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Analysis of The Relationship of Shipment Time and Productivity of Drilling Equipment and Transportation, Java Province

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Abstract

PT. Agung Satriya Abadi is engaged in mining sand and stone which is formed by weathering deposits, located in Wonosunyo village, Gempol District, Pasuruan Regency, East Java. Companies that run in this category of rock mining generally have quite complex problems, one of which is in terms of time management which is considered less attention by some rock mining companies. In this study, several analyzes will be carried out and run the scientific method. The analysis carried out in this study uses statistical methods by displaying mathematical modeling and analysis of the relationship between circulation time and productivity in linear regression analysis. The data values that arise from the use of this mathematical-statistical method are the value (R^2) = 0.8597 or 85% of the Doosan Giant Dx 520 Lca, then the value (R^2) = 0.8459 or 84% of the Doosan Giant 300 Class, then Hino Ranger 500 Fm 260 Ti paired with Doosan Giant Dx 520 Lca has a value of (R^2) = 0.9868 or 98%. And lastly, the Hino Ranger 500 Fm 260 Ti paired with the Doosan Giant 300 Class has a value of (R^2) = 0.9886 or 98%.The data generated from each distribution time and productivity relationship from Doosan Giant Dx 520 Lca generates a difference value = 13,031 m^3/hour, Doosan Giant 300 Class gives a difference value = 31.347 m^3/hour, Hino Ranger 500 Fm 260 Ti against Doosan Giant Dx 520 Lca raises the difference value = 1,659 m^3/hour, Hino Ranger 500 Fm 260 Ti against Doosan Giant 300 Class raises the difference value = 1,492 m^3/hour.

1. Introduction

Mining is one of the important elements in Indonesia's economic growth. One of the mining commodities in Indonesia is sand and stone. Sand and stone are mainly used as the main raw materials in development in Indonesia, especially infrastructure. One of the companies engaged in the mining of sand and stone commodities is PT. Agung Satriya Abadi, which is located in Wonosunyo village, Gempol district, Pasuruan regency, East Java.

In the process of mining commodity sand and stone at PT. Agung Satriya Abadi uses an open-pit mining system where this mining system is directly related to free air. In open-pit mining systems, mining production operations will use excavators for the mining process and dump trucks for transportation.

It has a direct impact and can be contaminated by free air, so there will be several problems in its production operations. The first problem is the weather factor, because it is on the earth's surface, when it rains, production operations will be directly affected by rainwater. The impact on the activities of the excavation process has emerged, one of which is about the excavation process carried out by the excavator itself, which is feared that there will be landslides on the slopes of the mine being excavated if the material is exposed to the effects of rainwater it will affect the cohesiveness of material and The adhesive power will be higher so that other materials will also be excavated in this process. The next impact that will be affected by this process is about the weight of the mined material, there will be an increase in the weight of the material from rainwater, another problem with dump trucks is almost the same as excavator digging tools, but will increase again, such as wear and tear by asphalt or the transport vehicle itself, besides that the rimpul factor can also affect the process of this obstacle. Furthermore, in the stage of the influencing factor, namely from the type of material with consideration of the hardness of the material, it is clear that it will greatly hinder the excavation process from the excavator, the longer this process will be, the potential for problems with delays in dump trucks waiting for the material loading process to arise. And this third obstacle factor is about the combination of digging and loading equipment with transportation equipment, the factors are starting from the number of units of the two which are not right or right then followed by the capacity between the two mechanical tools which are indeed less matched on both.

The above factors will directly affect the circulation time where this will affect the amount of productivity that can be achieved either by conveyance or by digging and loading equipment, the longer or the greater the value of the circulation time, the lower the amount of productivity that can be achieved. Based on this, it is necessary to analyze the relationship between circulation time and productivity of the digging and loading equipment. The analysis used is a mathematical model with a linear regression basis, the value of circulation time will be used as the dependent variable (x) and the value of productivity will be used as the value of the independent variable (y). the results of the study can show how much production value will be achieved from the digging and loading equipment for each change in the value of the circulation time based on the mathematical model obtained.

2. Methodology

This research method is taken from directly observed data and data that is already available from the company or other agencies. The data that has been obtained will later be processed in such a way by using a formula that is following the theory and will later be combined with field data to obtain analysis results and solutions to problems in the field. The stages of this research method include:

a. Study of Literature

A literature study was carried out to get an overview of the preparation and as complete data to make references in the data processing. Sources of data that will be processed will come from company data and data from library results both from campus and from outside such as the internet and libraries. The following is part of the literature used in this research, sourced from the manufacture of excavator and dump truck specifications, the RBI Map for the Pasuruan Regency area of 1: 25,000, the book "Pemindahan Tanah Mekanis" by Ir. Yanto Indonesianto, M. Sc.

b. Field Observation

Retrieval of the required data is carried out directly or indirectly and is obtained from the actual conditions at the mining site. So get accurate data to be used as a basic benchmark by researchers.

c. Data Collection

- Primary Data: Cycle time of excavator and Cycle time of dump truck, work cycle, mechanical equipment resistance, number of rainy days, topographic map, map of mining business permit (IUP).
- Secondary Data: Coordinates of mining business permits (IUP), rainfall data, excavator specification data, dump truck specification data.

d. Data Processing Stage

Data processing is carried out using several calculations and depictions, then presented in the form of tables, graphs, or a series of calculations after a certain process.

e. Conclusion

This stage is carried out to obtain a temporary conclusion, which will then be processed further towards the discussion section. The conclusion will be obtained after the correlation.

2.1 Method of Collecting Data

At the initial stage, namely conducting field observations regarding the types of tools, the number of tools used, and the obstacles to mining activities. Data collection activities were carried out in November-December 2020, the data collected became primary data and secondary data. Primary data taken include excavator cycle time and dump truck cycle time, work cycle, excavator and dump truck compatibility values, and digging and loading equipment needs and transportation equipment, as well as actual data on loading and unloading equipment and transportation equipment taken by direct observation. in field activities and by following the tools during mining operations. While the secondary data includes the coordinates of the mining business permit (IUP), rainfall data, excavator specification data, dump truck specification data.

2.2 Data Analysis Method

This stage of data analysis, it will be focused on linear regression research of any relationship between excavators and dump trucks. However, there are also supporting components as written in the primary data obtained during field observations. By performing a linear regression analysis, it will be known the magnitude of the effect generated from each mechanical device. The data that has been analyzed can be used by the company to improve the performance of each mechanical device that can be influenced by any inhibiting factors found in the field.

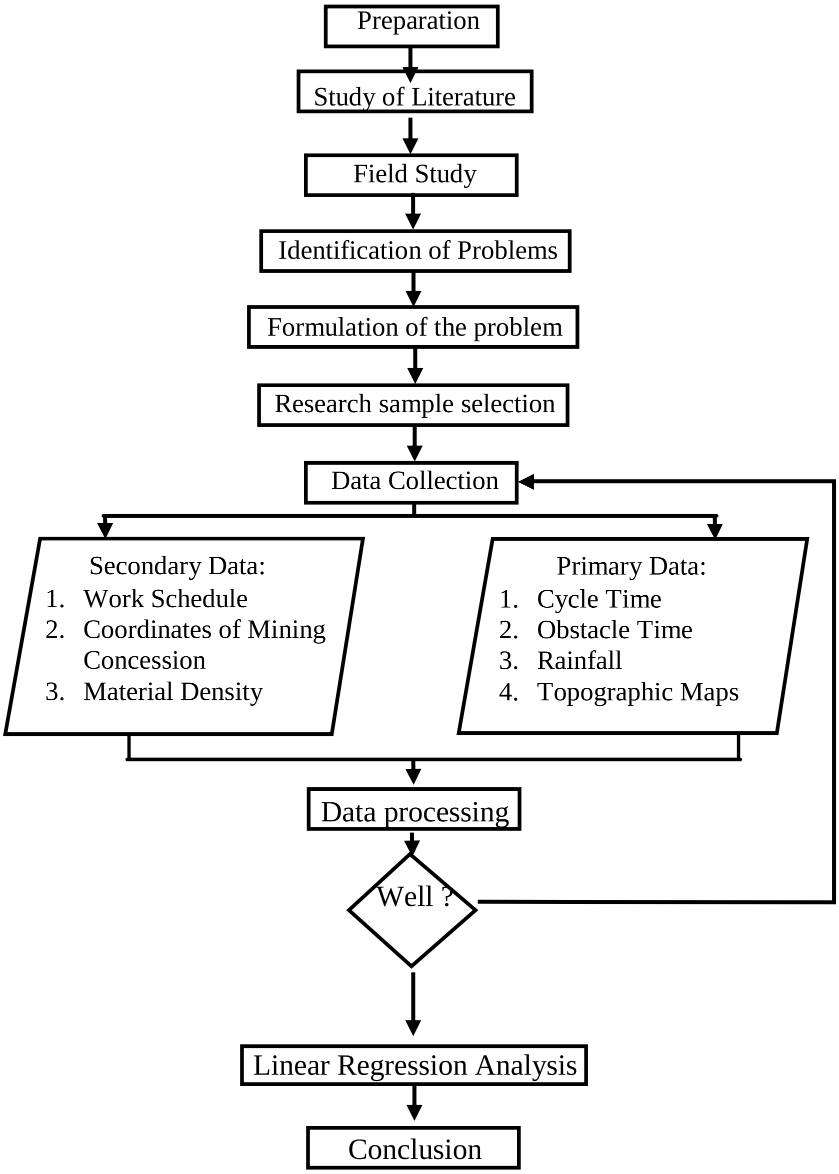

Figure 1. Research stages

2.3 Cycle Time

Is the time used by a mechanical device to perform one cycle of activities. The length of the cycle time of mechanical devices will differ from one material to another. This depends on the type of tool and the type and nature of the material being handled

a. Cycle Time Excavator

It is the sum of load digging time, charged swing time, load shedding time, and empty swing time. The formula for calculating the excavator cycle time is as follows:

$$CTM = A + B + C + D \tag{1}$$

Description:

CTm = Cycle time excavator
A = Digging
B = Swing Filled
C = Dumping
D = Empty Swing

b. Cycle Time Dump Truck

It is the sum of positioning time, loading time, hauling time, positioning time for shedding, shedding time, and empty return time to the mining site. The formula for calculating the dump truck cycle time is as follows:

$$CTa = A + B + C + D + E + F \tag{2}$$

Description:

CTa = Cycle time dump truck
A = Maneuver 1
B = Loading
C = Hauling
D = Maneuver 2
E = Dumping
F = Return Travel Time

2.4 Work Effectiveness

This is a factor that shows the condition of a mechanical device in the work by paying attention to every process in this mining, things that are usually considered include the time that is hindered by technical and non-technical obstacles, there are parameters of effectiveness in the use of these tools. mechanical, which includes:

a. Mechanical Availability

Is a factor that shows the willingness of the tool to do the job by taking into account the time lost due to machine repairs. The calculation formula is as follows:

$$MA = \frac{Working\ Hours}{(Working\ Hours + Repair\ Hours)}\ x\ 100\% \tag{3}$$

Description:

MA = Mechanical Availability
W = Working Hours
R = Repair Hours

b. Physical Availability

Is a record of the operational availability of the tools used or factors that indicate the willingness of a tool to do work by eliminating lost time due to various factors. The calculation formula is as follows:

$$PA = \frac{(Working\ Hours + Standby\ Hours)}{(Working\ Hours + Repair\ Hourse + Standby\ Hours)}\ x\ 100\% \tag{4}$$

Description:

PA= Phisical Availability
W = Working Hours

R = Repair Hours
S = The tool clock is not used and the tool is not damaged. (Stanby Hours)

c. Use Availability

A factor that shows the working efficiency of the tool during the available working time where the condition of the tool is not damaged. This is intended to find out how effectively the tool that is not damaged is used and a measure of how well the equipment is managed. a Low percentage indicates that the operation of the tool is not optimal. The calculation formula is as follows:

$$UA = \frac{Working\ Hours}{(Working\ Hours + Standby\ Hours)}\ x\ 100\% \quad (5)$$

Description:
W = Working Hours
S = The tool clock is not used and the tool is not damaged. (Stanby Hours)

d. Effective Utilization

Effective utilization shows what percentage of all available working time can be used for productive work. The calculation formula is as follows:

$$EU = \frac{Working\ Hours}{Working\ Hours + Stamdby\ Hours}\ x\ 100\% \quad (6)$$

Description:
EU = Effective Utilization
W = Working Hours
R = Repair Hours
S = The tool clock is not used and the tool is not damaged. (Stanby Hours)

2.5 Productivity of Excavator and Dump Truck

The amount of production can be achieved from several processes and the time difference can affect the theoretical data of target scheduling to the actual data with a correction factor consisting of fill factor, swell factor, and work efficiency.

a. Productivity of Excavator

Is the ability of a tool to do work in a certain period. The productivity of the digging and loading equipment will be expressed in the form of tonnage/unit of time, which later the value of this productivity will be used as data to determine the suitability of the match factor of both excavators and dump trucks. The following calculation formula for the digging tool can be seen in the worksheet below.

$$Qm = \frac{3600\ x\ Cm\ x\ F\ x\ sf\ x\ Eu}{Ct} \quad (7)$$

Description:
Qm = Productivity of Excavator (ton/hour)
Ct = Cycle time Excavator (second)
Cm = Bucket Capacity (m^3)
F = Fill Factor (%)
Eu = Effective Utilization (%)
Sf = Swell Factor

b. Productivity of Dump Truck

As with excavators, the productivity of the transportation equipment, namely dump trucks, is calculated from several data grouping results which are then processed to produce a value for the productivity of the tool itself. Productivity of transportation means expressed in tons/hour. The means of transportation can be said to be optimal when capacities of the digging and loading equipment work together without any obstacles, starting from a good loading time and so on. The following formula for calculating the means of transportation can be seen in the worksheet below.

$$Qa = \frac{3600 \ x \ Ca \ x \ sf \ x \ Eu}{Ct} \tag{8}$$

Description:
- Qa = Produktivitas alat angkut (ton/jam)
- Ct = Waktu edar alat angkut (detik)
- Ca = Kapasitas *vessel* (m^3)
- Eu = *Effective Utilization* (%)
- Sf = *Swell Factor* (%)

$$= \quad n \ x \ Cam \ x \ F \tag{9}$$

Description:
- n = number of filling bucket
- Cam = Bucket Capacity (m^3)
- F = Fill Factor (%)

2.6 Match Factor

To assess the compatibility of work, digging and loading equipment is used by using the match factor which is formulated as follows:

$$MF = \frac{nH \ x \ Lt}{nL \ x \ cH} x \ 100\% \tag{10}$$

Description:
- MF = Tool compatibility (match factor)
- nH = Number of conveyances
- Lt = Time required for loading equipment to fill the conveyance.
- nL = Number of loading tools
- cH = Circular time of transportation means outside the waiting time

The method of evaluating the parameters is as follows;

a. MF < 1, it means that the loading equipment is working less than 100%, while the transportation equipment is working 100% so that there is a waiting time for the loading equipment because it is waiting for the transportation equipment that has not arrived.

b. MF = 1, which means that the loading and hauling equipment works 100% so that there is no waiting time for the two types of equipment.

c. MF > 1, meaning that the loading equipment works 100%, while the transportation equipment works less than 100%, so there is a waiting time for the conveyance.

2.7 Linear Regression Method

In determining the form of a mathematical model to determine the level of fuel consumption, the influencing factors consist of cycle time (Ct) and productivity (Pr).

a. Mathematical Model

A way to study the relationship between cycle time (CT) is expressed as an independent variable (X) and productivity (PR) is expressed as a fixed variable (Y). Testing is done by trial and error or trial and error. The general form of the mathematical model is expressed in the form of a linear equation:

$$Y = ax + b \tag{11}$$

$$Pr = a \ ct + b \tag{12}$$

Description:
- Y = Dependent Variable (productivity = Pr)
- X = Independent Variable (cycle time = Ct)

a and b = Regression Constant

b. Linear Regression Analysis

To determine the values of the constants a and b the equation is through the application of linear regression by changing:

$$\Sigma Y = a\Sigma X + bn$$

$$\Sigma XY = a\Sigma X^2 + b\Sigma X$$

Based on the equation, the values for constants a and b will be obtained as follows:

$$a = \frac{(\sum Y)(\sum X) - n\sum XY}{(\sum X)^2 - n\sum X^2} \quad (13)$$

And

$$b = \frac{(\sum Y)(\sum (X)^2) - (\sum XY)(\sum X)}{n\sum X^2 - (\sum X)^2} \quad (14)$$

Description:
n = Amount of Data

c. Statistic Test

To determine the level of validity of the relationship between the dependent variable (variable Y) and the independent variable (variable X), a statistical test is needed which includes the correlation coefficient (R), the coefficient of determination (F), the standard deviation (SD) and the level of convergence (C). The forms of equations to determine these four variables are as follows:

$$R = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}} \quad (15)$$

$$F = R^2 \quad (16)$$

$$SD = \left|\frac{Y - Y^2}{Y}\right| x\ 100\% \quad (17)$$

$$C = 100 - SD \quad (18)$$

The value of the correlation coefficient (R) can be expressed as follows:

- R = 0, meaning that the dependent variable and the independent variable have no relationship or have no correlation.
- R = 1, meaning that the dependent variable and the independent variable have a strong and direct relationship or a perfect positive correlation.
- 0 < R < 1, meaning that the dependent variable is positively correlated with the independent variable but is also influenced by other factors.
- R = -1, meaning that the dependent variable has a perfect and indirect strong relationship (perfect negative correlation).
- –1 < R < 0, meaning that the dependent variable is negatively correlated with the independent variable but is also influenced by other factors.

The value of the coefficient of determination (F) is the value of the extent to which the relationship between the dependent variable and the independent variable is. If the value of F = 0.90 means that 90% of the dependent variable is directly related to the independent variable, while the other 10% is influenced by other factors. Standard deviation is the magnitude of the deviation of the results of the mathematical model to the actual value. A mathematical model will have high validity if the SD value is very small. The standard deviation is a measure of the level of convergence (C).

3. Results

3.1 Research Result

The following are the results of research conducted by students located at PT. Agung Satriya Abadi, in the results of this study, students got some field data that would be used as a basic reference for research, obtained data in the form of cycle time data for excavation, loading and transportation equipment, company work schedule data, obstacle data, and tool productivity calculation data digging and loading and attached are also the results of the match factor or the compatibility of the digging, loading, and conveying equipment.

a. Cycle Time Excavator Doosan Giant Dx 520 Lca

To obtain the magnitude of the effect of the circulation time required for the digging tool, it is necessary to first pay attention to the factors and components that cause the production time to be affected. Making the circulation time owned, namely the Doosan Giant Dx 520 Lca unit which is arranged in seconds taken from the mean value or average value of each available data, described in the following table.

Table 1. Cycle Time Doosan Giant Dx 520 Lca

Number	*Digging (second)*	*Swing Filled (second)*	*Dumping (second)*	*Empty Swing (second)*
1	11,36	5,07	2,07	4,87
2	8,02	4,46	2,28	5,5
3	20,52	5,77	1,98	4,85
4	19,84	4,44	4,22	4,11
5	16,36	6,56	2,22	5,97
6	18,09	4,83	2,68	9
7	10,13	7,62	4,86	6,42
8	7,61	4,58	2,53	3,8
9	7,09	4,35	2,65	4,29
10	25,99	4,15	2,6	4,83
11	40	3,72	2,61	6,48
12	20,97	4,07	2,71	4,59
13	20,36	4,05	2,83	4,42
14	23,21	4,32	3,15	7,04
15	20,08	3,79	2,45	4,62
16	19,03	4,6	3,01	5,03
17	17,03	4,46	2,43	4,29
18	20,43	4,81	4,82	6,42
19	120,47	7,42	2,82	5,86
20	3,84	7,41	2,82	5,84
21	3,62	7,41	2,84	5,72
22	3,69	7,38	2,83	5,81
23	4,47	7,4	2,81	5,83
24	3,78	7,4	2,75	5,79
25	3,8	6,89	2,89	5,21
Total	17,4	5,95	2,85	5,69

If the values of A + B + C + D are added up, it can be concluded that the average cycle time of Doosan Giant Dx 520 Lca is 31.89 seconds/cycle time.

b. Cycle Time Excavator Doosan Giant 300 Class

To obtain the magnitude of the effect of the circulation time required for the digging tool, it is necessary to first pay attention to the factors and components that cause the production time to be affected. Making the circulation time owned, namely the Doosan Giant 300 Class unit which is arranged in seconds taken from the mean value or average value of each available data, described in the following table.

Table 2. Cycle Time Doosan Giant 300 Class

Number	*Digging (second)*	*Swing Filled (second)*	*Dumping (second)*	*Empty Swing (second)*
1	2,8	4,77	2,2	3,92
2	10,56	5,1	2,02	4,15
3	7,02	4,21	1,48	3,85
4	15,44	4,5	2,03	7,98
5	20,77	5,11	1,99	3,92
6	49,97	5,38	2,1	5,6
7	10,65	5,43	5,72	5,92
8	6,03	5,45	2,03	4,79
9	13,29	5,62	2,28	2,85
10	17,45	5,58	5,46	3,63
11	14,36	5,3	1,47	5,81
12	13,67	5,35	2,27	4,35
13	19,38	5,58	2,1	4,02
14	5,77	6,41	2	4,57
15	5,78	5,59	1,93	4,13
16	22,69	5,41	2,02	4,07
17	13,21	4,95	2,32	10,63
18	17,16	5,19	3,55	20,59
19	10,65	5,43	5,72	5,92
20	6,03	5,45	2,03	4,79
21	13,29	5,62	2,28	2,85
22	5,52	2,09	4,89	6,16
23	3,63	8,88	6,37	5,27
24	3,97	4,78	4,77	2,72
25	3,3	4,78	4,29	2,78
26	5,09	5,64	4,66	3,21
27	4,06	5,95	6,44	2,21
28	5,85	6,29	5,16	2,6
29	5,47	5,22	4,76	2,85
30	4,93	4,69	5,73	3,4
31	8,38	4,13	5,1	2,73
32	4,31	2,84	4,91	3,64
33	5,98	6,05	5,15	4,12
34	5,52	8,88	4,77	2,78
35	3,63	4,87	4,29	3,21
36	3,97	4,78	4,66	2,21
37	3,3	5,64	6,44	2,6
38	5,09	5,95	5,16	2,85
39	4,06	6,29	4,76	3,4
40	5,85	5,22	5,73	2,73
41	5,47	4,69	5,1	3,64
42	4,93	4,13	4,91	4,12
Total	10,66	5,76	4,1	4,9

(Source: Research Data, 2020)

If the values of A + B + C + D are added up, it can be concluded that the average cycle time of Doosan Giant 300 Class is 25,42 seconds/cycle time.

c. Cycle Time Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

The Hino Ranger 500 Fm 260 Ti type, along with the circulation time of the Doosan Giant Dx 520 Lca excavator, are arranged in minutes as described in the table below.

Table 3. Cycle Time Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

Number	*Manuver 1 (minute)*	*Loading (minute)*	*Hauling (minute)*	*Manuver 2 (minute)*	*Dumping (minute)*	*Return Time (minute)*
1	0,3	9,46	25,34	0,29	1,63	20,02
2	0,28	10,02	24,23	0,32	1,83	19,23
3	0,29	10,01	28,53	0,23	2,03	23,21
4	0,3	9,34	22,55	0,32	1,94	21,09
5	0,31	9,47	23,43	0,39	2,19	18,27
6	0,33	9,3	25,39	0,29	2,02	20,33

7	0,29	9,32	23,23	0,43	2,32	18,34
8	0,3	9,24	19,55	0,41	1,56	20,03
9	0,28	9,41	21,42	0,38	2,03	18,24
10	0,27	9,28	22,51	0,33	2,32	19,85
11	0,3	9,45	24,17	0,36	2	20,01
12	0,29	10,2	27,09	0,42	2,04	19,05
13	0,29	10,14	26,49	0,37	1,98	20,26
14	0,29	9,51	26,53	0,35	2,37	18,88
15	0,28	9,48	27,33	0,37	2,1	20,32
16	0,29	9,32	24,45	0,33	2,22	19,03
17	0,26	9,31	25,09	0,31	1,9	20,1
18	0,28	9,52	26,49	0,3	1,87	19,1
19	0,29	10,19	25,34	0,34	1,76	20,62
20	0,31	9,48	27,06	0,32	1,83	21,04
21	0,29	9,6	28,49	0,32	1,8	18,43
22	0,27	9,51	25,18	0,31	2,32	19,53
23	0,29	10,03	26,04	0,32	1,57	20,35
24	0,32	9,21	28,45	0,28	2	19,56
25	0,25	9,32	25,24	0,28	2,31	22,74
26	0,26	10,03	23,14	0,24	2,02	21,87
27	0,37	9,46	21,44	0,31	1,94	18,08
28	0,25	9,15	24,18	0,34	2,32	20,33
29	0,29	9,45	27,19	0,32	1,91	20,42
30	0,28	9,59	24,43	0,32	1,87	21,67
31	0,3	9,46	25,34	0,29	1,63	20,02
32	0,28	10,02	24,23	0,32	1,83	19,23
33	0,29	10,01	28,53	0,23	2,03	23,21
34	0,3	9,34	22,55	0,32	1,94	21,09
35	0,31	9,47	23,43	0,39	2,19	18,27
36	0,33	9,3	25,39	0,29	2,02	20,33
37	0,29	9,32	23,23	0,43	2,32	18,34
38	0,3	9,24	19,55	0,41	1,56	20,03
39	0,28	9,41	21,42	0,38	2,03	18,24
40	0,27	9,28	22,51	0,33	2,32	19,85
41	0,3	9,45	24,17	0,36	2	20,01
42	0,29	10,2	27,09	0,42	2,04	19,05
Total	0,29	9,56	25	0,33	2	20

If the values of A + B + C + D + E + F are added up, it can be concluded that the average cycle time of Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca is 57,18 minutes/cycle time.

d. Cycle Time Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class
The Hino Ranger 500 Fm 260 Ti type, along with the circulation time of the Doosan Giant 300 Class excavator, are arranged in minutes as described in the table below.

Table 4. Cycle Time Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class

Number	***Manuver 1 (minute)***	***Loading (minute)***	***Hauling (minute)***	***Manuver 2 (minute)***	***Dumping (minute)***	***Return Time (minute)***
1	0,3	9,46	25,34	0,29	1,63	20,02
2	0,28	8,02	24,23	0,32	1,83	19,23
3	0,29	7,01	28,53	0,23	2,03	23,21
4	0,3	9,34	22,55	0,32	1,94	21,09
5	0,31	7,47	23,43	0,39	2,19	18,27
6	0,33	9,3	25,39	0,29	2,02	20,33
7	0,29	9,32	23,23	0,43	2,32	18,34
8	0,3	7,88	19,55	0,41	1,56	20,03
9	0,28	9,41	21,42	0,38	2,03	18,24
10	0,27	9,58	22,51	0,33	2,32	19,85
11	0,3	9,45	24,17	0,36	2	20,01
12	0,29	9,95	27,09	0,42	2,04	19,05
13	0,29	8,14	26,49	0,37	1,98	20,26
14	0,29	9,49	26,53	0,35	2,37	18,88
15	0,28	7,73	27,33	0,37	2,1	20,32
16	0,29	9,5	24,45	0,33	2,22	19,03
17	0,26	9,49	25,09	0,31	1,9	20,1

18	0,28	8,52	26,49	0,3	1,87	19,1
19	0,29	9,11	25,34	0,34	1,76	20,62
20	0,31	9,48	27,06	0,32	1,83	21,04
21	0,29	9,6	28,49	0,32	1,8	18,43
22	0,27	9,51	25,18	0,31	2,32	19,53
23	0,29	9,13	26,04	0,32	1,57	20,35
24	0,32	9,21	28,45	0,28	2	19,56
25	0,25	7,32	25,24	0,28	2,31	22,74
26	0,26	7,63	23,14	0,24	2,02	21,87
27	0,37	8,46	21,44	0,31	1,94	18,08
28	0,25	9,15	24,18	0,34	2,32	20,33
29	0,29	9,45	27,19	0,32	1,91	20,42
30	0,28	9,59	24,43	0,32	1,87	21,67
31	0,3	9,46	25,34	0,29	1,63	20,02
32	0,28	8,02	24,23	0,32	1,83	19,23
33	0,29	7,01	28,53	0,23	2,03	23,21
34	0,3	9,34	22,55	0,32	1,94	21,09
35	0,31	7,47	23,43	0,39	2,19	18,27
36	0,33	9,3	25,39	0,29	2,02	20,33
37	0,29	9,32	23,23	0,43	2,32	18,34
38	0,3	7,88	19,55	0,41	1,56	20,03
39	0,28	9,41	21,42	0,38	2,03	18,24
40	0,27	9,58	22,51	0,33	2,32	19,85
41	0,3	9,45	24,17	0,36	2	20,01
42	0,29	9,95	27,09	0,42	2,04	19,05
Total	0,29	8,89	25	0,33	2	20

If the values of A + B + C + D + E + F are added up, it can be concluded that the average cycle time of Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class is 56,51 minutes/cycle time.

4. Discussion

Based on the results of research and data processing with production targets set by PT. Agung Satriya Abadi is 334.62 m^3/hour. In this case study, it is about knowing the impact of a tool on the mining process by using linear regression analys.

a. Analysis of Cycle Time Relationship to Productivity of Doosan Giant Dx 520 Lca

In this analysis, the data used are the minimum, maximum, mean, median, and mode values of the cycle time and productivity of the Doosan Giant Dx 520 Lca. This cycle time will be used as the independent variable (X), while productivity is used as the dependent variable (Y). below has been presented a table of results from the calculation of the value of X, and the value of Y from the Doosan Giant Dx 520 Lca is as follows:

Table 5. X and Y Value of Doosan Giant Dx 520 Lca

Description	***X (second)***	***Y (m^3/hour)***
Minimum	18,38	206,96
Maximum	136,89	27,78
Mean	31,89	119,28
Median	19,71	165,71
Mode	19,71	193

Y = ax + b

Pr = -1,303 ct + 201,600

Description:

Y = Dependent Variable (productivity = Pr)

X = Independent Variable (cycle time = Ct)

a and b = Regression Constant

Table 6. X and Y Value of Doosan Giant Dx 520 Lca

X	*Y*	*X²*	*XY*	*Y²*	*Yreg*	*a*	*b*	*Y-Yreg*	*SD%*
18,38	206,96	337,8244	3803,925	42832,44	177,6479	-1,30316	201,6	29,3120662	14,16316
136,89	27,78	18738,8721	3802,804	771,7284	23,21037	-1,30316	201,6	4,56962844	16,44935
31,89	119,28	1016,9721	3803,839	14227,72	160,0422	-1,30316	201,6	-40,7622342	-34,1736
19,71	165,71	388,4841	3266,144	27459,8	175,9147	-1,30316	201,6	-10,2047302	-6,15819
19,71	193	388,4841	3804,03	37249	175,9147	-1,30316	201,6	17,0852698	8,852471
226,58	712,73	20870,6368	18480,74	122540,7	712,73	-1,30316	201,6	1,7053E-13	-0,86678

From the mathematical model, the results of statistical tests are as follows:

Table 7. Mathematical Model Test Statistics of Doosan Giant Dx 520 Lca

R *Correlation Coefficient*	***R²*** *Coefficient of Determination*	***SD*** *Standard Deviation*	***C*** *convergence*
-0,9272	0,8597	0,000000239	99,999999761

From the results of these statistical tests, it can be seen that the relationship between the cycle time values is very influential on the value of the productivity of a mechanical device. Therefore, the results obtained that R is -0.9272, R2 is 0.8597, SD is 0.000000239, and C is 99.999999761. Attached below is a graph of the results of the values of Y and R2, which are presented in Figure 2 as follows.

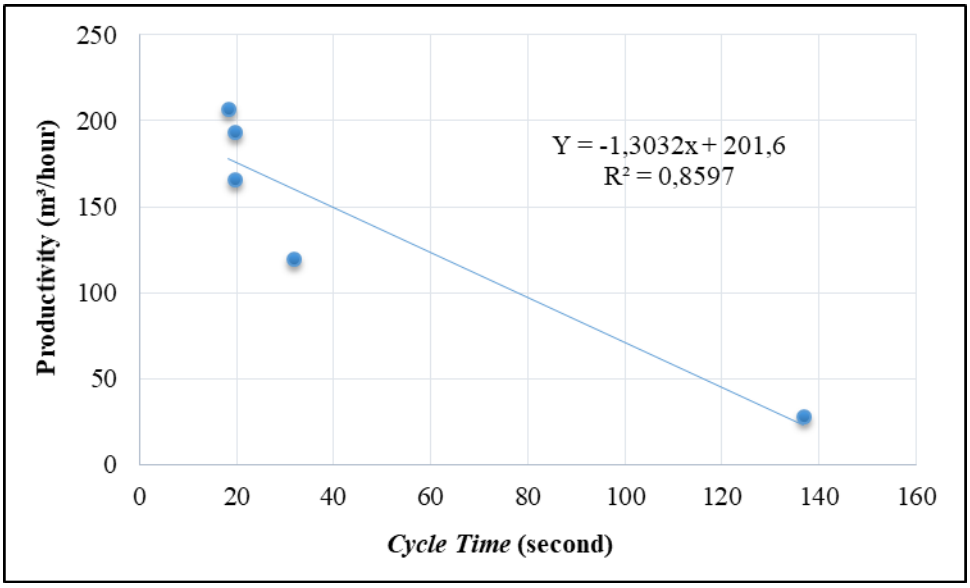

Figure 2. Mathematical Model Statistics Test graph of Doosan Giant Dx 520 Lca

Based on this mathematical model, it can be tested the relationship between the cycle time of the Doosan Giant Dx 520 Lca digging tool can be seen how much the productivity value changes with the change in the value of the cycle time. the cycle time values to be tested are as follows:

Table 8. Modeling Test of Doosan Giant Dx 520 Lca

a	*b*	*Ct (second)*	*Pr (m^3/hour)*	*Difference (m^3/hour)*
-1,30316	201,6	15	182,0526166	0
-1,30316	201,6	25	169,0210107	13,03160596
-1,30316	201,6	35	155,9894047	13,03160596
-1,30316	201,6	45	142,9577987	13,03160596
-1,30316	201,6	55	129,9261928	13,03160596
-1,30316	201,6	65	116,8945868	13,03160596
-1,30316	201,6	75	103,8629809	13,03160596
-1,30316	201,6	85	90,8313749	13,03160596
-1,30316	201,6	95	77,79976894	13,03160596
-1,30316	201,6	105	64,76816298	13,03160596

-1,30316	201,6	115	51,73655701	13,03160596
-1,30316	201,6	125	38,70495105	13,03160596
-1,30316	201,6	135	25,67334509	13,03160596
-1,30316	201,6	145	12,64173913	13,03160596

From the test data that has been carried out, it can be seen that each cycle time increases by 5 seconds, which will affect the value of productivity, which is 13.03160596 m^3/hour.

b. Analysis of Cycle Time Relationship to Productivity of Doosan Giant 300 Class

In this analysis, the data used are the minimum, maximum, mean, median, and mode values of the cycle time and productivity of the Doosan Giant 300 Class. This cycle time will be used as the independent variable (X), while productivity is used as the dependent variable (Y). below has been presented a table of results from the calculation of the value of X, and the value of Y from the Doosan Giant 300 Class is as follows:

Table 9. X and Y Value of Doosan Giant Dx 300 Class

Description	***X (second)***	***Y (m^3/hour)***
Minimum	13,69	236,19
Maximum	63,05	51,28
Mean	25,42	127,2
Median	19,29	167,62
Mode	18,3	176,69

Y = ax + b

Pr = -3,135 ct + 239,413

Description:

Y = Dependent Variable (productivity = Pr)

X = Independent Variable (cycle time = Ct)

a and b = Regression Constant

Table 10. X and Y Value of Doosan Giant 300 Class

X	***Y***	***X^2***	***XY***	***Y^2***	***Yreg***	***a***	***b***	***Y-Yreg***	***SD%***
13,69	236,19	187,4161	3233,441	55785,72	196,4979	-3,13478	239,413	39,69207146	16,80514
63,05	51,28	3975,3025	3233,204	2629,638	41,76531	-3,13478	239,413	9,514693663	18,55439
25,42	127,2	646,1764	3233,424	16179,84	159,727	-3,13478	239,413	-32,52698732	-25,5715
19,29	167,62	372,1041	3233,39	28096,46	178,9432	-3,13478	239,413	-11,32317399	-6,75526
18,3	176,69	334,89	3233,427	31219,36	182,0466	-3,13478	239,413	-5,356603813	-3,03164
139,75	758,98	5515,8891	16166,89	133911	758,98	-3,13478	239,413	-4,26326E-14	0,001105

From the mathematical model, the results of statistical tests are as follows:

Table 11. Mathematical Model Test Statistics of Doosan Giant 300 Class

R *Correlation Coefficient*	***R^2*** *Coefficient of Determination*	***SD*** *Standard Deviation*	***C*** *convergence*
-0,9198	0,8459	0,000000056	99,999999944

From the results of these statistical tests, it can be seen that the relationship between the cycle time values is very influential on the value of the productivity of a mechanical device. Therefore, the results obtained that R is -0,9198, R2 is 0,8459, SD is 0,000000056, and C is 99,999999944. Attached below is a graph of the results of the values of Y and R2, which are presented in Figure 3 as follows.

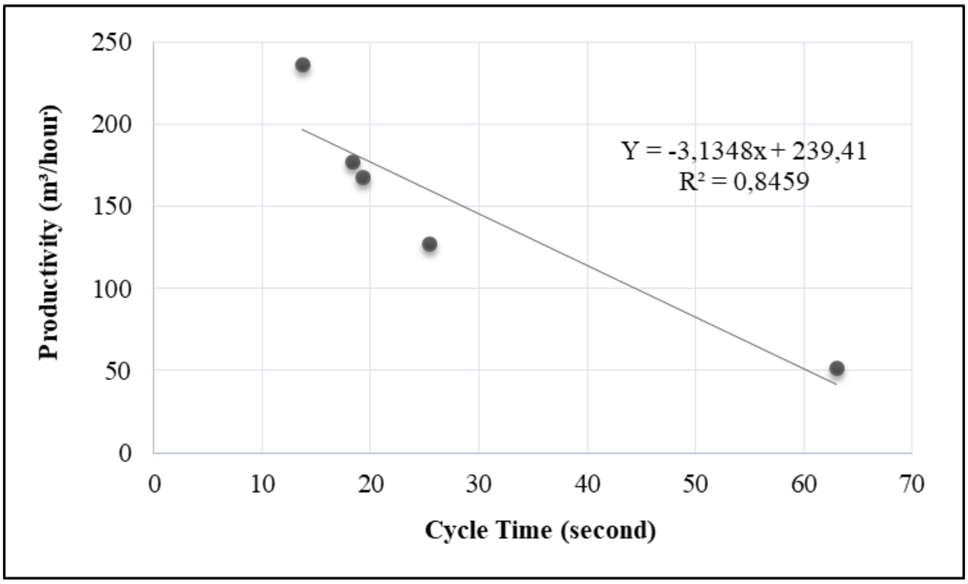

Figure 3. Mathematical Model Statistics Test graph of Doosan Giant 300 Class

Based on this mathematical model, it can be tested the relationship between the cycle time of the Doosan Giant 300 Class digging tool can be seen how much the productivity value changes with the change in the value of the cycle time. the cycle time values to be tested are as follows:

Table 12. Modeling Test of Doosan Giant 300 Class

a	*b*	*Ct (second)*	*Pr (m^3/hour)*	*Difference (m^3/hour)*
-3,13478	239,413	15	192,3913699	0
-3,13478	239,413	25	161,0435939	31,34777597
-3,13478	239,413	35	129,6958179	31,34777597
-3,13478	239,413	45	98,34804197	31,34777597
-3,13478	239,413	55	67,00026599	31,34777597
-3,13478	239,413	65	35,65249002	31,34777597

From the test data that has been carried out, it can be seen that each cycle time increases by 5 seconds, which will affect the value of productivity, which is 31,34777597 m^3/hour.

c. Analysis of Cycle Time Relationship to Productivity on Hino Ranger 500 Fm 260 Ti with Doosan Giant Dx 520 Lca

In this analysis, the data used are the minimum, maximum, mean, median, and mode values of the cycle time and productivity of the Hino Ranger 500 Fm 260 Ti against the Doosan Giant Dx 520 Lca. This cycle time will be used as the independent variable (X), while productivity is used as the dependent variable (Y).

Table 13. X and Y Value of Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

Description	*X (second)*	*Y (m^3/hour)*
Minimum	48,82	21,66
Maximum	65,11	16,24
Mean	57,18	18,44
Median	57,31	18,45
Mode	55,64	19

Y = ax + b

Pr = -0,332 ct + 37,616

Description:

Y = Dependent Variable (productivity = Pr)

X = Independent Variable (cycle time = Ct)

a and b = Regression Constant

Table 14. X and Y Value of Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

X	*Y*	*X²*	*XY*	*Y²*	*Yreg*	*a*	*b*	*Y-Yreg*	*SD%*
48,82	21,66	2383,392	1057,441	469,1556	21,41086	-0,33194	37,61615	0,249139	1,150227
65,11	16,24	4239,312	1057,386	263,7376	16,00357	-0,33194	37,61615	0,236434	1,455876
57,18	18,44	3269,552	1054,399	340,0336	18,63585	-0,33194	37,61615	-0,19585	-1,06207
57,31	18,45	3284,436	1057,37	340,4025	18,59269	-0,33194	37,61615	-0,14269	-0,77341
55,64	19	3095,81	1057,16	361	19,14703	-0,33194	37,61615	-0,14703	-0,77386
284,06	93,79	16272,5	5283,756	1774,329	93,79	-0,33194	37,61615	2,03E-13	-0,00324

From the mathematical model, the results of statistical tests are as follows:

Table 15. The Model Test Statistics of Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

R Correlation Coefficient	*R²* Coefficient of Determination	*SD* Standard Deviation	*C* convergence
-0,9934	0,9868	0,000002159	99,999997841

From the results of these statistical tests, it can be seen that the relationship between the cycle time values is very influential on the value of the productivity of a mechanical device. Therefore, the results obtained that R is -0,9934, R^2 is 0,9868, SD is 0,000002159, and C is 99,999997841.

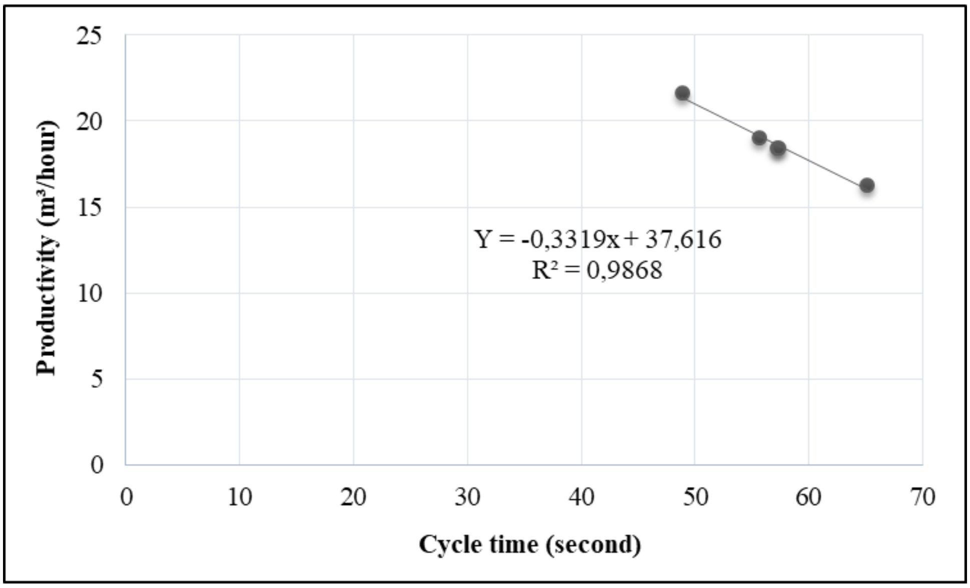

Figure 4. The Model Statistics Test graph of Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

Based on this mathematical model, it can be tested the relationship between the cycle time of the Hino Ranger 500 Fm 260 Ti against the Doosan Giant Dx 520 Lca which can be seen how much the productivity value changes with the change in the value of the cycle time. The cycle time values to be tested are as follows:

Table 16. Modeling Test of Hino Ranger 500 Fm 260 Ti to Doosan Giant Dx 520 Lca

a	*b*	*Ct (second)*	*Pr (m³/hour)*	*Difference (m³/hour)*
-0,33194	37,61615	40	24,3385674	0
-0,33194	37,61615	45	22,67886975	1,659697657
-0,33194	37,61615	50	21,01917209	1,659697657
-0,33194	37,61615	55	19,35947443	1,659697657
-0,33194	37,61615	60	17,69977677	1,659697657
-0,33194	37,61615	65	16,04007912	1,659697657
-0,33194	37,61615	70	14,38038146	1,659697657

From the test data that has been carried out, it can be seen that each cycle time increases by 5 minutes, which will affect the value of productivity, which is 1,659697657 m^3/hour.

d. Analysis of Cycle Time Relationship to Productivity on Hino Ranger 500 Fm 260 Ti with Doosan Giant 300 Class

In this analysis, the data used are the minimum, maximum, mean, median, and mode values of the cycle time and productivity of the Hino Ranger 500 Fm 260 Ti against the Doosan Giant 300 Class. This cycle time will be used as the independent variable (X), while productivity is used as the dependent variable (Y).

Table 17. X and Y Value of Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class

Description	*X (second)*	*Y (m^3/hour)*
Minimum	46,68	21,66
Maximum	64,86	16,24
Mean	56,51	18,44
Median	57,155	18,45
Mode	56,56	19

Y = ax + b

Pr = -0,298 ct + 35,578

Description:

Y = Dependent Variable (productivity = Pr)

X = Independent Variable (cycle time = Ct)

a and b = Regression Constant

Table 18. X and Y Value of Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class

X	*Y*	*X^2*	*XY*	*Y^2*	*Yreg*	*a*	*b*	*Y-Yreg*	*SD%*
46,68	21,66	2179,022	1011,089	469,1556	21,64507	-0,29847	35,57751	0,01493	0,068927
64,86	16,24	4206,82	1053,326	263,7376	16,21894	-0,29847	35,57751	0,021058	0,129668
56,51	18,44	3193,38	1042,044	340,0336	18,71114	-0,29847	35,57751	-0,27114	-1,47039
57,155	18,45	3266,694	1054,51	340,4025	18,51863	-0,29847	35,57751	-0,06863	-0,37198
56,56	19	3199,034	1074,64	361	18,69622	-0,29847	35,57751	0,303783	1,598856
281,765	93,79	16044,95	5235,609	1774,329	93,79	-0,29847	35,57751	3,13E-13	-0,04492

Table 19. The Model Test Statistics of Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class

***R** Correlation Coefficient*	***R^2** Coefficient of Determination*	***SD** Standard Deviation*	***C** convergence*
-0,9943	0,9886	0,000003333	99,999996667

From the results of these statistical tests, it can be seen that the relationship between the cycle time values is very influential on the value of the productivity of a mechanical device. Therefore, the results obtained that R is -0,9943, R^2 is 0,9886, SD is 0,000003333, and C is 99,999996667.

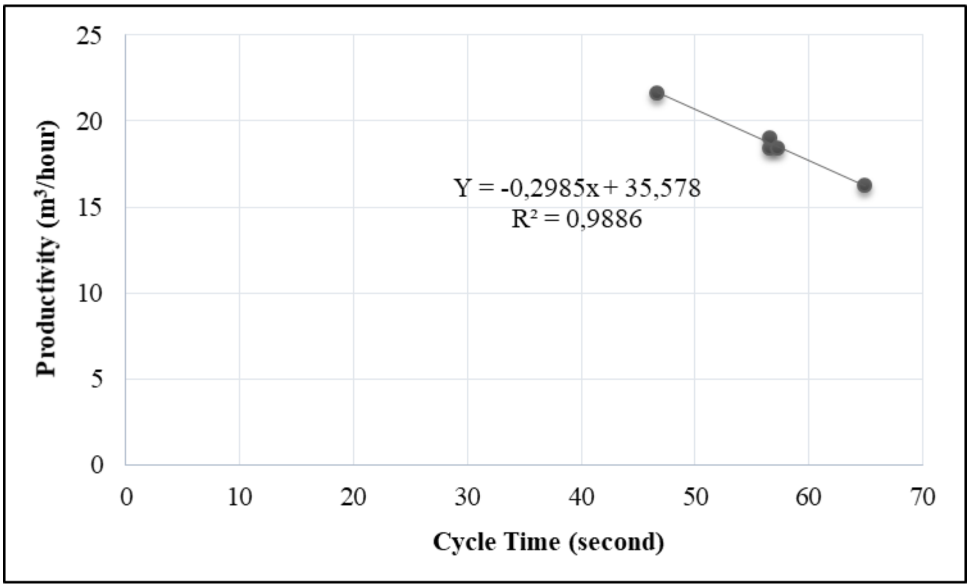

Figure 5. The Model Statistics Test graph of Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class

Based on this mathematical model, it can be tested the relationship between the cycle time of the Hino Ranger 500 Fm 260 Ti against the Doosan Giant 300 Class which can be seen how much the productivity value changes with the change in the value of the cycle time. The cycle time values to be tested are as follows:

Table 20. Modelling Test of Hino Ranger 500 Fm 260 Ti to Doosan Giant 300 Class

a	*b*	*Ct (second)*	*Pr (m^3/hour)*	*Difference (m^3/hour)*
-0,29847	35,57751	40	23,63882941	0
-0,29847	35,57751	45	22,14649485	1,492334561
-0,29847	35,57751	50	20,65416029	1,492334561
-0,29847	35,57751	55	19,16182573	1,492334561
-0,29847	35,57751	60	17,66949117	1,492334561
-0,29847	35,57751	65	16,17715661	1,492334561
-0,29847	35,57751	70	14,68482205	1,492334561

From the test data that has been carried out, it can be seen that each cycle time increases by 5 minutes, which will affect the value of productivity, which is 1,492334561 m^3/hour.

5. Conclusion

Based on the results of the research that has been done, the following conclusions are obtained:

1. Cycle time and Productivity

The cycle time of the Doosan Giant Dx 520 Lca is 31.89 seconds/cycle with productivity of 119.28 m^3/hour, and the cycle time of the Doosan Giant 300 Class digging tool is 25.42 seconds/cycle with productivity of 127.2 m^3/hour, there is also a circulation time of the digging tool paired with each conveyance, namely the Hino Ranger 500 Fm 260 Ti paired with the Doosan Giant Dx 520 Lca, namely has a cycle time value of 57.18 minutes/cycle with productivity of 18.49 m^3/hour, then the Hino Ranger 500 Fm 260 Ti transportation equipment paired with the Doosan Giant 300 Class has a cycle time value of 56.51 minutes/cycle with productivity of 18.79 m^3/hour.

2. Mathematical model between cycle time and productivity

This modeling raises the values of the relationship between cycle time and productivity which is displayed according to the type of mechanical equipment. For mathematical graph modeling, it is obtained from:

a. Doosan Giant Dx 520 Lca with a coefficient of determination (R^2) = 0.8597.
b. Doosan Giant 300 Class with a coefficient of determination (R^2) = 0.8459.
c. Hino Ranger 500 Fm 260 Ti against Doosan Giant Dx 520 Lca with a coefficient of determination (R^2) = 0.9868.
d. Hino Ranger 500 Fm 260 Ti against Doosan Giant 300 Class with a coefficient of determination (R^2) = 0.9886.

3. The relationship between cycle time and productivity

a. Doosan Giant Dx 520 Lca, the relationship between the two (cycle time and productivity) produces a data difference of 13,031 m^3/hour for every 5-second increase.
b. Doosan Giant 300 Class, the relationship between the two (cycle time and productivity) produces a data difference of 31.347 m^3/hour for every 5-second increase.
c. Hino Ranger 500 Fm 260 Ti against Doosan Giant Dx 520 Lca, the relationship between the two (cycle time and productivity) produces a data difference of 1,659 m^3/hour for every 5-minute increase.
d. Hino Ranger 500 Fm 260 Ti against the Doosan Giant 300 Class, the relationship between the two (cycle time and productivity) produces a data difference of 1,492 m^3/hour for every 5-minute increase.

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