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# Analysis of Productivity and Costs of Heavy Equipment in Road & Drainage Work on The Marvel - 3 Unilever Oleochemical Indonesia Project

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## *ABSTRACT*

*Heavy equipment productivity is a critical determinant of time and cost performance in road and drainage construction projects, particularly in industrial environments where operational restrictions may affect equipment efficiency. This study evaluates the productivity of heavy equipment used in road and drainage works at the Modern Cikande Industrial Estate, Banten, Indonesia, including excavators, dump trucks, motor graders, vibratory rollers, and foco trucks. The analysis combines field-measured cycle times, productivity calculations based on national standards, fleet balance analysis, and operating cost estimation. The results show that excavators, motor graders, vibratory rollers, and foco trucks achieved productivity levels close to or exceeding standard benchmarks, while dump truck productivity declined significantly due to speed restrictions imposed for safety reasons within the industrial area. The analysis identifies an optimal equipment configuration of one excavator and seven dump trucks, generating effective productivity of 27.23 m³/hour with an operating cost of IDR 3,265,205 per hour. The novelty of this study lies in its context-specific decision-support framework that integrates field productivity, safety constraints, equipment balance, and operational cost under restricted industrial operating conditions. The findings contribute practical guidance for contractors and project managers in improving fleet allocation and cost efficiency while maintaining compliance with industrial safety regulations.*
***Keywords:*** *heavy equipment productivity; fleet balancing; industrial construction; equipment management; operational efficiency; drainage construction.*

## ABSTRAK

Produktivitas alat berat merupakan faktor penentu yang krusial terhadap kinerja waktu dan biaya pada proyek konstruksi jalan dan drainase, khususnya di lingkungan industri yang memiliki pembatasan operasional yang dapat memengaruhi efisiensi alat. Penelitian ini mengevaluasi produktivitas alat berat yang digunakan pada pekerjaan jalan dan drainase di Kawasan Industri Modern Cikande, Banten, Indonesia, meliputi excavator, dump truck, motor grader, vibratory roller, dan foco truck. Analisis dilakukan dengan mengombinasikan pengukuran waktu siklus lapangan, perhitungan produktivitas berdasarkan standar nasional, analisis keseimbangan armada, serta estimasi biaya operasional. Hasil penelitian menunjukkan bahwa excavator, motor grader, vibratory roller, dan foco truck mencapai tingkat produktivitas yang mendekati atau melampaui standar acuan, sedangkan produktivitas dump truck mengalami penurunan signifikan akibat pembatasan kecepatan yang diterapkan untuk alasan keselamatan di kawasan industri. Analisis mengidentifikasi konfigurasi alat yang optimal, yaitu satu excavator dan tujuh dump truck, yang menghasilkan produktivitas efektif sebesar 27,23 m³/jam dengan biaya operasional sebesar Rp3.265.205 per jam. Kebaruan penelitian ini terletak pada kerangka pendukung keputusan yang spesifik terhadap konteks, yang mengintegrasikan produktivitas lapangan, kendala keselamatan, keseimbangan alat, dan biaya operasional dalam kondisi operasional industri yang terbatas. Temuan penelitian ini memberikan panduan praktis bagi kontraktor dan manajer proyek dalam meningkatkan alokasi armada dan efisiensi biaya, dengan tetap memenuhi ketentuan keselamatan di kawasan industri.
**Kata kunci:** produktivitas alat berat; keseimbangan armada; konstruksi industri; manajemen peralatan; efisiensi operasional; konstruksi drainase.

## 1. INTRODUCTION

Road and drainage infrastructure development is a fundamental element in supporting the operational sustainability of industrial areas, especially in factory areas with high traffic intensity of materials and heavy vehicles. Road infrastructure serves as the main logistics distribution route, while the drainage system plays a role in maintaining road structure stability and controlling surface water runoff. Therefore, the quality of road and drainage work implementation is a determining factor in ensuring operational efficiency and the sustainability of industrial facilities.

Road and drainage work in modern construction projects is generally carried out mechanically using heavy equipment. The use of heavy equipment aims to increase work productivity, speed up implementation time, and ensure the quality of work that is difficult to achieve manually (Janizar & Ardianto, 2023). However, the high cost of ownership and operation of heavy equipment requires effective and planned equipment management to ensure that its use is truly efficient and economical (Rochmanhadi, 1992).

The Marvel-3 project of PT Unilever Oleochemical Indonesia is a project to build a ±2.3 km access road and drainage system that serves as the main supporting infrastructure for factory activities. The construction work on this project includes earthworks, rigid pavement construction, and the installation of precast drainage, all of which are highly dependent on the performance of heavy equipment such as excavators, dump trucks, motor graders, vibratory rollers, and foco trucks. The high intensity of heavy equipment use makes productivity and operational costs important variables that must be analyzed comprehensively.

In field practice, the actual productivity of heavy equipment often does not fully comply with the standard values listed in national technical guidelines. These differences can be influenced by various factors, including field conditions, transport distances, operational management, and project safety policies. Previous studies have shown that an imbalance between loading and transport equipment can lead to high idle time and reduce the overall efficiency of the work system (Hasan Sarmada et al., 2022; Ma'ruf Nuzola, 2023).

In addition, work safety regulations in industrial areas, such as speed restrictions for dump trucks, have the potential to significantly reduce the productivity of transport equipment if not balanced with adjustments to the number of vehicles. The heavy equipment productivity standards listed in the Circular Letter of the Director General of Construction Number 68 of 2024 are often used as a reference for planning, but an evaluation based on actual field data is needed to ensure its suitability for specific project conditions.

Although heavy equipment productivity has been widely discussed in construction management studies, fewer studies have examined how industrial safety regulations alter the operational balance between loading and hauling equipment in road and drainage works. In industrial estates, productivity is not determined solely by machine capacity or haul distance, but also by site-specific constraints such as speed limitations, traffic control, and safety compliance. These conditions create a practical trade-off between operational efficiency and risk control, yet this issue is still underexplored in the literature. Therefore, a field-based analysis is needed to understand how productivity standards should be adjusted when actual site conditions differ from normative assumptions.

This study addresses that gap by developing an applied analytical framework that compares actual field productivity with national standards, evaluates fleet balance under restricted

operating speed, and estimates the cost implications of equipment allocation. The contribution of this research is not limited to reporting productivity values, but extends to showing how a practical equipment configuration can be derived for constrained industrial projects. In this way, the study offers a context-sensitive decision basis for contractors and project managers who must maintain output while complying with strict safety rules.

Based on these conditions, this study aims to analyze the productivity of each heavy equipment, determine the most optimal combination of equipment, and calculate the operational costs of heavy equipment in the road and drainage work of the Marvel-3 Project of PT Unilever Oleochemical Indonesia. The results of this study are expected to provide a realistic picture of the actual performance of heavy equipment in the field, serve as a basis for evaluating project management decision-making, and contribute as a scientific reference in the development of heavy equipment management studies in road and drainage construction projects.

## 2. METHODOLOGY

This research uses a quantitative descriptive approach aimed at analyzing productivity, heavy equipment combinations, and heavy equipment operational costs in road and drainage work. This approach was chosen because it is able to describe actual conditions in the field in a measurable manner through mathematical calculations based on heavy equipment mechanics theory and direct observation data (Rochmanhadi, 1992).

### Research Location and Object

The research was conducted at the Marvel-3 Project of PT Unilever Oleochemical Indonesia, located in the Sei Mangkei Special Economic Zone (KEK). The scope of the research focused on road and drainage work, including earthwork, base course, compaction, and precast drainage installation. This location was chosen because it has a high intensity of heavy equipment use and implements work safety regulations that affect equipment operational performance. The research objects were heavy equipment used in the implementation of the work, including excavators, dump trucks, motor graders, vibratory rollers, and foco trucks.


**Figure 1.** Map of the Sei Mangkei SEZ Location
Source: *Unilever Shop Drawing, 2025*

### Research Variables

Research variables are divided into independent and dependent variables. Independent variables include the type and capacity of heavy equipment, cycle time, work efficiency factors,

and field conditions such as transport distance and material characteristics. Dependent variables include the productivity value of heavy equipment per hour and the operational cost of heavy equipment per hour. The relationship between these variables is analyzed to assess the level of efficiency in the use of heavy equipment in the project under review.

**Data Collection Methods**

The data used in this study consists of primary and secondary data. Primary data was obtained through direct observation in the field by measuring the cycle time of heavy equipment using a stopwatch, observing the number of transport trips, and identifying operational and working environment conditions. Secondary data was obtained from project documents, including shop drawings, heavy equipment technical specifications, rental price lists or unit prices for equipment operation, and heavy equipment productivity standards as stated in the Circular Letter of the Director General of Construction No. 68 of 2024

**Data Analysis Method**

To improve the transparency of the analysis, the measured cycle times were interpreted as field-based operational observations rather than abstract theoretical values. The resulting productivity figures were used to identify the performance gap between actual conditions and the standard reference values, while the equipment combination analysis was conducted to minimize imbalance between loading and hauling capacity. Although the study adopts a deterministic descriptive approach, the interpretation of the results remains bounded by field conditions, operational discipline, transport restrictions, and the specific safety policy applied in the project area. This methodological choice is appropriate for a case-based construction study because it captures the operational reality that influences equipment performance on site.

Data analysis began with calculating the average cycle time of each heavy equipment based on field observations. These cycle time values were then used to calculate the production capacity of heavy equipment by referring to the heavy equipment productivity formula proposed by Rochmanhadi, (1992). Work efficiency factors were determined by considering field conditions and operational time management. Heavy equipment combination analysis was conducted by evaluating the balance between the productivity of loading and transport equipment to minimize waiting time and improve the effectiveness of the work system (Hasan Sarmada et al., 2022). Furthermore, operational cost analysis was carried out by calculating the cost of ownership and operational costs of heavy equipment per hour, which included fuel, lubricants, maintenance, and operator wages (Octavia et al., 2021).

The results of the actual productivity and cost calculations are then compared with national standard values to evaluate the efficiency level of heavy equipment use in the road and drainage projects reviewed. The research flow is systematically arranged, starting from data collection, data processing, productivity analysis, equipment combination analysis, to drawing conclusions.

## 3. RESULT AND DISCUSSIONS

This study was conducted at the Marvel-3 Fatty Alcohol Plant Project of PT Unilever Oleochemical Indonesia, located in the Sei Mangkei Special Economic Zone (KEK). The scope of work reviewed was the construction of a permanent road and drainage system with a road length of approximately 2.3 km, which serves as the main access for the factory's operational

activities. The project contract value was recorded at IDR 35,455,820,222, with PT Trima Anugerah Sejahtera as the contractor.

The construction work analyzed includes earthworks, base course, compaction, rigid pavement, and precast drainage installation. All of this work was carried out with the support of heavy equipment, namely excavators, dump trucks, motor graders, vibratory rollers, and foco trucks. The average distance between the material placement location and the work area is approximately 1 km, with relatively flat terrain but limited by project safety regulations, specifically a maximum vehicle speed limit of 10 km/hour

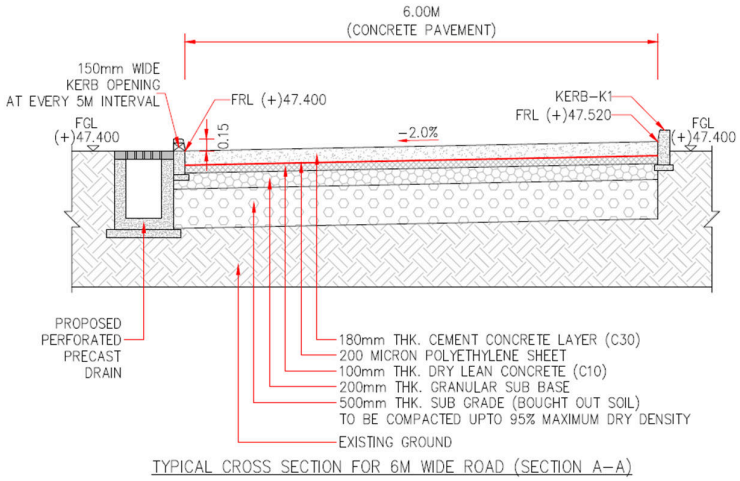


**Figure 2.** Typical Cross Section

Source: *Unilever Shop Drawing, 2025*

**Heavy Equipment Productivity**

The productivity analysis results show that the performance of heavy equipment in the road and drainage work of the Marvel-3 Project varies between types of equipment. Based on field observation data and cycle time calculations, the actual productivity of heavy equipment was 29.73 m³/hour for excavators, 3.89 m³/hour for dump trucks, 239.33 m³/hour for motor graders, 87.97 m³/hour for vibratory rollers, and 13.04 segments/hour for foco trucks

**Table 1.** Recapitulation of Heavy Equipment Productivity and Comparison

| **Equipment** | **Productivity ($m^3$/hour)** (Calculation Results) | **Productivity ($m^3$/hour)** (SE-DJBK-No-68-2024) |
|---|---|---|
| Excavator | 29.73 ($m^3$/hour) | 26.35 ($m^3$/hour) |
| Dump Truck | 3.89 ($m^3$/hour) | 8.79 ($m^3$/hour) |
| Motor Grader | 239.33 ($m^3$/hour) | 228.86 ($m^3$/hour) |
| Vibratory Roller | 87.97 ($m^3$/hour) | 72.21 ($m^3$/hour) |
| Foco Truck | 13.04 segments/hour | 12.77 segments/hour |

Source: *Research Data Analysis, 2025*

When compared to the heavy equipment productivity standards listed in the Circular Letter of the Director General of Construction No. 68 of 2024, most of the equipment showed relatively good performance. Excavators, motor graders, vibratory rollers, and foco trucks have actual productivity that is close to or exceeds the standard value. This indicates that the work

methods and operation of heavy equipment in this project have been carried out effectively (Rochmanhadi, 1992).

However, dump trucks experienced a significant decline in productivity, which was approximately 55.74% lower than the national standard value. This decline was mainly due to operational speed restrictions in industrial areas, which had a direct impact on increasing the transportation cycle time. This finding is in line with the research by Dian Febrianti and Zakia (2018), which states that vehicle speed and transport distance are dominant factors in determining the productivity of transport equipment.

**Heavy Equipment Combination Analysis**

The combination of loading and transport equipment is a determining factor in the efficiency of the work system.

$$\text{Dump Truck Requiremens} = \frac{\text{KP Excavator}}{\text{KP Dump Truck}}$$

$$= \frac{29{,}73\ \text{m}^3/\text{hour}}{3{,}89\ \text{m}^3/\text{hour}}$$

$$= 7{,}64\ \text{units} \approx 7\ \text{units}$$

Based on the analysis results, the most ideal combination of heavy equipment for this project is 1 excavator serving 7 dump trucks. This ratio is obtained from a comparison between the productivity of excavators and dump trucks so that a balance in production capacity can be achieved.

With this combination, the effective productivity of the excavator adjusts to the capacity of the transport equipment, which is

$$\text{Excavator Productivity} = \text{KP Dump Truck} \times \text{Number of Dump Truck}$$

$$= 3{,}89\ \text{m}^3/\text{hour} \times 7$$

$$= 27{,}23\ \text{m}^3/\text{hour}$$

This adjustment is necessary to avoid excessive waiting time for one of the machines, which can reduce the overall efficiency of the work system. These results support the statement by Hasan Sarmada et al. (2022) that the balance of heavy equipment combinations greatly affects productivity and the smooth running of projects.

**Heavy Equipment Operating Costs**

The operational cost analysis shows that each type of heavy equipment has different cost characteristics. The hourly operating costs for each piece of equipment are IDR 294,059/hour for excavators, IDR 430,878/hour for dump trucks, IDR 1,052,476/hour for motor graders, IDR 517,709/hour for vibratory rollers, and IDR 927,845/hour for foco trucks. These cost differences are influenced by the unit price of the equipment, fuel consumption, lubricants, as well as maintenance and labor costs.

Based on the ideal combination of heavy equipment, the total operational cost for one combination package (1 excavator and 7 dump trucks) is IDR 3,265,205/hour. Although the productivity of dump trucks has decreased due to speed restrictions, adjusting the number of fleets has proven to compensate for these limitations so that project operational costs remain at a controlled level. This finding aligns with the research findings of Octavia et al. (2021), which emphasize the importance of optimizing heavy equipment combinations in controlling construction project costs.

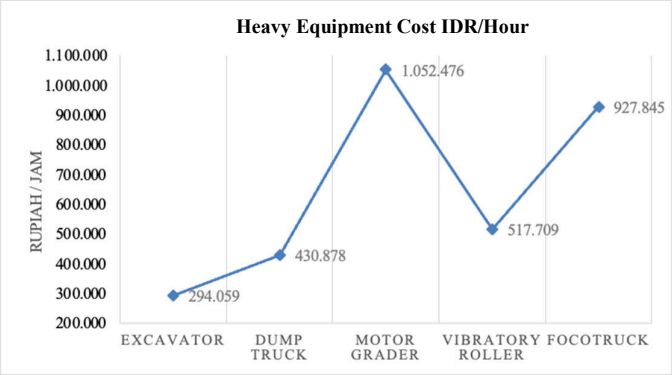


**Figure 3.** Summary of Heavy Equipment Costs
Source: *Research Data Processing, 2025*

The reduction in dump truck productivity should be interpreted as an operational consequence of safety governance rather than as a purely mechanical inefficiency. In industrial projects, traffic control and speed restrictions are necessary to reduce the risk of accidents, but these controls increase cycle time and reduce hauling output. This finding indicates that equipment productivity in industrial corridors cannot be evaluated using standard assumptions alone; it must be adjusted to reflect the actual operating environment. From a construction management perspective, this result highlights the importance of aligning logistics planning with safety policy so that risk mitigation does not produce avoidable idle time and cost escalation.

The 1:7 equipment ratio should therefore be understood as a practical dispatch configuration under the observed site conditions. Its significance is not only that it balances production capacity, but also that it reduces idle time caused by mismatched loading and hauling rates. In other words, the optimal ratio is a managerial response to the constrained transport environment of the project. This implies that equipment planning for industrial road and drainage works should be based on actual cycle performance and regulatory constraints, rather than on generic fleet assumptions. Such an approach can support more reliable scheduling, better fleet utilization, and more controlled project costs.

The calculated operating cost of the combined fleet indicates that productivity and cost must be evaluated as a single management problem. A fleet configuration that appears economical on a per-unit basis may become inefficient if the hauling cycle is distorted by speed limits or waiting time. Therefore, cost control in this project is achieved not by reducing the number of vehicles indiscriminately, but by adjusting the fleet composition to match the actual production rhythm of the site. This finding reinforces the view that equipment cost efficiency depends on synchronization among machines, site logistics, and safety requirements.

## 4. CONCLUSION

This study demonstrates that heavy equipment performance in road and drainage works is strongly shaped by site-specific operational constraints. The actual productivity of excavators, motor graders, vibratory rollers, and foco trucks was close to or higher than the national benchmark, whereas dump truck productivity decreased significantly due to speed restrictions in the industrial area. The most effective fleet configuration under these conditions was 1 excavator serving 7 dump trucks, which produced a balanced work system with an effective productivity of 27.23 $m^3$/hour and an operational cost of IDR 3,265,205/hour. Beyond confirming the influence of restricted logistics on productivity, this study contributes a practical decision framework for adjusting fleet composition in industrial construction projects. The main limitation of the study is that it is based on one project case; therefore, future research should test the same framework using scenario analysis, sensitivity analysis, or simulation across different haul distances, speed limits, and site conditions.

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