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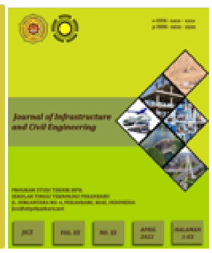

Analysis of Heavy Equipment Productivity in Normalization and Embankment Work in Sei Berapit Indragiri Hilir Regency

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Abstract

The 30% delay in construction progress on the Normalization and Embankment Construction project in Sei Berapit, Indragiri Hilir Regency, where as of the last week of November 2025 only 70% of the work had been completed, indicates that heavy equipment productivity has not met the planned target. This study aims to analyze the productivity of amphibious excavators and determine the effective number of equipment alternatives to accelerate project completion. The method used is a quantitative method with a case study approach, with productivity analysis based on work cycle time data, equipment efficiency, and actual production capacity from field observations. The analysis results show that in Alternative I, namely the use of two amphibious excavators, daily production capacity increased significantly to around 980,627 m^3/day, so that the remaining work volume of 5,760.416 m^3 could theoretically be completed in around 6 working days. This increase in productivity not only has an impact on accelerating the duration of implementation but also provides better operational flexibility in anticipating field disruptions. Compared to other equipment addition alternatives, Alternative I is considered the most rational because it reduces unproductive time, minimizes the risk of delays due to equipment damage or other operational disruptions, and remains within an acceptable daily operational cost level of IDR. 27,363,200. This finding confirms that productivity control and determining the number of amphibious excavators play a crucial role in time and cost management. Therefore, heavy equipment productivity evaluation should be conducted from the project planning stage, especially for excavation work in flooded terrain, to ensure optimal achievement of implementation targets.

Keywords: *Cost, Excavator, Productivity, Cycle Time, Swamp Terrain*

1. Introduction

The normalization project of the main and secondary channels of Sei Berapit in Indragiri Hilir Regency, Riau Province, has a high level of complexity because it is carried out in a tidal swamp area with saturated soil conditions and constant exposure to brackish water.

This work aims to restore the function of channels that have experienced silting with a total excavation volume of 19,201.387 m^3. These extreme working conditions place great pressure on the performance and reliability of heavy equipment. When determining the appropriate type of heavy equipment for a project, there are a number of important aspects that must be considered to avoid mistakes in equipment selection [1][2].

The productivity of heavy equipment is a major factor in achieving work volume targets. Theoretically, productivity is influenced by equipment capacity, work cycle time, operator efficiency, terrain conditions, and operational management in the field [3]. Amphibious excavators are used because they have low ground pressure and high mobility in flooded areas. However, brackish water and soft soil conditions increase the risk of mechanical damage, especially to the track, bucket, and engine systems, which causes high downtime and reduced effective working time.

Figure 1. Damage to Amphibious Excavator Buckets

In addition to technical factors, heavy rainfall causes soil instability, leading to frequent excavation collapses that require rework. This increases the workload on excavators and heightens the risk of equipment damage. Based on the implementation document, the project was planned to run from July 3, 2025, to the end of December 2025, but by the last week of November 2025, progress had only reached 70% and there was still a volume of 5,760.416 m^3 remaining. This condition indicates that the project is at a critical stage due to the high and unpredictable frequency of equipment damage.

The theoretical calculation approach shows that one excavator unit is still capable of completing the remaining work within ±12 working days, but this calculation does not represent the actual field conditions affected by operational disruptions. This shows a gap between theoretical capacity and actual productivity.

Previous research by Ramdhani and Johari [4] shows that heavy equipment management has a significant effect on project duration and cost, where work acceleration can be achieved even though it requires additional operational costs. However, that study was conducted under dry land conditions. Therefore, this study focuses on analyzing the productivity of the PC210 Amphibious Excavator in normalization work in the Sei Berapit swamp area to evaluate the effect of equipment damage on time and cost efficiency in extreme working environments [5].

2. Methodology

This study uses a descriptive approach with a field survey method. Descriptive research aims to describe and explain problems based on actual conditions at the work site. The initial stage was conducted through investigation and direct observation to obtain relevant field data, followed by calculations and analysis of the objects studied. The approach used was quantitative, beginning with a site survey to obtain data relevant to the research problem. The data collected consisted of primary and secondary data.

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2.1. Primary data

Primary data was obtained through direct observation of heavy equipment activity in the field, including:

a. Cycle time of amphibious excavators
b. Productivity per effective working hour
c. Number and specifications of equipment used

2.2. Secondary data

Secondary data was obtained from contractors and related agencies, including:

a. Volume of excavation work
b. Project time schedule
c. Equipment rental and operational costs

In addition, this study was supported by a literature review to obtain a theoretical basis related to heavy equipment productivity, sourced from literature, lecture materials, construction journals, and other print and electronic media.

2.3. Data Analysis Method

The research data obtained from the survey and project documentation was then analyzed to determine the performance of the equipment in actual field conditions. This analysis aimed to evaluate the productivity of the Amphibious Excavator and its implications for the duration and cost of normalization and embankment construction work in Sei Berapit.

The stages of analysis carried out include:

a. Calculation of excavator productivity analysis.
b. Calculation of the time required for the work.
c. Calculation of equipment usage costs.

The following is a research flowchart that illustrates the stages of systematic analysis implementation.

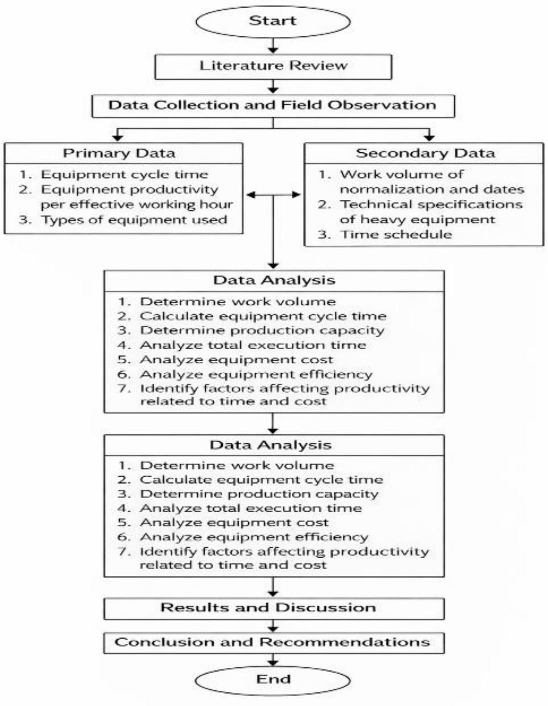

Figure 2. Research Flowchart

3. Results and Discussion

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3.1. Project Data

The case study in this research is the Sei Berapit Main and Secondary Channel Normalization Project in Indragiri Hilir Regency, Riau Province. This normalization work was carried out on the main channel segment of the Sei Berapit tidal swamp area with a total excavation volume of 19,201.387 m^3. The following is the project data obtained:

a. Project location:
Indragiri Hilir Regency, Riau Province (Sei Berapit Tidal Swamp Area).

b. Implementation period:
July 3, 2025 – end of December 2025.

c. Contractor:
PT. Irfanira Mitra Bersama

d. Type and specifications of heavy equipment used
- Equipment Type : Amphibious Excavator
- Brand/Type : Komatsu/PC210-10M0
- Capacity : 0.45 m^3
- Equipment Condition : Good
- Equipment Function : Excavation
- Number of Units : 1 unit

The location of the Sei Berapit Channel Normalization Project in Indragiri Hilir Regency, Riau Province, can be seen in Figure 3. below.

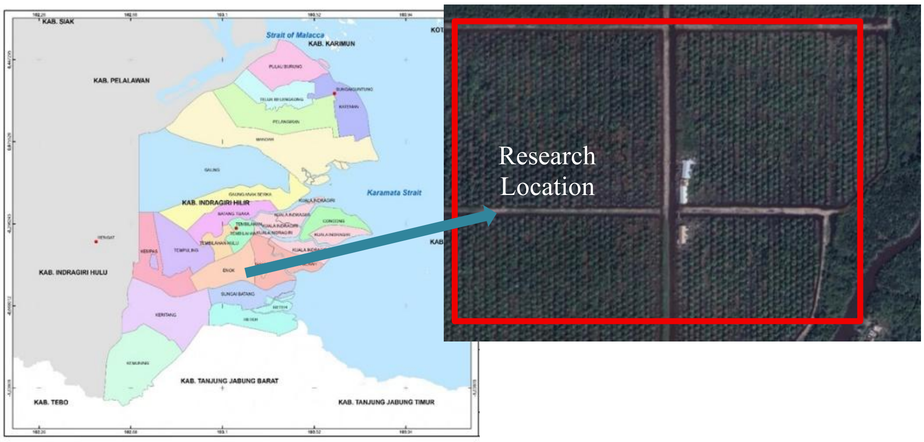

Figure 3. Research Location

3.2. Productivity Analysis

Productivity analysis was conducted to determine the ability of amphibious excavators to produce excavation volume during effective working hours. Productivity calculations were based on actual cycle times in the field, bucket capacity, and work efficiency factors influenced by equipment and working conditions[6].

The excavator's working cycle time in this study was obtained from direct observations in the field of the operational activities of the PC210-10M0 amphibious excavator during the work. The digging time is the duration required for the excavator from the moment the bucket begins to penetrate the material until the bucket is full and ready to be lifted. The loaded swing time is recorded from the moment the boom and arm begin to swing from the excavation position to the material disposal area. Furthermore, the dumping time is the duration of the process of emptying the material from the bucket at the disposal site until the bucket is completely empty. After the material is dumped, the empty swing time is recorded, which is the duration of the excavator's movement back from the disposal site to the initial excavation position without carrying a load[7][8].

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Calculation of the average time value for each element of the excavator's work cycle and determination of the total excavator cycle time as a representation of one full work cycle in the analysis of equipment productivity and evaluation of the operational performance of the PC210-10M0 amphibious excavator in the work studied.

$$T_{Digging} = \frac{T_1 + T_2 + T_3 ....T_n}{n} \quad (1)$$

$$T_{Digging} = \frac{11{,}41+10{,}2+12{,}24+10{,}56+10{,}79+9{,}14+12{,}29+11{,}28+10{,}32+12{,}49}{10}$$

$$T_{Digging} = 11{,}072 \text{ Seconds}$$

Cycle time (Cms) = excavation time + filled rotation time + dumping time + empty rotation time (2)

Cycle time (Cms) = 11.072 + 8.05 + 14.03 + 5.85

Cycle time (Cms) = 39 Seconds

The following is a summary of the cycle time observations for the Komatsu/PC210 – 10M0 amphibious excavator in Table 1.

Table 1. Amphibious excavator cycle time observation data

Cycle	Observation			
	Dig	Turn (Filled)	Dump	Turn (Empty)
	Time (Seconds)			
1	11.41	8.87	14.2	5.85
2	10.2	7.97	14.67	5.82
3	12.24	8.68	13.4	5.9
4	10.56	7.14	14.1	5.83
5	10.79	7.34	13.09	5.76
6	9.14	6.98	14.22	5.85
7	12.29	9.38	14.58	5.89
18	11.28	7.76	13.4	5.78
9	10.32	6.75	14.08	5.87
10	12.49	9.65	14.56	5.91
Average	11.072	8.05	14.03	5.85
Cycle Time	39			

a. Excavation productivity

q = ql × K

q = 1 × 0,8

q = 0,8 m^3

b. Hourly Productivity

$$Q = \frac{q \times 3600 \times E}{cms}$$

$$Q = \frac{0{,}8 \times 3600 \times 0{,}83}{39}$$

Q = 61,29 m3/hour

c. Daily Productivity

$$Qd = Q \; x \; T \; x \; n$$

$$Qd = 61{,}29 \; x \; 8 \; x \; 1$$

$$Qd = 490{,}31 \text{ m}^3$$

d. Available working hours

Available working hours = Working days x Working hours
= 180 x 8
= 1,440 hours

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3.3. Existing Analysis Calculation

Due to the limited time remaining for implementation and the volume of excavation that has not been completed, an acceleration strategy is needed to ensure that project targets are achieved on time. Acceleration is carried out through several technical alternatives that consider equipment production capacity, time efficiency, and field operational conditions, with the aim of increasing daily output and minimizing the risk of further delays.

a. Time required for work (hk)

$$\frac{Total\ Volume}{\text{Number of equipment } \times \text{Hourly Productivity } \times \text{Working hours}}$$

$$= \frac{5.760{,}416}{1 \times 61{,}29 \times 8}$$

$= 11{,}75$ hk = 12 hk

b. Daily excavation productivity
Qd =Q x T x n
Qd = 61,29 x 8 x 1
Qd = 490,313 m^3/day

c. Cost Calculation
Rental cost calculation = Rental cost per hour x Work time x Number of equipment
= IDR. 1,300,000 x 8 x 1
= IDR. 10,400,000/day

d. Daily fuel requirement
Daily fuel requirement = Fuel requirement per hour x Daily working hours x Number of equipment
= 18 x 8 x 1
= 144 liters/day

e. Total fuel cost per day
Total fuel cost per day = Daily fuel requirement x Fuel price
= 144 x IDR. 21,400
= IDR. 3,081,600/day

f. Operator wages
Operator wages = Number of equipment x Daily wages
= 1 x IDR. 200,000
= IDR. 200,000/day

g. Total excavator equipment cost
Total excavator equipment cost = Rental cost + Fuel cost + Operator cost
= IDR. 10,400,000 + IDR. 3,081,600 + IDR. 200,000
= IDR. 13,681,600/day

3.4. Alternative 1 Analysis Calculation

The simulation of the addition of alternative equipment I to be used in this project is as follows:

Excavator = 2 units

a. Time required for work (hk)

$$\frac{Total\ Volume}{\text{Number of equipment } \times \text{Hourly Productivity } \times \text{Working hours}}$$

$$= \frac{5.760{,}416}{2 \times 61{,}29 \times 8}$$

$= 5{,}87$ hk = 6 hk

b. Daily excavation productivity
Qd =Q x T x n
Qd = 61,29 x 8 x 2

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Qd = 980,627 m^3/day

c. Cost Calculation

Rental cost calculation = Rental cost per hour x Work time x Number of equipment
= IDR. 1,300,000 x 8 x 2
= IDR. 20,800,000/day

d. Daily fuel requirement

Daily fuel requirement = Fuel requirement per hour x Daily working hours x Number of equipment
= 18 x 8 x 2
= 288 liters/day

e. Total fuel cost per day

Total fuel cost per day = Daily fuel requirement x Fuel price
= 288 x IDR. 21,400
= IDR. 6,163,200/day

f. Operator wages

Operator wages = Number of equipment x Daily wages
= 2 x IDR. 200,000
= IDR. 400,000/day

g. Total excavator equipment cost

Total excavator equipment cost = Rental cost + Fuel cost + Operator cost
= IDR. 20,800,000 + IDR. 6,163,200 + IDR. 400,000
= IDR. 27,363,200/day

3.5. Alternative 2 Analysis Calculation

The simulation of the addition of alternative equipment II to be used in this project is as follows:

Excavator = 3 units

a. Time required for work (hk)

$$\frac{Total\ Volume}{\text{Number of equipment } \times \text{Hourly Productivity } \times \text{Working hours}}$$

$$= \frac{5.760,416}{3 \times 61,29 \times 8}$$

= 3,91 hk = 4 hk

b. Daily excavation productivity

Qd =Q x T x n

Qd = 61,29 x 8 x 3

Qd = 1.470,94 m^3/day

c. Cost Calculation

Rental cost calculation = Rental cost per hour x Work time x Number of equipment
= IDR. 1,300,000 x 8 x 3
= IDR. 31,200,000/day

d. Daily fuel requirement

Daily fuel requirement = Fuel requirement per hour x Daily working hours x Number of equipment
= 18 x 8 x 3
= 432 liters/day

e. Total fuel cost per day

Total fuel cost per day = Daily fuel requirement x Fuel price
= 432 x IDR. 21,400
= IDR. 9,244,800/day

f. Operator wages

Operator wages = Number of equipment x Daily wages

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= 3 x IDR. 200,000
= IDR. 600,000/day

g. Total excavator equipment cost
Total excavator equipment cost = Rental cost + Fuel cost + Operator cost
= IDR. 31,200,000 + IDR. 9,244,800 + IDR. 600,000
= IDR. 41,044,800/day

3.6. Alternative 3 Analysis Calculation

The simulation of the addition of alternative equipment II to be used in this project is as follows:

Excavator = 4 units

a. Time required for work (hk)

$$\frac{Total\ Volume}{\text{Number of equipment } \times \text{Hourly Productivity } \times \text{Working hours}}$$

$$= \frac{5.760,416}{4 \times 61,29 \times 8}$$

= 2,93 hk = 4 hk

b. Daily excavation productivity
Qd =Q x T x n
Qd = 61,29 x 8 x 4
Qd = 1.961,25 m^3/day

c. Cost Calculation
Rental cost calculation = Rental cost per hour x Work time x Number of equipment
= IDR. 1,300,000 x 8 x 4
= IDR. 41,600,000/day

d. Daily fuel requirement
Daily fuel requirement = Fuel requirement per hour x Daily working hours x Number of equipment
= 18 x 8 x 4
= 576 liters/day

e. Total fuel cost per day
Total fuel cost per day = Daily fuel requirement x Fuel price
= 576 x IDR. 21,400
= IDR. 12,326,400/day

f. Operator wages
Operator wages = Number of equipment x Daily wages
= 4 x IDR. 200,000
= IDR. 800,000/day

g. Total excavator equipment cost
Total excavator equipment cost = Rental cost + Fuel cost + Operator cost
= 41,600,000 + 12,326,400 + 800,000
= IDR. 54,726,400/day

Table 2. Alternative Recapitulation of Excavator Numbers

Number of Additional Units	Unit Productivity (m^3/hour/unit)	Daily Production (m^3/day)	Remaining Time (days)	Equipment Cost Per Day (Rp)	Daily Operational Cost
Eksisting	61,29	490,313	12	10.400.000	13.681.600
Alternative 1	61,29	980,627	6	20.800.000	27.363.200
Alternative 2	61,29	1.470,94	4	31.200.000	41.044.800
Alternative 3	61,29	1.961,25	3	41.600.000	54.726.400

3.7. Analysis

The analysis of existing conditions shows that, theoretically, the use of one excavator unit is still capable of completing the remaining work volume of 5,760.416 m^3 in approximately 12 working days. However, this calculation approach does not fully represent the actual conditions in the field, which are affected by various unexpected operational disruptions, particularly damage to heavy equipment used as the main tool for the work [9].

Thus, although the technical calculation of the duration of implementation appears to be sufficient, the dominance of disruptions due to heavy equipment damage accompanied by weather influences indicates that time estimates based on a theoretical approach may be unrealistic. Therefore, a time control strategy is needed that not only considers the mathematical productivity of the equipment, but also anticipates the risk of unpredictable equipment damage and unfavorable weather conditions [8].

In Alternative I, adding two excavators significantly increases daily production capacity to approximately 980,627 m^3/day, thereby shortening the project completion time to approximately 6 working days. More than just speeding up the process, this alternative provides operational capacity reserves so that work can continue even if one of the machines breaks down or experiences a decline in performance. In terms of cost, the total daily operating cost of IDR. 27,363,200 is still considered reasonable and comparable to the benefits of reducing the risk of delays due to technical equipment malfunctions. This shows that Alternative I is the most logical and applicable option for controlling project delays that are dominated by the risk of equipment damage and exacerbated by weather conditions in the field [10].

Meanwhile, Alternative II and Alternative III, with the use of three and four excavators respectively, are indeed capable of reducing the duration of work to around 4 days and 3 working days. However, this acceleration is accompanied by a significant increase in operational costs, reaching IDR. 41,044,800/day for Alternative II and IDR. 54,726,400/day for Alternative III. Additionally, the limited workspace in the excavation area has the potential to cause overlapping equipment movements, increased idle time due to waiting for each other, and a decrease in the actual effectiveness of the equipment. In wet and muddy field conditions due to rain, excessive addition of equipment risks reducing operational efficiency and increasing the potential for work safety hazards. Therefore, although theoretically capable of accelerating completion time, Alternatives II and III are considered suboptimal when viewed from a comprehensive technical and economic perspective.

Figure 4 presents a comparison of project duration and operational costs for each analyzed alternative, thereby providing a clear picture of the trade-off between shortening project duration and increasing costs in each scenario involving the use of heavy equipment.

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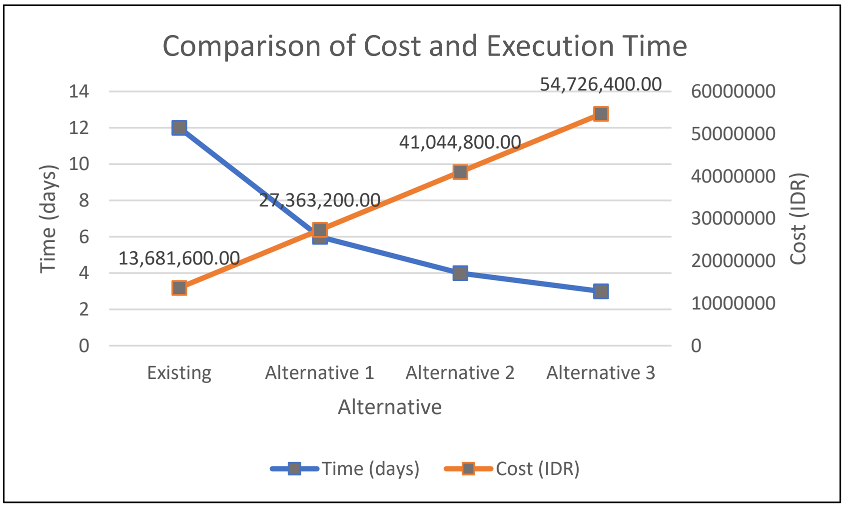

Figure 4. Comparison of Cost and Execution Time

4. Conclusion

Based on the results of the productivity analysis of the PC210-10M0 amphibious excavator in the Normalization and Embankment Construction work in Sei Berapit, Indragiri Hilir Regency, it can be concluded that Alternative I, namely the use of two amphibious excavators, is the most efficient option in terms of time and operational costs. The addition of equipment can increase production capacity to around 980,627 m^3/day, thereby shortening the duration of work to around 6 working days, while reducing unproductive time and increasing operational flexibility, especially in unfavorable weather conditions. In addition, the use of two excavators provides effective operational backup so that work can continue if one of the machines breaks down or experiences other technical problems, thereby minimizing the risk of delays in implementation. With a total daily operating cost of IDR. 27,363,200, which is proportional to the increase in productivity and acceleration of implementation achieved, the use of two PC210-10M0 amphibious excavators is considered efficient and recommended to support the normalization and embankment construction work at the research site.

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