Investment Analysis of Heavy Equipments for Cut and Fill Work on Toll Road Construction Project (Case Study: Trans Sumatra Toll Road Section 3, Bakauheni-Terbanggi Besar)

I Kustiani[1,*], RA Syahputra[1], and A Dasaputra[1]

[1]*The Department of Civil Engineering, the Faculty of Engineering, the University of Lampung*
Jl. S. Brojonegoro No. 1, Bandar Lampung – Indonesia

[*]*Email: ika.kustiani@eng.unila.ac.id*

Article Information:

Received:
18 September 2025

Received in revised form:
2 October 2025

Accepted:
5 December 2025

Volume 7, Issue 2, December 2025
pp. 147 – 152

http://dx.doi.org/10.23960/jesr.v7i2.256

Abstract

Toll roads are vital infrastructure; however, their construction requires significant capital expenditures. One significant cost component is the cost of heavy equipment. The investment schemes considered in this study are cash new purchase, leasing, and rental. The best investment decision requires engineering investment analysis, including the NPV, IRR, BCR, and PP methods. The estimated cost of owning heavy equipment with a cash scheme is Rp 46.06 billion, a leasing scheme is Rp 53.50 billion, and a rental scheme is Rp 66.66 billion. The operating cost for all schemes is the same, amounting to Rp 56.44 billion during the construction period. The financial analysis results show that the cash scheme is the best with an NPV of Rp 9,198 billion, an IRR of 10.39%, a BCR of 1.12, and a PP of 3,3 years. Sensitivity analysis to interest rate increases shows that the cash scheme is feasible up to a 10% interest rate.

Keywords: *Cut and Fill Works, Engineering Investment Analysis, Heavy Equipment*

I. INTRODUCTION

INFRASTRUCTURE improvements are essential for economic growth. When a country's economy relies heavily on land transportation like Indonesia, transportation infrastructure such as toll roads significantly boosts economic efficiency. However, toll road infrastructure development is always faced with limited resources, one of which is financial limitations for procuring heavy equipment. The availability of such equipment, significantly increases the efficiency of toll road construction. Therefore, a sound strategy is essential for planning and procuring heavy equipment for toll road projects.

Engineering investment analysis is important to be carried out on a project to ensure the project's financial success [1]. Therefore, heavy equipment procurement methods are important to be analyzed since they impact operational costs, in which it will increase with the age of the equipment [2]. Based on this, this study is intended to obtain output in the form of a cost analysis that can help toll road implementers (contractors) to be able to make decisions in procuring heavy equipment (buying new, buying used, renting or leasing). Inaccuracy in heavy equipment procurement strategies can result in financial losses [3], [4].

The case study is the Trans-Sumatra Toll Road Construction Project, Section 3 Bakauheni - Terbanggi Besar. The project stretches 29.5 kilometers from South Lampung Regency to Pesawaran Regency. The total project cost is 2.4 trillion Rupiah. However, only the cut and fill work (earthwork) using heavy equipment will be analyzed in this study.

II. MATERIALS AND METHODS

Cut and fill work on a toll road project is a complex undertaking requiring significant resources. Heavy equipment is a key component in completing the work. The equipment used for cut and fill work includes excavators, dump trucks, bulldozers, motor graders, vibratory rollers, and water tank trucks [5]. A schematic of the cut and fill work on a toll road project can be seen in the illustration in Figure 1.

Figure 1. Cut and fill work illustration

In this study, the number of heavy equipment required within the frame of match factor concept is based on several variables, including cut and fill volume (m^3), execution time (months), and mass-haul diagrams. The volume of embankment work can be seen in Table 1.

Table 1. Volume and Duration of Work

Year	Duration (Months)	Work Volume (m^3)
2022	4	360,000
2023	12	1,080,000
2024	12	1,080,000
2025	12	1,080,000
2026	12	1,080,000
2027	8	720,000

The number of heavy equipment required within the frame of match factor concept of digging equipment (excavators), hauling equipment (dump trucks), and spreading equipment (bulldozers) is calculated using Equation 1. For other supporting equipment such as motor graders, vibro-rollers, and water tank trucks, they follow the bulldozer production capacity.

$$\boldsymbol{MF} = \frac{N \; x \; nt \; x \; CTm}{nl \; x \; CTa} \quad (1)$$

The variables calculated in the equation above include: cycle time (CT), in which is taken from the technical analysis of heavy equipment; the number of transport equipment (nt) and loading equipment (nl), are the number of excavators and dump trucks used in 1 work fleet; and the number of transports from the excavator to the dump truck or the number of buckets to fill a transport equipment (N).

After determining the required quantity of heavy equipment based on the match factor calculation, the next step is to analyze the owning and operating costs associated with the equipment. Owning costs consist of investment costs and depreciation costs. Investment cost also include taxes, insurance, interest rates, storage costs and repair costs throughout the equipment's useful life.

Contractors must decide on the procurement method for heavy equipment: whether to purchase with cash (new or used), lease, or rent. Cash purchases are best suited for long-term projects, but require a substantial initial capital outlay. Leasing involves paying in installments or on credit, in which the heavy equipment only be owned after the purchase is paid in full. Rentals are suitable for small-scale projects with relatively short project durations, and the company's finances do not allow for purchasing heavy equipment.

Depreciation is the reduction in the value/price of an asset, in this case heavy equipment, due to its useful life. To calculate the amount of depreciation, it is necessary to first knowing the purchase price, useful life, and residual value of the heavy equipment at the end of its useful life. In this study, depreciation was calculated using the Straight-Line Method, which means the depreciation value of the heavy equipment is equal each year. With this method, the annual depreciation is obtained by dividing the production value with the economic life of the equipment as shown in Equation 2.

$$\textbf{Depreciation} = \frac{Owning\ Cost - Cost\ of\ Tire - Residual\ Value}{Usefull\ Life\ (hour)} \quad (2)$$

Capital interest applies not only to equipment purchased in installment but also to equipment purchased in cash from internal funds, in which is considered as a loan. Currently, loan terms are rarely longer than two years. Meanwhile, the amount of insurance depends on the newness of the equipment, the condition of the project site and the type of work being handled. The calculation of capital interest, taxes, and insurance can be seen in Equation 3.

$$\textbf{Capital Interest} + \textbf{Tax} + \textbf{Insurance} = \frac{Factor\ x\ Machine\ Cost\ x\ Interest\ p.a.}{Hours\ of\ Use\ per\ Year} \quad (3)$$

Meanwhile, the factor value as shown in Equation 4, is obtained from the variable n, namely the economic life (useful life) of the equipment (years) and the variable r, namely the residual value of the equipment (%).

$$\textbf{Factor} = \frac{1-(n-1)(1-r)}{2n} \quad (4)$$

Operational costs are the costs related to the operation of an equipment. Unlike ownership costs, operating costs are only incurred when the equipment is operational and it will also be considered as a variable cost. Equipment operating costs include fuel costs, service costs, and operator costs. The higher the operating factor, the more the machine works [5].

After calculating the owning and operating costs, the next step is to assess the financial viability of investing in heavy equipment using the Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR), and Payback Period (PP). If these four parameters are viable, it can be concluded that the investment will generate the expected benefit/profit [1], [6].

NPV is a method used in investment analysis to determine the present value of expected future cash flows from a project or investment. The basis of this method is that all future benefits and costs associated with a project are discounted to their present values using a discount rate. The general equation for this method can be seen in equation 5.

$$\boldsymbol{NPV} = \sum_{t=0}^{T} \frac{C_t}{(1+i)^t} - C_0 \qquad (5)$$

The value of NPV is obtained by inputting the net cash flow during period t (Ct). Meanwhile, Co represents the total investment cost, i represents the discount rate, and t represents the project's economic life. There are three indicators of NPV value:

1. If NPV > 0 (positive), the project is viable
2. If NPV < 0 (negative), the project is not viable
3. If NPV = 0, the project is also not viable

The decision to accept or reject an investment proposal can also be made by looking at the BCR value. BCR is the ratio of the present value of benefits/profits divided by the present value of costs. BCR measures the costs incurred, denoted by C; compared to the results (benefit/profit) obtained, denoted by B. There are three indicators of BCR value:

1. If BCR > 1, the project is viable
2. If BCR < 1, the project is not viable
3. If BCR = 1, the project's benefits are equivalent with the costs, in which is also not viable

IRR is a parameter used to determine the efficiency or profitability of an investment by estimating the annual rate of return (ROR) that will be earned based on future cash flows. In other word, IRR calculates the interest rate on an investment and equating it to its current value based on the net cash flow in the future period. To simplify it, the IRR is the interest rate when the NPV = 0. There three indications of IRR:

1. IRR > Hurdle Rate, the investment is viable (acceptable) since it generates more than the cost of capital
2. IRR < Hurdle Rate, the investment is not viable (rejected) since it does not cover the cost of capital
3. IRR = Hurdle Rate, the investment breaks even, creating no significant added value

The IRR can be calculated using Equation 6.

$$\boldsymbol{IRR} = i_1 + (i_2 - i_1)\frac{NPV_1}{NPV_1 - NPV_2} \qquad (6)$$

IRR value can be obtained by trial-and-error method. The method utilizes several interest rates values to obtain NVP values, then plotted them on a graph. From the graph, the IRR value is obtained when the graph crossing the NPV = 0. A much easier way is to utilize an Excel spreadsheet and use the IRR formula.

PP measures how long it will take (usually in years) to recoup the entire initial investment from the cash inflows generated by the project. The shorter the payback period, the quicker the return on investment - the more attractive the project since it indicates a shorter time to reach the break-even point (BEP) i.e., the point where costs equal revenues.

PP is calculated based on the cumulative net cash flow from the initial investment (Fo) to period t (Ft), indicating the year in which the NPV value begins to change to be greater than or equal to zero as shown by Equation 7.

$$\sum_{t=0}^{n} \boldsymbol{F_t} \geq \boldsymbol{0} \qquad (7)$$

Furthermore, a sensitivity analysis can be conducted to see what will happen in a business if there are changes in variables such as initial costs, interest rates, etc. In this study, since interest rates is projected has a very significant effect on cash flow analysis, therefore a sensitivity analysis will be carried out on this criterion.

III. Results and Discussions

To optimize heavy equipment utilization, there are several steps must be carried out. Firstly, site plan drawings, cross section drawings, type of earthworks and its quantity, methods for carrying out cut and fill work, site condition as well as project master schedule must be understood. Subsequently, the information about specifications, types, capacity, pricelist of heavy equipment must be gathered. Then, calculate the productivity, number required, matching factor and combination of heavy equipment. From here, the cost of heavy equipment finally can be projected [7], [8], [9].

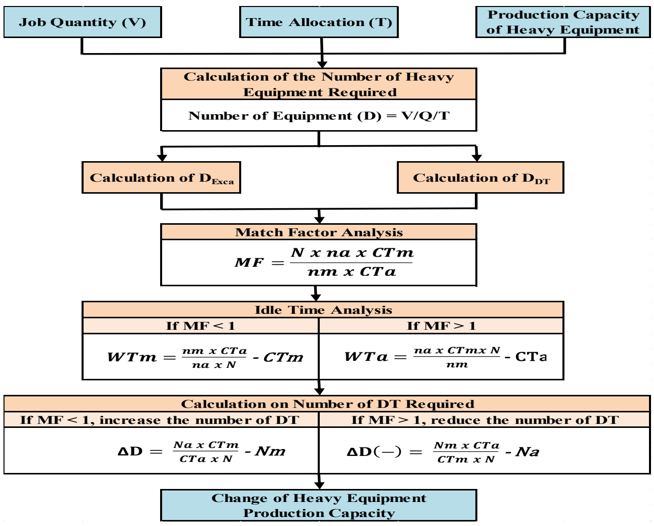

Figure 2. Flow chart of machine requirements calculation

Based on the description above, the above flowchart illustrates the stages in calculating heavy equipment requirements.

Before calculating the match factor, the production capacity of each unit of heavy equipment was calculated using technical analysis. The production capacity of each unit of heavy equipment can be seen in Table 2.

Table 2. Heavy Equipment Production Capacity

Heavy Equipment	Unit	Production Capacity
Excavator	m^3/hour	47.26
Bulldozer	m^3/hour	91.64
Dump Truck	m^3/hour	82.72
Vibro-Roller	m^3/hour	90.00
Water Tank Truck	m^3/hour	87.27

Source: Ministry of Public Works [10]

Based on the data in Table 2, the number required for each heavy equipment is calculated by dividing the total work volume with the duration of the project and the production capacity. This yields the number of heavy equipment unit as shown in Table 3. It is assumed that the equipment will operate for 8 hours per day during the project duration.

Table 3. The Number of Heavy Equipment Required

Heavy Equipment	Unit	Number of Units
Excavator	Unit	8
Bulldozer	Unit	4
Dump Truck	Unit	4
Vibro-Roller	Unit	4
Water Tank Truck	Unit	4

Based on the Table 3 above, the match factor is calculated based on the cycle time of each type of heavy equipment. The most important match factor in earthwork is between excavators and dump trucks, as shown in Table 4 below.

Table 4. Match Factor of Excavator – Dump Truck

Heavy Equipment	MF Exca – DT	
	Cycle Time (Minutes)	Number of Unit
Excavator	0.65	8
Dump Truck	11.75	4
Loading Quantity	22.5 m^3	
Match Factor	0.62	
Idle Time	0.39 minute	
Additional Dump Truck	2 unit	
Dump Truck Capacity	55.15 m^3	

From the data above, it is known that the number of dump truck has increased to 6 units. The subsequent calculation is to examine the match factor between dump trucks (6 units) and bulldozers (4 units) as shown in the Table 5 below.

Table 5. Revision of Match Factor of Dump Truck – Bulldozer

Heavy Equipment	MF Exca – DT	
	Cycle Time (Minutes)	Number of Unit
Dump Truck	11.75	6
Bulldozer	2.2	4
Loading Quantity	0.31 m^3	
Match Factor	1.11	
Idle Time	0 minute	
Additional Bulldozer	0 unit	

Once it is obtained the number of dump trucks required to be 6 units (Tables 4 and 5), then the owning and operating costs can be calculated. The owning costs can be seen in Table 6. For the cash scenario, the costs include insurance, service, and spare parts. For the leasing scenario, the costs include administration, insurance, service, and spare parts. However, these costs are not taken into account in the rental scenario.

Table 6. Owning Cost (Rp in Billions)

Heavy Equipment	Cash	Rent	Lease
Excavator	14,586	21,360	16,943
Bulldozer	18,393	19,500	21,366
Motor Grader	4,933	7,200	5,730
Vibro-Roller	6,000	11,400	6,970
Water Tank Truck	2,145	7,200	2,491
Total	46,059	66,660	53,503

The investment analysis period corresponds to the construction period, which is 5 years (September 2022 – August 2027). Therefore, depreciation is calculated over 5 years (with a spread of 4-12-12-12-12-8 months). As previously explained, depreciation is calculated using the Straight-Line Method, which assumes the same amount of heavy equipment depreciation each year.

For the cash scenario, the purchase is assumed to be made through a loan with 9% interest. Installment payments are based on the depreciation calculation. The depreciation and loan installment calculations for the cash scenario are shown in Table 7.

Table 7. Depreciation and Loan Installment (Rp)

Year	Depreciation/Loan Repayment	Outstanding Loan	Loan Installment
2022	3,070,567,500	42,987,945,000	0
2023	9,211,702,500	33,776,242,500	3,868,915,050
2024	9,211,702,500	24,564,540,000	3,039,861,825
2025	9,211,702,500	15,352,837,500	2,210,808,600
2026	9,211,702,500	6,141,135,000	1,381,755,375
2027	6,141,135,000	0	552,702,150

Next, the operating costs are calculated. It includes all costs incurred from operating the heavy equipment during construction, such as diesel fuel, operator salaries, insurance, and repairs. Operating costs is shown in the table below.

Table 8. Heavy Equipment Operating Cost (Billions Rp)

Year	Cost	Mobilization	Total
2022	6,112	0.400	6,512
2023	8,643	0	8,643
2024	9,716	0	9,716
2025	10,359	0	10,359
2026	11,149	0	11,149
2027	10,061	0	10,061
TOTAL	56,043	0.400	56,443

After the amount of owning and operating costs, as well as depreciation are obtained; subsequently the cashflow of each procurement scenario of cash, rent and lease can be analyzed. A single discounted cashflow of 10% was utilized to determine the value of an investment based on its future cash flows.

Apart from the discount rate, an inflation rate of 7% (the rental price increases by 7% annually) and an interest rate of 9% are utilized based on the rate set by the Indonesian central bank, Bank Indonesia. Furthermore, an interest rate of 14% is also applied for leasing scenario. From the cashflow analysis, the NPV, BCR, IRR, and PP parameters of each procurement scenario can be summarized as can be seen in Table 9.

Table 9. Summary of the Value of BCR, IRR, NPV and PP

Parameter	Scenario			
	Cash	Cash on Loan	Rent	Lease
BCR	1.12	1.02	0.96	1.05
IRR (%)	0.17	12.52	n.a.	8.84
NPV (Rp)	0.21 billion	1.21 billion	-4.24 billion	-0.55 billion
PP (year)	5	4	n.a.	n.a.
Conclusion	Viable	Most viable	Not viable	Less viable

From the Table 9, it is known that investment with a cash purchase scenario, whether with or without loans produces NPV > 0. On the other hand, rent and lease scenario NPV < 0, therefore they are considered not viable. As for the PP, cash purchase with and without loan scenario are viable to be executed. Further analysis on IRR, cash purchase with and without loan yield IRR > interest rate of 9%. Therefore, these two options are viable. Lastly, since an investment is said to be feasible if the BCR value is > 1, only rent scenario that is not fulfill the requirement. Thus, it can be concluded that the best option for the project to procure the heavy equipment is by purchase it cash with loan. in to Therefore, the cash purchase and leasing scenario are worth to continue.

Based on the analysis of the 4 procurement methods above, the scenario to buy new heavy equipment with loan is the most feasible investment option to execute. Therefore, the sensitivity analysis was carried out on this scenario. As can be seen in Table 10, the IRR value plummeted as interest rates rise. A 9% interest rate is the highest viable rate. Anything above 9% is no longer viable. For this reason, it is crucial observing the impact of interest rate increases on investment during the production period.

Table 10. Sensitivity Analysis to IRR for Cash Scenario

Interest Rate (%)	IRR (%)	Conclusion
6	59.90	Viable
7	41.64	Viable
8	25.70	Viable
9	**12.52**	**Viable**
10	1.93	Viable
11	n.a.	Not viable
12	n.a.	Not viable

IV. Conclusions

According to calculations, the production capacity of each piece of heavy equipment used is 47.26 m3/hour for excavators; 91.64 m3/hour for bulldozers; 82.72 m3/hour for dump trucks; 90 m3/hour for vibrator rollers; and 87.72 m3/hour for water tank trucks. Based on these calculations, to achieve a Match Factor (MF) close to 1, 6 dump trucks and 4 bulldozers are needed to service 8 excavators. For compaction, the vibrator capacity must match the capacity of 4 dozers.

The total cost of owning a machine with a cash purchase is Rp 46,058,512,500.00, while leasing costs Rp 53,502,812,500.00 and renting costs Rp 66,660,000,060.00. The operating costs are IDR 56,443,500,000.00 for a five-year construction period. The conclusions from the cash flow analysis are as follows:

It can be concluded that the cash heavy equipment purchase scheme is the most feasible. However, a sensitivity analysis to interest rate increases indicates that this scheme is feasible up to a maximum interest rate of 10%.

Acknowledgment

The authors gratefully acknowledge the contributions of P.T. Adhi Karya Persero in providing access to data for this research.

References

[1] C.S. Park and G.P. Sharp-Bette, Advance Engineering Economics – 2nd eds., New York, John Wiley & Sons, 2121.

[2] R. L. Peurifoy, C. J. Schexnayder, R. Schmitt, and A. Shapira, "Construction Planning, Equipment, and Methods – 9th Edition". New York, McGraw-Hill, 2018.

[3] G. Padmanaban and P.K. Anjani P.K, "Analysis of Renting Versus Buying Construction Heavy Equipment", *Proceedings of the 3rd International Conference on Optimization Techniques in the*

Field of Engineering (ICOFE-2024), 15 November 2024.

[4] A.A.A, "Hammad, Economic Analysis of Construction Equipment in Public Projects in Jordan, *International Journal of Membrane Science and Technology*, vol. 10, no. 1, p. 1054-1062, 2023.

[5] S.W. Nunally, "Managing Construction Equipment, Pearson, New Jersey, 1997.

[6] F.S. Hanafi, K.L. Mandagie and H. Moektiwibowo, "Analisis Kelayakan Investasi Alat Berat dengan Metode NPV, IRR dan Net B/C di Perusahaan PLWJ", *Jurnal Teknik Industri*, vol. 9, no. 2, p. 136-148, 2020.

[7] M.F.A. Arifin, "Cost Analysis for Heavy Equipment in Earthfill Work – an Optimization of Heavy Equipment Fleet (Case Study: Jabung Ring Dike Project)", *Engineering International Conference (EIC) 2016*, *AIP Conference Procedeengs 1818*, AIP Publishing, 2016.

[8] S.S. Riskijah, B.A. Pradipta & D. Lidyaningtyas, "Optimization of Heavy Equipment for Earthwork in the Construction of Mainroad Section X of Pandaan-Malang Toll Road", *IOP Conf. Series: Materials Science and Engineering* 1073, 2021.

[9] H. Kundrad SR, M. Simatupang and S. Sudarsono, "Evaluasi Produktivitas dan Optimasi Penggunaan Peralatan Peralatan Mekanis pada Pekerjaan Cut and Fill", *Jurnal Manajemen Rekayasa (Journal of Engineering Management)*, vol. 3 no. 2, 2021.

[10] Kementerian Pekerjaan Umum, "Katalog Alat Berat Tahun 2013", Jakarta, Pusat Pembinaan Sumber Daya Investasi Badan Pembinaan Konstruksi, 2013.