Cold milling machine productivity analysis for determining operator efficiency values in road maintenance projects

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Abstract. In construction work uses various types of heavy equipment to make road construction and maintenance, one of which is Cold Milling Machine. The use of cold milling machine is influenced by the operator efficiency factor in its operation and will have an impact on the productivity of the machine. The purpose of this study was to determine the productivity ratio between old and new operators and the number of efficiency factors for cold milling machine operators. The variable reviewed is the result of excavation from the cold milling machine operated by the operator. The research method used is direct observation in the field then the data is processed using t-test analysis. The results of this study are there are differences in skills between operator A and operator B based on the results of the t value (2.846> 1.812) greater than t table. The result of the calculation of the efficiency factor of cold milling machine operators is that by using a comparison of theoretical and actual productivity, it gets a very good category with a value of 0.84 for old operators and for new operators obtains a value of 0.48 which is categorized as less.

1. Introduction
Maintenance of damaged roads at this time is not a problem because with the development of construction technology there is a heavy equipment called the Cold Milling Machine. This Cold Milling Machine is used for stripping the old asphalt surface to be repaired into small pieces [1]. Factors affecting machine productivity are the ability of the mechanical operator to run the Cold Milling Machine. The ability of the operator in operating the machine is needed so that the tool can operate optimally [2]. Operator expertise and skills can be obtained from education and skills. The ability of the operator can be obtained by looking at the operator efficiency factor. Because the efficiency factor is one of the factors that can affect the machine in addition to machine capacity and cycle time [3]. The conditions that exist in toll road maintenance projects, the operators who operate cold milling equipment consist of unskilled operators who have little work time and skilled operators with years of service, these unskilled operators replace the previous operators due to resignation, so that only know how to operate which is obtained from the instructions of skilled operators so that his knowledge is limited. Therefore, the importance of determining the work productivity factor of cold milling machine operators on road maintenance projects is to determine the factors that can increase operator efficiency in operating cold milling machine tools.
1.1 Literature review

1.1.1 Productivity. Productivity is the amount of output (output) of a particular volume of work produced by time unity [4]. Productivity is defined as the ratio between output and input or the ratio between production output with the total resources used, resources including labor, materials, methods, and tools [5].

1.1.2 Operator Heavy equipment operator is a job that requires special skills to run a variety of tools such as Cold Milling Machines, mastery of these tools is highly needed by highly skilled professionals in their fields, mastery of heavy equipment, knowledge, and operator attitudes about equipment will affect other aspects [6].

1.1.3 The Important Role of a Heavy Equipment Operator Productivity is defined as the ratio between output and input or the ratio between production output and the total resources used [7]. Resources include labor, materials, money, methods and tools. Productivity is the ability of the tool in units of time (m³/hr) that depends on the capacity, tool cycle time, and tool efficiency [8]. Operators who operate heavy equipment must be capable or competent (preferably certified) through rigorous selection. We recommend that each device and operator remain, do not change operators too often without sufficient reason [9].

1.1.4 Efficiency Factor Factors that affect work productivity, it is very difficult to determine the amount of work efficiency at the operator, but with the training gained and the experiences gained by the operator. In order to obtain a value that is close to reality on the ground, a correction factor must be included that is suitable for working conditions.

| Table 1. Operator Efficiency |
|-----------------------------|
| **Skills**                 | **Efficiency** |
| Very good                  | 0,90 – 1,00   |
| Well                       | 0,83          |
| Less                       | 0,5 – 0,60    |

1.1.5 Cold Milling Machine Cold Milling Machine is a heavy equipment used in road maintenance projects with asphalt concrete or rigid pavement construction which functions to damage asphalt pavement layers (surface course and binder course) with a certain depth and width so that flat surfaces are obtained (level) [10]. The specifications of a Cold Milling Machine are determined by the width, depth of cutting capability, and cutting speed. Cold Milling Machine per hour production capacity is:

\[ Q = v \times b \times t \times 60 \text{ m}^3 \quad (1) \]

Explanation:
b = excavation / demolition width capacity (m)
t = thickness of excavation / demolition (m)
v = disassembly rate (m / min)
Fa = work efficiency factor
60 = hour to minute conversion

Cold Milling Machine is one type of working tool used to peel the asphalt pavement layer. This tool is very helpful for time and cost efficiency. Cold milling movement in the direction of traffic and scrapping results are directly loaded into the dump truck, at this stage of the work the data is collected once every 1 hour by measuring the results of cold milling excavation.
2. Methodology
This research uses a comparative quantitative approach by conducting literature studies, surveys and observations in the field to obtain productivity data. Each operator, observations were made on 2 lanes namely the Surabaya-Gempol toll road, from the samples obtained were categorized as correlated samples so that the test used a t-test and to determine the value of the operator efficiency factor using a comparison of theoretical productivity with actual productivity. There are two data needed, namely primary and secondary data. Primary data consists of excavated volume data, observation data and direct interviews with operators. Whereas secondary data consists of shop drawing, device specifications, and operator profiles.

3. Result and Discussion
Road Conditions

\[ K \,(\%) = \frac{P_k \times L_k}{P_r \times L_r} \times 100 = 15.83\% \]

- \( P_r \): Length of section (m)
- \( L_r \): Section width (m)
- \( P_k \): Damage length (m)
- \( L_k \): Damage width (m)

Cold Milling Machine Operator

| Table 2. Operator Profiles |
|---------------------------|
| **Operator A** | **Operator B** |
| Age | 37 | 21 |
| Gender | Male | Male |
| Education | Vocational High School | Vocational High School |
| Years of service | 12 | 0 |
Operator Productivity A and Operator B

Table 3. Operator Productivity A and Operator B

| Numb | Operator A | Operator B |
|------|------------|------------|
| 1    | 40,71      | 14,8       |
| 2    | 56,06      | 12,85      |
| 3    | 55,97      | 27,83      |
| 4    | 53,73      | 47,55      |
| 5    | 69,12      | 29,61      |
| 6    | 51,64      | 56,73      |

Sample Calculation, Standard Deviation and Variants

Table 4. Sample Calculation Results, Standard Deviation and Variants

|                  | Operator A | Operator B |
|------------------|------------|------------|
| Sample           | 6          | 6          |
| Average          | 54,54      | 31,56      |
| Standard Deviation | 9,14    | 17,54      |
| Variant          | 83,45      | 307,58     |

The hypothesis to be tested is based on the same n. But the second variant of the homogeneity of the sample or not, then the variance homogeneity needs to be tested first with the F test.

\[ F = \frac{\text{The biggest variant}}{\text{The smallest variant}} = 3,686 \]  

(2)

Because \( n_1 = n_2 \), the t-test can use the separated variant or polled variant formula.

\[ t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}} = 2,846 \]

Theoretical Productivity

\[ \frac{\text{tonase}}{\text{specific gravity}} = \frac{150}{2.3} = 65,22 m^3/day \]  

(3)

Based on field conditions that work at night and cold milling equipment that only operates for 4 hours, the planned production value of 65.22 m³ / day is divided by operating the equipment for 4 hours. with the result productivity of 16.304 m³ / hour.

Operator Efficiency Value

\[ Q = \nu \times b \times F_a \times t \times 60 \text{ m}^3 = 0.697 \]

In determining the efficiency value of the operators, the actual productivity of each operator is divided by terrorist productivity as shown in table 5.
Table 5. Operator Efficiency Values A and B

| Day | Operator A | Operator B |
|-----|------------|------------|
| 1   | 0.624      | 0.227      |
| 2   | 0.860      | 0.197      |
| 3   | 0.858      | 0.427      |
| 4   | 0.824      | 0.729      |
| 5   | 1.060      | 0.454      |
| 6   | 0.792      | 0.855      |
| Average | 0.836 | 0.481 |

4. Conclusions
The conclusions obtained from this study are:
1. There are significant differences in productivity of cold milling operators between operators who have skills based on years of service.
2. The productivity of cold milling equipment operated by the operator is used as a benchmark in finding the value of the operator efficiency factor using a method by comparing the theoretical productivity with the actual productivity of the two cold milling machine operators. Operator efficiency factor for cold milling machine is very good = 0.9-1, good = 0.8 and less = 0.5-0.6 results that have been obtained from the analysis conducted, the operators who have skills based on work period have a value of 0.84 in. in the very good category while operators who do not have skills based on years of service score 0.48 in the poor category.
3. The performance of the two operators in this study after the analysis was not included in the category very well. Therefore, operators should be disciplined, improve work ethic and the company provides motivational support that will help in increasing operator productivity.

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