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# ANALYSIS OF HEAVY EQUIPMENT PRODUCTIVITY IN ASPHALT PAVING WORK ON THE WANARAYA ROAD RECONSTRUCTION PROJECT

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## ABSTRACT

*The reconstruction of Wanaraya Road is very important for the people of Wanaraya especially the economic impact because most of the livelihood of its citizens is as farmers and citrus fruit gardeners. This study's objective is to examine the contrast of heavy equipment productivity and the duration of paving work calculated using the Minister of PUPR Regulation no.8 of 2023 with analysis based on realization in the field and analyzing influencing factors in paving work. The method used in the analysis of heavy equipment productivity is time study. Time study is a method of measuring the productivity of the workforce in the field by determining the standard time for a job*

*The findings from the examination of the heavy equipment theory productivity in paving work are asphalt plant facility (AMP) 262.5 tons/day, Truk pengangkut material by 274.65 tons/day, Asphalt Finisher amounting to 711.65 tons/day, Tandem Roller 317.8 tons/day, and pneumatic tire rollers of 392.4 tons/day. The value of heavy machinery in terms of productivity for paving work based on theory is 262.5 tons/day with a work duration of 5 (five) days. Meanwhile, according to the field's analysis, the value of productivity of all heavy equipment is 105.48 tons/day with a duration of paving work for 18 (eighteen) working days. The factors that affect the productivity of heavy equipment in this study are the availability of materials, the state of the heavy equipment used, as well as the weather.*

Keywords: *Productivity, Heavy Equipment, Work Duration, Paving, Factors Affecting*

## 1. INTRODUCTION

The Wanaraya Road Reconstruction Project in Wanaraya Subdistrict spans 2.6 kilometers with a contract value of IDR 13,524,717,160, funded by the South Kalimantan Provincial Government's APBD for the 2024 fiscal year. The project owner is the South Kalimantan Public Works and Public Housing Agency (Dinas PUPR). Hot asphalt mix, specifically HRS-Base (Hot Rolled Sheet-Base), is used for the paving work. Several large construction machines used in the asphalt work include the asphalt processing facility, material hauling trucks, asphalt finishers, tandem rollers, and pneumatic-tired rollers.

Large construction machinery refers to large-sized machines designed to facilitate construction activities such as loading, transporting, spreading, and other tasks. The use

of these machines must be done properly to understand their capabilities, types, limitations, and operational costs. However, in practice, construction projects are often delayed due to the low productivity of the machines used (William, 2022).

The productivity of large construction machines is typically defined as the calculation of the machine's work capacity measured in hours. Time study is one of the methods used in productivity analysis. It measures the amount of time required to complete a task by collecting data on the time taken to finish the work. This method is also implemented to measure the standard time of a task (Rahmanto, 2023).

## 2. THEORITICAL STUDY

### Definition of Heavy Equipment Productivity

Large construction machinery refers to equipment designed for use in carrying out construction activities in a simple, fast, and efficient manner (Rahmanto, 2023). Prima & Edwar (2022) state that production is the ratio between what has been achieved (output) and all the resources used (input). The working capacity of large construction machinery is defined as the productivity of the machinery.

### Heavy Equipment Cycle Time

In calculating the cycle time of large construction machinery for material handling, several time components need to be considered, including cycle time (Ts), loading time (T1), hauling time (T2), return time (T4), and dumping time (T3) (Aris. M, 2023).

### Working Capacity of Equipment

The working capacity of heavy machinery refers to the machine's ability to produce output per hour, expressed in volume units. This varies depending on the type of equipment used, the nature of the work, the duration of operations, and the efficiency of the equipment (Mayasari & Santi, 2023).

### Work Efficiency Factor

In the implementation of a project, the productivity of equipment per hour is calculated as the standard output of the equipment under ideal conditions, which is then adjusted with a certain efficiency factor (William et al., 2022).

Table 1: Equipment Efficiency Factor (Fa)

| OPERATIONAL CONDITIONS OF LARGE CONSTRUCTION MACHINERY | | Very Good | Good | Fair | Poor | Very Poor |
|---|---|---|---|---|---|---|
| MACHINE MAINTENANCE | **Very Good** | 0,83 | 0,78 | 0,72 | 0,63 | 0,52 |
| | **Good** | 0,81 | 0,75 | 0,69 | 0,61 | 0,50 |
| | **Fair** | 0,76 | 0,71 | 0,65 | 0,57 | 0,47 |
| | **Poor** | 0,70 | 0,65 | 0,60 | 0,52 | 0,42 |
| | **Very Poor** | 0,63 | 0,60 | 0,54 | 0,45 | 0,32 |

**Time Study Method**

Time study, also known as time measurement, is a method used to assess employee productivity on-site by determining how long it takes them to complete a specific task. The primary goal of time study is to determine how long an employee takes to complete a particular task, which then allows for the calculation of their productivity (Natalia et al., 2020).

**Task Duration and Working Time of Heavy Construction Machinery**

Ngono (2014) explains that determining task duration is the process of estimating how much time is needed to complete a job using the available resources. Meanwhile, the working time of equipment refers to the duration required for heavy construction machinery to achieve the necessary amount of work per hour to complete a project.

## 3. METHOD

**Research Location**

The object of this research is the Asphalt Mixing Plant (AMP) of PT. Pandji Pratama Indonesia and the Wanaraya Road Reconstruction Project.

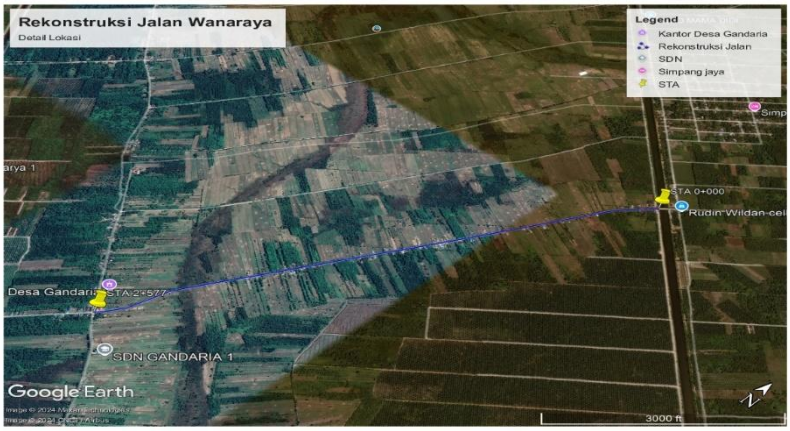


**Figure 1**. Project Location Map

**Research Procedure**

The first stage of this study involves collecting primary data, including equipment working hours, heavy construction machinery cycle time, daily material delivery quantity, and the condition of the heavy construction machinery. Then, secondary data will be gathered, which includes general project information, specifications of the heavy construction machinery, work drawings, and S-curves. Next, interviews will be conducted to determine the equipment efficiency factor, followed by calculating the cycle time of the heavy construction machinery to assess the productivity of each piece of equipment. Finally, task duration will be calculated to compare with the actual field results.

## 4. RESULT AND DISCUSSION

In this study, the volume of work for the Hot Rolled Sheet-Base (HRS-Base) foundation layer is 1,164.80 tons. The heavy construction machinery used in the asphalt paving work includes the asphalt processing facility, material hauling trucks, asphalt finishers, tandem rollers, and pneumatic-tired rollers. The effective working hours on-site are 7 hours.

**Data and Heavy Construction Machinery Cycle Time Calculations**

1) Asphalt Processing Facility

The Asphalt Mixing Plant (AMP) is located on Jl. Pengayuan, Gambut Subdistrict, 67 km from the project site. The asphalt processing facility has a pugmill capacity of 800 kg per batch. The specific gravity of HRS-Base is 2.26 tons/m$^3$.

2) Material Hauling Trucks

Material hauling trucks are used to transport hot mix from the asphalt processing facility to the project site in Wanaraya.

Table 2. Material Hauling Truck Cycle Time

| Cycle No. | Loading Time (minutes) | Travel Time with Load (minutes) | Waiting and Dumping Time (minutes) | Return Time Empty (minutes) | Cycle Time (minutes) |
|---|---|---|---|---|---|
| 1 | 12.5 | 100.5 | 10.4 | 67 | 190.4 |
| 2 | 12.5 | 100.5 | 9.9 | 67 | 189.9 |
| 3 | 12.5 | 100.5 | 11 | 67 | 191 |
| Average | 12.5 | 100.5 | 10.4 | 67 | 190.4 |

3) Asphalt Finisher

The asphalt finisher functions as a machine for spreading hot asphalt mixture.

Table 3. Asphalt Finisher Cycle Time

| Cycle No | Spreading Time (minutes) | Weight of HRS-Base Material (kg) | Spreading Length (meters) |
|---|---|---|---|
| 1 | 8.4 | 9.69 | 39.5 |
| 2 | 8.08 | 9.81 | 43 |
| 3 | 8.5 | 9.73 | 42.7 |
| Total | 24.98 | 29.23 | 125.2 |
| Average | 8.32 | 9.743 | 41.73 |

Average Speed of the Asphalt Finisher:

v = (Average spreading length) / (Average spreading time)

= (41.37 meters) / (8.32 minutes)

= 4.97 m/min ≈ 5 m/min

4) Tandem Roller

The tandem roller moves at a speed (v) of 3 km/h. Since the width of the compaction area (W) is 5 m, which exceeds the roller base width (b) of 1.45 m, the number of passes (N) must be calculated with an overlapping width of 0.15 m. The number of passes (n) for the tandem roller is 2 initial passes + 4 final passes, with the HRS-Base compaction thickness (t) of 0.04 m.

5) Pneumatic-Tired Roller

This equipment moves at a speed (v) of 4 km/h. Since the width of the compaction area (W) is 5 m, which exceeds the total roller base width (b) of 2.27 m, the number of

passes (N) must be calculated with an overlapping width of 0.15 m. The number of passes (n) for the pneumatic-tired roller is 10 passes.

**Productivity of Large Construction Machines Based on Theory**

1) Productivity of Asphalt Processing Plant

AMP Capacity (v) = 50 tons/hour

Efficiency Factor (Fa) = 0.75

Working Hours = 7 hours

Q = V x Fa = 50 tons/hour x 0.75 = 37.5 tons/hour

Q per day = 37.5 tons/hour x 7 hours/day = 262.5 tons/day

Number of asphalt processing plant units: 1 unit

Working duration of the asphalt processing plant: 7 hours/day

$$\frac{Realized\ work\ volume}{PDaily\ productivity\ of\ the\ asphalt\ mixing\ plant}$$

$$\frac{1.160{,}04\ \text{ton}}{262{,}5\ ton/day}$$

= 4,42 ≈ 5 day

2) Productivity of Material Transport Truck

The production capacity of the material transport truck can be calculated using the equation:

Q Material Transport Truck = (v × Fa × 60) / Ts

Truck capacity (v) = 10 tons

Efficiency factor (Fa) = 0.83

Cycle time (Ts) = 190.4 minutes

Q Material Transport Truck = (10 tons × 0.83 × 60 minutes/hour) / 190.4 minutes = 2.62 tons/hour

Daily Productivity:

Q Material Transport Truck per day = 2.62 tons/hour × 7 hours/day = 18.31 tons/day

Number of Trucks Required:

= (Daily productivity of asphalt mixing plant) / (Daily productivity of dump trucks)

= (262.5 tons/day) / (18.31 tons/day)

= 14.336 ≈ 15 units

Work Duration of Material Transport Trucks:

= (Realized work volume) / (Daily productivity of dump trucks)

= (1,160.04 tons) / (274.65 tons/day)

= 4.223 ≈ 5 days

3) Productivity of Asphalt Finisher

The production capacity of the asphalt finisher can be calculated using the equation:

Q Asphalt Finisher = V × b × 60 × Fa × t × D

- Spreading speed (V) = 5 m/min
- Instrument efficiency factor (Fa) = 0.75
- Spreading thickness (t) = 0.04 m
- Spreading width (b) = 5 m
- HRS-Base density (D) = 2.26 tons/m³

Q Asphalt Finisher = 5 m/min × 5 m × 60 × 0.75 × 0.04 m × 2.26 tons/m³

= 101.7 tons/hour

Daily Productivity:

Q Asphalt Finisher per day = 101.7 tons/hour × 7 hours/day = 711.9 tons/day

Work Duration:

= (Realized work volume) / (Daily productivity of asphalt finisher)

= (1,160.04 tons) / (711.9 tons/day)

= 1.63 ≈ 2 days

Number of Units Required:

= (Daily productivity of asphalt mixing plant) / (Daily productivity of asphalt finisher)

= (262.5 tons/day) / (711.9 tons/day)

= 0.369 ≈ 1 unit

4) Productivity of Tandem Roller

The hourly production capacity of the tandem roller can be calculated using the equation:

Q = ({N(b - bo) + bo} × v × 1000) × fa × t / (N × n)

- Width of compacted area (N) = 3.85
- Roller base width (b) = 1.45 m
- Overlapping width (bo) = 0.15 m

- Speed (v) = 3 km/hour
- Efficiency factor (fa) = 0.75
- Compaction thickness (t) = 0.04 m
- Number of passes (n) = 6

Q = ({3.85(1.45 - 0.15) + 0.15} × 3 km/hour × 1000) × 0.75 × 0.04 / (3.85 × 6)

= 20.085 $m^3$/hour

To convert to tons/hour, multiply by the HRS-Base density:

Q Tandem Roller = Q × D HRS-Base

= 20.085 $m^3$/hour × 2.26 tons/$m^3$

= 45.40 tons/hour

Daily Productivity:

Q Tandem Roller per day = 45.40 tons/hour × 7 hours/day = 317.8 tons/day

Work Duration:

= (Realized work volume) / (Daily productivity of tandem roller)

= (1,160.04 tons) / (317.8 tons/day)

= 3.65 ≈ 4 days

Number of Units Required:

= (Daily productivity of asphalt mixing plant) / (Daily productivity of tandem roller)

= (262.5 tons/day) / (317.8 tons/day)

= 0.826 ≈ 1 unit

5) Productivity of Pneumatic-Tired Rollers

The hourly production capacity of pneumatic-tired rollers can be calculated using the equation:

Q = ({N(b - bo) + bo} × v × 1000) × fa × t / (N × n)

- Width of compacted area (N) = 2.36
- Roller base width (b) = 2.27 m
- Overlapping width (bo) = 0.15 m
- Speed (v) = 4 km/hour
- Efficiency factor (fa) = 0.71
- Compaction thickness (t) = 0.04 m
- Number of passes (n) = 10

Q = ({2.36(2.27 - 0.15) + 0.15} × 4 km/hour × 1000) × 0.71 × 0.04 / (2.36 × 10)

= 24.805 m³/hour

To convert to tons/hour, multiply by the HRS-Base density:

Q Pneumatic Tire Rollers = Q × D HRS-Base

= 24.805 m³/hour × 2.26 tons/m³

= 56.06 tons/hour

Daily Productivity:

Q Pneumatic Tire Rollers per day = 56.06 tons/hour × 7 hours/day = 392.4 tons/day

Work Duration:

= (Realized work volume) / (Daily productivity of pneumatic tire rollers)

= (1,160.04 tons) / (392.4 tons/day)

= 2.96 ≈ 3 days

Number of Units Required:

= (Daily productivity of asphalt mixing plant) / (Daily productivity of pneumatic tire rollers)

= (262.5 tons/day) / (392.4 tons/day)

= 0.669 ≈ 1 unit

**Productivity of Heavy Equipment Based on Field Realization**

The average amount of HRS-Base material per day is 105.48 tons, which means the productivity of the work or the productivity of heavy equipment (asphalt processing facilities, material transport trucks, asphalt finishers, tandem rollers, and pneumatic tire rollers) is also 105.48 tons. Meanwhile, the actual work duration on-site, from the start of the asphalt work on July 22, 2024, until the completion of the asphalt work on August 9, 2024, excluding holidays, is a total of 18 working days.

## 5. CONCLUSION

Based on the research results, the analysis of the heavy equipment productivity theory for the asphalt work is as follows: asphalt processing facility (AMP) has a productivity of 262.5 tons/day, material transport trucks have a productivity of 274.65 tons/day with 15 trucks, the asphalt finisher has a productivity of 711.65 tons/day, the tandem roller has a productivity of 317.8 tons/day, and the pneumatic tire rollers have a productivity of 392.4 tons/day. The productivity value of the heavy equipment for the asphalt work based

on the theory is 262.5 tons/day with a work duration of 5 (five) days. Meanwhile, based on the field analysis, the productivity value of all heavy equipment is 105.48 tons/day with a total asphalt work duration of 18 (eighteen) working days. The production is influenced by several variables in this study, including material availability, the condition of the heavy equipment used, and the weather.

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