}}$$
$$= \frac{29.96}{6.99}$$
$$= 4.29$$
$$= 5 \text{ units}$$

3.3 Heavy Equipment Rental Cost

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 (Rafi & Witjaksana, 2023). The rental fee for equipment depends on the type and specification of the used brand. From the specification, it will get the price and operator wage.

- **Excavator**

Brand & Type : Komatsu PC78 US
Equipment Rental Price : Rp. 250.000,00/hour
Fuel Cost : Rp. 5.150,00/liter
Operator Wage : Rp. 25.000,00/hour

From the data above, the rental cost is as follows:

Fuel Cost

H = $C_h \times P_W \times M_s$
= 10% × 57 × 5.150
= Rp. 29.355/hour

Operator Wage Cost

L = Number of People × U_1
= 1 × Rp. 25.000
= Rp. 25.000/hour

Total operation cost is analysed using fuel cost and operator wage cost with additional cost of rental price.

P = H + L + Rental Price
= Rp. 29.355 + Rp. 25.000 + Rp. 250.000
= Rp. 304.355/hour

So that the total costs incurred by heavy excavator equipment to complete excavation and urugan work, namely:

Total Rental Cost = P × (Excavator Working Time + Excavator Landfill Working Time) × n
= 304.355 × (87 + 118) × 2
= Rp. 124.785.550

- **Dump Truck**

Brand & Type : Mitsubishi Canter
Equipment Rental Price : Rp. 100.000/hour
Fuel Cost : Rp. 5.150/liter
Operator Wage : Rp. 12.500/hour

From the data above, the rental cost is as follows:

Fuel Cost

H = $C_h \times P_W \times M_s$
= 10% × 125 × 5.150
= Rp. 64.375/hour

Operator Wage Cost

L = Number of People × U_1
= 1 × Rp. 12.500
= Rp. 12.500/hour

Total operation cost is analysed using fuel cost and operator wage cost with additional cost of rental price.

P = H + L + Rental Price
= Rp. 64.375 + Rp. 12.500 + Rp. 100.000
= Rp. 176.875/hour

Total Rental Cost = P × Dump Truck Uptime × n
= 176.875 × 13 × 5
= Rp. 11.496.875

4. Conclusion

From the research and discussion of heavy equipment productivity in the construction project of the Medical Building Phase 2 of Siti Khodijah Muhammadiyah Hospital Along Branch, the following conclusions are obtained:

- Based on the data analysis above, the results of heavy equipment needs were obtained, namely, 2 units of excavated excavators, 5 units of dump trucks, and 2 units of urugan excavators.
- The rental fee for the excavator from the calculation results is Rp. 304,355.00/hour, for the dump truck rental fee, is Rp. 176,875.00/hour. And the total costs

incurred to complete the excavation and urugan work are Rp. 124,785,550.00 and dump trucks Rp. 11,496,875.00. To complete the excavation and urugan work takes 205 hours excavator and 13 hours dump truck.

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6. Author's Note

I, at this moment, declare that the article entitled " Planning of Heavy Equipment Requirement in Excavation and Soil Management Work " 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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