Productivity Analysis of Heavy Equipment in the Nglurup Pond Project, Tulungagung Regency East Java Examined from Time and Cost Analysis

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Abstract: The construction of the Reservoir Nglurup in Tulungagung District has a length of 50 meters, this is used to store water when it rains and can be stored for use during the summer. The process of excavating the body of the reservoir uses heavy equipment to support dewatering work at the work site, excavating soil and removing soil. The large number of heavy equipment operating at the location limits the ability of heavy equipment to move, so it is necessary to plan the position of the heavy equipment in order to facilitate the work. The research method was carried out by observing in the field. The excavation work for the reservoir body took 19 working days with a total heavy equipment operational cost of IDR 270,000,000. While the planning calculation for 14 days with the total operational cost of heavy equipment amounted to IDR 382,889,800. The results of calculating operator efficiency in terms of Availability Index, Physical Availability, Use of Ability, Effective Utilization show how the operator's work is planned better than operators in the field.

1 INTRODUCTION

The pond development project is a building that is built between hills where the area is limited for maneuvering because the contours have extreme different elevation. Meanwhile, excavation process in the pond body needs to be prepared since the excavation process would affect the water surface of the construction area. Starting from the dewatering and flow out the water to nearby body water such as river (Robert J. Kodoatie & Roestam Sjarief, 2008). As quoted from Rostiyanti in 2002, (Susy Fatena Rostiyanti, 2008) heavy equipment is important for construction project work, where the purpose of the heavy equipment was utilized in construction work in huge scale can be achieved as scheduled with result as it planned. Excavation work on the body of the Nglurup pond uses heavy equipment including excavators, dump trucks, and water pumps. The effectivity of heavy equipment is influenced by several factors, the most significant of which are the capacity, the duration of the process, and efficiency factor (Hidayat, Iskandar, & Kudiantoro, F. F. Wijayaningtyas, 2019). The skill level of the operator in using the equipment will greatly affect the effectiveness of the tool. skillful operator adaptive their operation to the excavating environment based on their empirical knowledge, and realizing the efficient excavating. (Sakaida, Chugo, Yamamoto, & Asama, 2008) The pond construction project needs to pay attention to the stages of excavation work and the effectivity of heavy equipment.

The pond was built due to drought conditions and reduced water availability irrigation, construction of reservoirs using the hydrological analysis method by looking at the flood discharge using the Weduwen method (Utami et al., 2015), analysis of the mainstay discharge using the basic year method, analysis of water demand and water balance (Herison, Romdania, Purwadi, & Effendi, 2018). From the results of the analysis of water demand, it is known that the pond was planned with 100,752.736 m3, the pond height is 18m, the elevation of the base of the reservoir is 274.48 m, the effective width is 22.127 m. (Hanggara & Irvani, 2019)

The work was planned to be completed in 14 days whereas in reality, the work in the field was completed in 19 days. Due to this delay, this study was conducted to offer some solutions by changing the specifications and amount of heavy equipment

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from result of data analysis. However, the technic of the pond's construction will not be re-evaluated in this study.

2 THEORETICAL REVIEWS

2.1 Heavy Equipment Productivity

As Rostiyanti (Susy Fatena Rostiyanti, 2008) state that productivity is a comparison of the completion achieved with all the resources used. The hourly productivity equation and the factor of an equipment efficiency are entered, the equation used is:

$$\text{Productivity} = \text{Capacity} \times (60 : \text{Cycle Time}) \times \text{Efficiency} \quad (1)$$

2.2 Job Duration

How to calculate the duration of work is obtained from the calculation of the volume of work divided by productivity per day:

$$\text{Duration} = \text{Work Volume} / \text{Productivity per days} \quad (2)$$

2.3 Water Pump Productivity

The equation for calculating water pump productivity refers to:

$$Q = \text{Max Pump Capacity} \times \text{Equipment Efficiency} \times 60 \quad (3)$$

2.4 Excavator Productivity

The amount of productivity is influenced by capacity, efficiency and cycle period. So that work can be done without any problems and heavy equipment can be used properly, the productivity requirements for the excavator that will be used must be estimated first.

The equation for calculating excavator cycle time (CT)

$$CT = \text{Digging Time} + \text{Swing Fill Time} + \text{Empty Swing Time} + \text{Dumping Time} \quad (5)$$

The equation for calculating the productivity of an excavator (Q)

$$Q = (\text{Work Volume per cycle (m3)} \times 60 \times \text{Efficiency}) : CT \quad (6)$$

The equation calculates the cost per day

$$\text{Operating Cost} = (\text{Rental price} + \text{Fuel Price} + \text{Operator Cost}) \times \text{Working hours} \quad (7)$$

Determination for a small size of the bucket value can be influenced by soil conditions according to Table 1 as follows: (Sağlam & Bettemir, 2018).

Table 1: Bucket filling factor.

Material	Bucket Filling Factor
General Floor	0.85-1.10
Sand and Gravel	0.90-1.05
Firm Clay	0.75-0.95
Soft Clay	0.65-0.90
Rock, well blasted	0.65-0.85
Rock, poorly blasted	0.40-0.65

2.5 Dump Truck Productivity

The equation for calculating dump truck cycle time (CT)

$$CT = \text{Load Time} + \text{Hauling Time (Loaded)} + \text{Dumping Time} + \text{Hauling Time (Unloaded)} + \text{Idle Time} \quad (8)$$

The equation for calculate the productivity of a dump truck (Q)

$$Q = (\text{Work Volume per cycle (m3)} \times 60 \times \text{Efficiency}) : CT \quad (9)$$

The equation calculates the cost per day, same as Eq.7.

2.6 Operator Work Efficiency

Operator efficiency depends on the operator's mastery or expertise in working on equipment while completing a job. The more ideal the ability of an operator, the higher the effectiveness factor. One of the rules that can be used to calculate the operator efficiency factor is as shown in Table 2 as follows: (Zulkarnain, 2020).

Table 2: Operator efficiency value.

Tire Type	Efficiency Criteria	
	Day Time	Night Time
Crawler	50 minutes (83%)	45 minutes (75%)
Rubber	45 minutes (75%)	40 minutes (67%)

Availability Index (AI) is used to understand the condition of the heavy equipment used. The equation used is like:

$$AI\ (\%) = \frac{\text{Total duration (W)}}{\text{Total duration (W)} + \text{Equipment maintenance duration (R)}} \times 100\% \quad (10)$$

Physical Availability (PA) is a record of the physical condition of the heavy equipment used. The equation used is like:

$$PA = (W + \text{Standby Duration (S)}) : (W+R+S)) \times 100\% \quad (11)$$

Use of Ability (UA) is a way to find out how much duration is used by heavy equipment to work when used. The equation used is like:

$$UA = (W : (W+S)) \times 100\% \quad (12)$$

Effective Utilization (EU) is a way of knowing what percentage of available work time can be used to operate productively. The equation used is like:

$$UE = (W : (W+R+S)) \times 100\% \quad (13)$$

2.7 Heavy Equipment Used

The equation for calculating water pump productivity refers to: Heavy equipment, which is often known in work, is a device used to assist human work in completing a job that is expected to use the assistance of heavy equipment, especially for very large scope development projects. Using heavy equipment aims to ease human work and can provide the best results in development work in a fairly short period of time (Rochmanhadi, 1992). In the process of excavating the reservoir body requires an effective tool to support the work. Useful tools for the field are:

2.7.1 Water Pump

Water pump is a tool used to remove water or drain water in the excavation area so that the workplace can be effective when work is carried out. The diesel-powered water pump was used in this project for its portability and independently of electric supply. (Water Master, 2017).

2.7.2 Excavator

According to Rostiyanti (Susy Fatena Rostiyanti, 2008) an excavator is a hydraulic digger that has a bucket mounted in front of it. Excavators have two types of wheels, namely tires and crawler wheels. The excavator can be used in the same way that the bucket is moved down and then up to the excavator body where there is an arm, a boom, and a bucket which driven by hydraulic power using a machine on the track shoe.

2.7.3 Dump Truck

A dump truck is primarily used to transport materials to and from a construction site. It is the safest way to quickly transport loose materials from a site, and is especially important in the early phases of a project where the ground is being prepared for work to commence. (ARDENT NEWSLETTER, 2019).

3 RESEARCH METHOD

3.1 Secondary Data Collections

Secondary data were used as mentioned are technical specifications, to determine the length, height and width of the reservoir body. Shop drawings were used to calculate the volume for excavation. And the Budgeting and Cost Estimating was used to estimate the cost of excavation of the pond. The flowchart of this research can be seen at figure 1.

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In order to construct the pond, the river stream would be dammed and turned to other side until the construction of pond had completed (Li, Xu, Xu, Liu, & Wang, 2018). The following illustration, figure 2a, depict the river meandering with A as the dam on upstream and downstream, B as the diversion channel, and C is the location of the water pump for dewatering.

Figure 2b was depict the excavation process of the pond gradually done from the left side of the origin stream. Therefore, the loose soil would be transferred by dump truck outside the area.

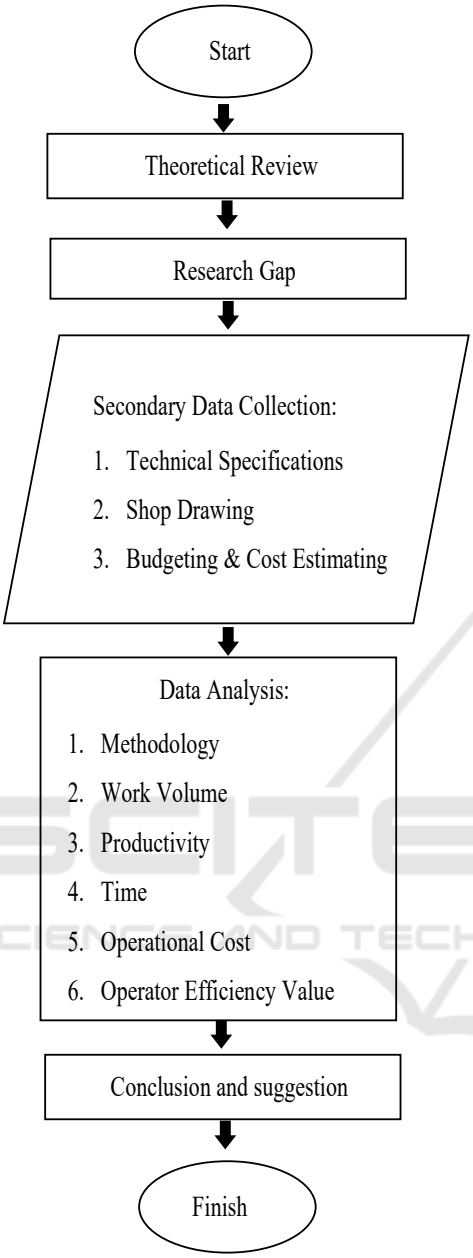

Figure 1: Research flowchart.

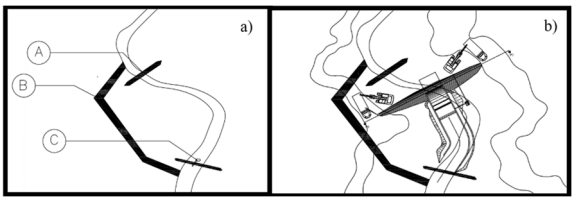

Figure 2: a) Dewatering Process, b) Excavation Process.

4 RESULT AND DISCUSSION

When carrying out the work on the Nglurup pond project, the suggested technique should be easier to assess time and cost, excavation work on the Nglurup pond body has a volume of 9,157 m3, on the excavation planning schedule, it is planned to work for 14 days, while the implementation that occurs in the field is up to 19 days, so researchers re-evaluate and provide better solutions to achieve planned schedule.

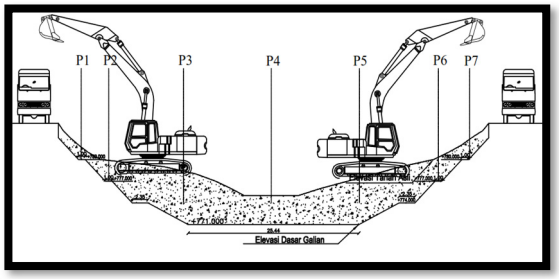

Figure 3: Reservoir cut image.

Based on the figure 2a, before excavation was carried out, it was necessary to make diversion channels and dams so that water from upstream can flow downstream through temporary diversion channels without disturbing the excavation area, then the next stage can be dewatered because there is no water flow until the work area is free from remaining water, while the excavation work area for the pond body is divided into 2 sides, namely the left side P1 to P4 and the right side P4 to P7. And the volume of soil that needs to be excavated in total is 9158 m3, then the excavated soil is put into the dump truck and moved to a predetermined location

4.1 Calculation of Heavy Equipment Productivity

The specifications of the heavy equipment used in the site can be seen in Table 3.

Table 3: Specifications of Heavy Equipment in the Field.

Equipment	Type	Efficiency	Bucket factor	Working hour/Days	Cost (IDR) /Hours
Water pump	-	0,78	Cap 6 HP	7	Rent: 13.400
					Fuel: 20.000
Excavator	Komatsu PC-200-8 MO	0,75	1,2 m^3	7	Rent: 276.500
					Operator: 102.200
					Fuel: 143.000
Dump truck	Hino 130 HD	0,8	5 m^3	7	Rent: 185.000
					Operator: 63.200
					Fuel: 30.000

4.2 Comparison of on Site and Planned Productivity

The results of calculating the productivity, time and cost of each heavy equipment in the field can be seen in Table 4, namely:

Table 4: Productivity of Heavy Equipment on site.

No.	Equipment Type	Tools Amount (Unit)	Production/ Hours	Production/ Hours	Cycle Time (Mins)	Amount/ Days
1.	On site water pump	1	211 m^3	1477 m^3		1
2.	Planned water pump	1	211 m^3	1477 m^3		1
1.	On site Excavator	2	34 m^3	233 m^3	0,6	19
2.	Planned Excavator	2	51 m^3	357 m^3	0,6	14
1.	On site dump truck	6	11,2 m^3	78,4 m^3	30	19
2.	Planned dump truck	8	11,2 m^3	78,4 m^3	30	14

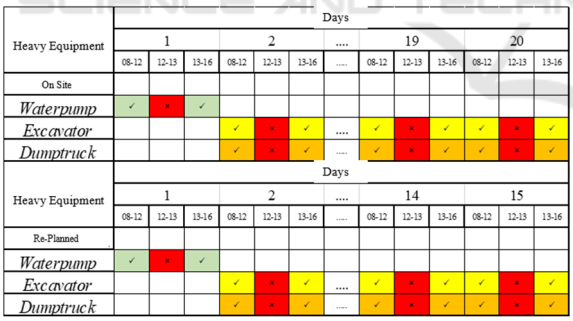

Figure 4: Graph simulation comparison of heavy equipment work time.

According to Figure 4, Green; yellow; and orange mark represents working hours, while red mark represents lunch break hours. The data related to the simulation graph that excavation is planned for 14 days but in the field of work it takes up to 19 days, so the researchers tried to remark to the initial duration of 14 days.

4.3 Comparison of Costs for Excavation of Reservoir Body

After calculating the rental costs for each tool on the table 3, the next step is to compare the productivity on-site with planned as depict on table 5 and could be conclude in table 5. It showed the total cost was increased since the productivity by well-skilled operator would also cost more.

Table 5: Cost comparison chart.

Equipment	Duration (Days)	Cost Total	Remark
Water pump	1	IDR 270.000.000	On site work
Excavator	19		
Dump truck	19		
Water pump	1	IDR 382.889.800	Re-plan work
Excavator	14		
Dump truck	14		

5 CONCLUSIONS

Based on the results of the analysis of productivity, time, operating costs of heavy equipment and comparison of operator work efficiency in the Nglurup reservoir body excavation, the following conclusions can be drawn:

1. The cost required for the work to go according to the 14-day plan is IDR 382,889,800
2. Because there are differences in the specifications of excavators and the number of dump trucks, productivity was also different. Productivity was planned to be better than in the field because it has bigger specifications and more numbers.
3. The results of calculations carried out by researchers due to delays in work in the field where the work should have gone 14 days to 19 days, the solution needs to be a change in the specifications of the excavator and an increase in the number of dump trucks so that the results obtained are in accordance with the desired target.

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