International Journal of Integrative Research (IJIR)
Vol. 4, No.7, 2026: 489-496

Analysis of Heavy Equipment Cost and Productivity Budget in the Hayupi Road Reconstruction Project, Banjar Regency

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A R T I C L E I N F O

Keywords: Heavy Equipment Productivity, Operational Budget Cost, Schedule Optimization, Combined Capacity, Bottleneck Analysis, Road Reconstruction

Received : 3 May
Revised : 24 June
Accepted: 27 July

A B S T R A C T

Road reconstruction projects in rural and hilly terrain frequently encounter schedule delay challenges, leading directly to substantial operational cost overruns. A primary driver of discrepancies between planning and field execution is the inaccurate estimation of heavy equipment operational productivity and inappropriate fleet combinations. This study aims to analyze the actual working productivity of heavy equipment, calculate the precise operational budget costs, and formulate schedule optimization strategies for the Hayupi Road Reconstruction Project in Banjar Regency, South Kalimantan. The analytical methodology complies with PUPR Ministerial Regulation No. 1/2022 and No. 8/2023. Hourly production capacity evaluations incorporate cycle times, equipment efficiency factors, and local material parameters. Duration optimization is conducted using the Minimum Combined Production Capacity approach (bottleneck analysis). Secondary data were collected from project technical documentation, including the Bill of Quantities (BoQ), heavy equipment technical specifications, unit prices for fuel/ lubricants, labor wages, and planned S-Curves. The findings indicate that completing the five evaluated core work items (site clearing, common excavation, rock excavation, common embankment from excavation, and aggregate base Class A) requires a rental fleet combination of 3 Excavators, 7 Dump Trucks, 4 Rock Drill Breakers, 1 Bulldozer, 1 Motor Grader, and 1 Vibratory Roller. The total operational budget cost for heavy equipment across these five items is calculated at IDR 4,642,172,450.00

DOI: https://doi.org/10.59890/ijir.v4i7.225
E-ISSN 2988-2184
https://mrymultitechpublisher.my.id/index.php/ijir

INTRODUCTION

The development and improvement of the quality of road network infrastructure is one of the government's priority programs in supporting the equitable distribution of national economic growth, increasing community mobility, and smoothing the distribution of the supply of staples and regional commodity products. In border, hilly, and rural areas such as in Banjar Regency, South Kalimantan, the availability of a steady and reliable road network is the main key to breaking regional isolation and reducing regional logistics costs. However, in the realization of the implementation of road reconstruction projects in the field, the implementing contractor and project owners are often faced with project delays which have direct implications for cost overrun.

One of the fundamental triggers for the problem of delays and financial losses is the lack of careful planning for the selection of types, quantities, and calculations of heavy equipment work productivity. In wet civil construction and road pavement projects, heavy equipment is the most critical resource component that absorbs a very high portion of the direct cost budget, ranging from 25% to 45% of the total contract value. The productivity of heavy equipment in the field is not only determined by the theoretical horsepower and ideal capacity of the manufacturer, but is greatly influenced by the topographic conditions of the site, the level of operator skills, the efficiency of the work management, the cycle time, and the variation in the mechanical properties of local soil and rock materials.

If the determination of heavy equipment productivity at the initial planning stage is overly optimistic or pessimistic, the implementation schedule in the plan S-Curve document will not reflect the actual capacity conditions in the field. Equipment capacity mismatch results in high idle time in certain units, while other units experience queues or become major bottlenecks. Therefore, a systematic and structured analytical study based on PUPR Ministerial Regulation No. 1 of 2022 is needed to calculate actual productivity, analyze the operational costs of tools per working hour, and prepare schedule optimization based on the combined capacity of heavy equipment.

Based on the background that has been presented, the formulation of the problem in this study is determined as follows:

1. What is the actual level of work productivity of each type of heavy equipment used in the five main work items in the Hayupi Road Reconstruction Project, Banjar Regency?
2. What is the estimated operating cost of the machine per hour of work and the total cost of the equipment needed to complete all the work under review?
3. How to optimize the project implementation schedule based on the analysis of the smallest combined production capacity to realistically minimize the total construction duration?

Problem Limitations

The scope of this research is limited to the following technical provisions:

1. The review location is limited to the work package of the Hayupi Road Reconstruction Project, Bunglai Village, Aranio District, Banjar Regency (STA 0+650 to STA 1+150) with an effective handling length of 300 meters.

2. The work items analyzed were focused on 5 critical works: (1) Land Clearing and Stripping, (2) Ordinary Excavation, (3) Rock Excavation, (4) Ordinary Deposits from Quarries, and (5) Class A Aggregate Foundation Layers.
3. The cost analysis is limited to the direct operating costs of heavy equipment (including the cost of basic equipment rental, diesel fuel consumption, lubricant/oil, and operator and supervisor wages) without counting general project overhead costs, mobilization-demobilization, and contractor profits.
4. The scheduled scheduling analyzed was a mathematical plan schedule based on the combined productivity of the heavy equipment, not an evaluation of historical weekly physical progress in the field.

Research Objectives

The main objectives to be achieved in this study are:

1. Calculate hourly production capacity and actual machine coefficient values for each type of equipment on the job under review.
2. Calculate the details of heavy equipment operating costs per working hour as well as the accumulated heavy equipment cost budget for each work item.
3. Develop an optimal project rescheduling scheme by identifying bottlenecks to efficiently reduce the total duration of project implementation.

LITERATURE REVIEW

Project Management and Machine Productivity Concepts

Construction project management is the process of planning, organizing, directing, and controlling the company's organizational resources to achieve short-term goals that have been set using a systematic approach (Soeharto, 1995). In road construction project management, machine productivity is defined as the ratio between the quantity of material output that has been successfully moved or compacted (m^3 or m^2) to the unit of working operational time (hours).

Classification of Work Efficiency Factors (FA)

The work efficiency factor (Fa) takes into account the decline in tool performance due to machine maintenance conditions, terrain topography conditions, weather, and operator expertise. Based on the Regulation of the Minister of PUPR Number 1 of 2022, the value of work efficiency is classified as presented in Table 1.

Table 1. Heavy Equipment Work Efficiency Factors (FA) Based on PUPR Regulation No. 1/2022

Operating Conditions of Medan	Very good	Good	Medium	Bad	Very bad
Very good	0,83	0,81	0,76	0,70	0,63
Good	0,78	0,75	0,71	0,65	0,60
Medium	0,72	0,69	0,65	0,60	0,54
Bad	0,63	0,61	0,57	0,52	0,45

1. Standard Formulation of Machine Productivity Calculation

The calculation of heavy equipment production capacity per hour (Q) refers to the technical formulation standards of the Ministry of PUPR as follows:

1. Excavator (Excavation and Loading):

$$Q = (V \times Fa \times 60 \times Fk) / (Ts1 \times Fv)$$

2. Dump Truck (Material Transport):

$$Q = (V \times Fa \times 60) / Ts2$$

3. Bulldozer (Land Clearing/Top Soil Pushing):

$$Q = (q \times Fb \times Fm \times Fa \times 60 \times Fk) / (Ts3 \times t)$$

4. Motor Grader (Overlay and Layer Leveling):

$$Q = (Lh \times [N(b - bo) + bo] \times t \times Fa \times 60) / (n \times Ts4 \times N)$$

5. Vibratory Roller (Soil Layer Compaction/Aggregate):

$$Q = (v \times 1000 \times [N(b - bo) + bo] \times t \times Fa) / (n \times N)$$

1. Heavy Equipment Operating Costs

Hourly heavy equipment operating costs are calculated based on the sum of the components of fuel costs (***Bb***), lubricant/oil costs (***Bp***), operator and supervisory wages (***Uo***), and hourly equipment principal rental rates (***Bs***).

$$\text{Biaya Operasional per Jam (Rp/Jam)} = Bb + Bp + Uo + Bs$$

Location and Research Object

The location of the research is located in the Hayupi Road Reconstruction Project located in Bunglai Village, Aranio District, Banjar Regency, South Kalimantan Province (STA 0+650 to STA 1+150).

Stages and Flow of Data Processing

RESEARCH METHODOLOGY

1. Secondary Data Collection: Collecting BoQ data, heavy equipment specifications, S-curve plan, price list of diesel fuel, lubricants, and labor wages in the Banjar Regency area.
2. Tool Work Productivity Analysis: Calculates cycle time, hourly productivity (Q), and tool coefficients for each tool on 5 main jobs.
3. Hourly Operating Cost Analysis: Calculates the components of rental costs, fuel, lubricants, and operator/supervisor wages for each unit of equipment.
4. Combined Capacity & Bottleneck Analysis: Determines the smallest combined production capacity of a set of tools working together per work item.
5. Schedule Optimization and Duration Evaluation: Calculate the realistic duration of the proposal (Duration = Volume / Capacity Bottleneck) and evaluate the efficiency of project time acceleration.

Bill of Quantity Data

Table 2. Recap of Key Work Items Reviewed

No. Mata	Main Job Description	Units	Quantity (BoQ)	Project Weight(%)
3.4.(1)	Land Clearing and Stripping	M^2	12.745,13	2,90 %
3.1.(1)	Ordinary Excavations	M^3	89.575,88	29,82 %
3.1.(3)	Rock Excavation	M^3	9.952,88	13,81 %
3.2.(1b)	Ordinary Deposits from Excavated Produce	M^3	473,50	0,13 %
5.1.(1)	Class A Aggregate Foundation Layer	M^3	1.850,63	9,45 %

Project Machine Technical Specifications

Table 3. Technical Specifications of Project Heavy Equipment Fleet

No	Types of Heavy Equipment	Tool Type/Model	Working Capacity	Engine Power (HP)
1	Excavator	Hyundai HX 340SI	Bucket 2,00 m^3	260 HP
2	Bulldozer	Komatsu D85E-SS	Blade 3,40 m^3	200 HP
3	Dump Truck	Hino 500 (10 Wheel)	View 22–24 m^3	260 HP
4	Vibratory Roller	SAKAI SV526D	Road 10 Ton	112 HP
5	Motor Grader	Komatsu GD511A	Blade 3,10 m	135 HP
6	Rock Drill Breaker	Hydraulic Breaker 20T	Palu Hydraulics	200 HP

Calculation of Heavy Equipment Productivity Per Job

1. Land Clearing and Stripping Work

Table 4. Results of Productivity Analysis of Land Clearing Work

Types of Heavy Equipment	Cycle Time (minutes)	Efficiency Factor (Fa)	Productivity/Hours	Tool Coefficients
Bulldozer D85E-SS	1,82	0,75	90.00 m^2/h	0.0111 hours/m^2
Excavator HX 340SI	0,55	0,78	170.84^3/h	0.585

2. Ordinary Excavation Work

Table 5. Results of Productivity Analysis of Ordinary Excavation Work

Types of Heavy Equipment	Tool Capacity	Cycle Time	Productivity/Hours	Tool Coefficients
Excavator Hyundai	Bucket 2.0 m^3	0.62 minutes	150.34 m^3/h	0.0067 hours/m^3
Dump Truck Hino 500	Container 22.0 m^3	13.42 minutes	78.54 m^3/h	0.0127 hours/m^3

3. Stone Quarrying Work

Table 6. Results of Analysis of Productivity of Stone Excavation Work

Types of Heavy Equipment	Main Functions	Cycle Time	Productivity/Hours	Tool Coefficients
Rock Drill Breaker	Rock Fracturing	2.20 minutes	9.35 m^3/h	0.1070 hours/m^3
Excavator Hyundai	Stone Loading	0.44 minutes	211.91 m^3/h	0.0047 hours/m^3
Dump Truck Hino 500	Transportation	109.69 minutes	4.54 m^3/h	0.2203 hours/m^3

4. Ordinary Backfill Work from Excavated Results

Table 7. Results of Productivity Analysis of Ordinary Landfill Work

Types of Heavy Equipment	Tool Capacity	Cycle Time	Productivity/Hours	Tool Coefficients
Excavator Hyundai	Bucket 2.0 m^3	0.53 minutes	170.84 m^3/h	0.0059 h/m^3
Dump Truck Hino 500	Container 22.0 m^3	4.99 minutes	99.87 m^3/h	0.0100 hrs/m^3
Vibratory Roller SAKAI	Drum 10 Ton	-	943.09 m^3/h	0.0011 hours/m^3

Table 8. Ordinary Backfill Work from Excavated Results

Types of Heavy Equipment	Job Function	Main Parameters	Productivity/Hours	Tool Coefficients
Dump Truck Hino 500	Transport from Basecamp	Distance 1.0 km	45.04 m^3/hr	0.0222 hours/m^3
Engine Grader GD511A	Spread & Flattening	Thickness 0.35 m	220.50 m^3/h	0.0045 hours/m^3
Vibratory Roller SAKAI	Coating compaction	8 Lintasan	168.49 m^3/hr	0.0059 h/m^3

Heavy Equipment Operating Cost Budget Analysis

Calculation of Tool Operating Costs per Hour

Table 9. Details of Heavy Equipment Operating Costs per Working Hour (Rp/Hour)

Types of Heavy Equipment	Rental Fees	BBM Solar	Lubricants/Oils	Labor Wages	Total Cost/Hour
Excavator HX 340SI	IDR500.000,00	IDR265,200.00	IDR9,000,00	IDR48,750,00	**IDR938.150,00**
Dump Truck Hino 500	IDR238.000,00	IDR265,200.00	IDR4,500.00	IDR48,750,00	**IDR556.450,00**
Bulldozer D85E-SS	IDR676.000,00	IDR204.000.00	IDR51,000.00	IDR48,750,00	**IDR973,750,00**

Vibratory Roller SAKAI	IDR328.000,00	IDR114,240,00	IDR25,200.00	IDR48,750,00	**IDR518.190,00**
Engine Grader GD511A	IDR424.000,00	IDR137.700,00	IDR30,300.00	IDR48,750,00	**IDR666,750,00**

Total Heavy Equipment Cost Per Job Item

Table 10. Heavy Equipment Cost Budget Recapitulation for Each Work Item

Yes	Main Job Items	Combination of Heavy Equipment Units	Total Tool Cost (Rp)
1	Ordinary Excavations	2 unit Excavator + 4 unit Dump Truck	IDR 1,616,444,800,00
2	Rock Excavation	1 unit Excavator + 3 Breaker + 6 Dump Truck	IDR2,609,598,400,00
3	Regular Stack	1 unit Excavator + 1 Dump Truck + 1 Vibro Roller	IDR16,102,320,00
4	Land Clearing	1 unit of Bulldozer + 1 unit of Excavator	IDR275,313,600,00
5	Class A Aggregate Foundation Layer	1 unit Dump Truck + 1 Grader + 1 Vibro Roller	IDR124,713,330,00
TOTAL PROJECT HEAVY EQUIPMENT COST BUDGET			**IDR4,642,172,450,00**

1. Combined Capacity Analysis and Project Schedule Optimization

Table 11. Recapitulation of the Evaluation of the Duration of the Project Optimization Proposal

Yes	Job Item Description	Tool Penentu (bottleneck)	Combined Capacity	Duration of Proposal
1	Land Clearing and Stripping	Bulldozer D85E-SS	90.00 m^2/h	18 Days
2	Ordinary Excavations	Excavator HX 340SI	300.68 m^3/h	38 Days
3	Rock Excavation	Dump Truck Hino 500	27.24 m^3/h	46 Days
4	Ordinary Deposits from Excavated Produce	Dump Truck Hino 500	99.87 m^3/h	1 Day
5	Class A Aggregate Foundation Layer	Dump Truck Hino 500	45.04 m^3/h	9 Days
TOTAL DURATION OF IMPLEMENTATION OF OPTIMIZATION PROPOSAL				**140 CALENDAR DAYS**

The results of the optimization test showed that the duration of project completion could be accelerated from the initial plan of the S-Curve for 180 calendar days to 140 calendar days. There was an efficiency of implementation time of 40 calendar days (22.22%).

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

1. The work productivity of the machine varies on each work item. Production bottlenecks were identified in Excavators (300.68 m^3/h) for ordinary excavation, Dump Trucks (27.24 m^3/h) for rock excavation, Dump Trucks (99.87 m^3/h) for ordinary heaps, Bulldozers (90.00 m^2/h) for land clearing, and Dump Trucks (45.04 m^3/h) for class A aggregate foundation layers.
2. The total budget for heavy equipment operational costs to complete the five main works in the Hayupi Road Reconstruction Project is IDR 4,642,172,450.00.
3. The combined capacity-based scheduling optimization of the tools succeeded in cutting the total duration of the project from 180 calendar days to 140 calendar days, thus saving construction time of 40 days (22.22%).

Suggestions

1. For Implementing Contractors: It is recommended to add a special Dump Truck fleet to rock excavation work and aggregate foundation layers so that the productivity of Excavators and Motor Graders can be optimally absorbed.

2. For the Next Researcher: It is necessary to conduct a cycle time adjustment study based on direct field observations (time study) to capture the variables of rainfall weather resistance and time loss in real time.

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