OPTIMIZING PRODUCTION BY INCREASING THE SPEED OF KOMATSU HD 785-7 PT. KALIMANTAN PRIMA PERSADA SITE INDEXIM KALIORANG, EAST KUTAI, EAST KALIMANTAN

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Abstract. PT. Kalimantan Prima Persada Jobsite Indexim is mining company operating in the field of coal mining contractors. From the results of observations, the influence on the non-achievement of Productivity is the condition of the haul road is not in accordance with the standards and the performance of hauler operators is not optimal. Therefore, to achieve the overburden and coal production targets that have been set, it is necessary to pay attention to several things, namely tool work efficiency, tool cycle time, and haul road conditions. The stages used to determine the ideal standard for mining roads use 3 reference parameters, the first is based on the AASHTO (American Association of State Highway and Transportation Officials) method, Ministerial Decree of the Ministry of Energy and Mineral Resources (ESDM) in 2018, and the KPP Road Management System. In this research, the type of research used is quantitative research. The results and discussion show that the increase in the average speed of the HD785-7 from April to July which has an effect on increasing the productivity of the HD 785 with the best achievement at 232 BCM/hour.

Keywords: *productivity, speed, grade, road maintenance, operator performance*

1 Introduction

PT Kalimantan Prima Persada is one of the mining service companies engaged in coal mining. In overburden and coal excavation activities, it is necessary to plan the needs of digging equipment and transportation equipment in order to obtain high production. To achieve the overburden and coal production targets that have been set, it is necessary to consider several things, namely the work efficiency of the equipment, the cycle time of the equipment, and the condition of the haul road.

Overburden production data in October-December 2022 shows that Productivity HD 785 contributed the lowest achivement point at 87% with an achievement of 192.3 Bcm/hour/km from the plan of 220 Bcm/hour/km, this data is clearly less than planned by the company. The non-achievement of Productivity HD 785 in the October-December 2022 period resulted in a production loss of 1,325,153 Bcm or loss of opportunity +/-.

Based on the deviation of Achivement to Productivity HD 785, it can be found that the one that has the most influence on the non-achievement of Productivity HD 785 is the Average Speed HD 785 parameter with an achievement of 89% (18.3 Km/hour out of 20.5 Km/hour). From the observations, the cause is the condition of the haul road that is not in accordance with the standards and the performance of the hauler operator is not optimal. HD785 productivity achievement for the period Oct-Dec 2022 can be seen that the productivity achievement of Pit Tempudo 3 is the smallest. So as to support the KPI of production regarding increased production.

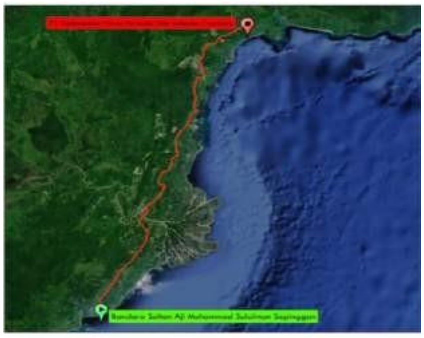
There are several previous researchers investigating factors in increasing speed such as research conducted in the journal Uyu Saismana, Raf'an Hidayatullah and Andi Fadly with the title Evaluation of Overburden Pit 1 Block 15 Pt Rimau Energy Mining Site Putut Tawuluh Karosen Janang District. discusses the effect of mine road geometry on hauler cycle time which affects hauler speed. Furthermore, in the journal Kurniawan Nur Pratomo, Dono Guntoro and Dudi Nasrudin Usman with the title "Evaluation of the Haul Road from the Andesite Mine Front to Crusher II in Andesite Mining at PT Gunung Kecapi, Purwakarta Regency, Java Province". Good hauling road conditions will increase the value of the efficiency and effectiveness of the work of the conveyance and the level of the haul road. In Kurniawan's research, he analyzed and found out the factors that affect productivity activities. Then research in the journal Golbasi, Onur. & Kina, Elif in 2021 with the title Haul truck Fuel Consumption Modeling Under Random Operating Conditions: A Case Study Middle East Technical University. Discusses road geometry on feul ratio and tool productivity.

Based on this, the author raises the topic "Optimizing Production by Increasing the Speed of Komatsu HD 785-7 PT Kalimantan Prima Persada Site Indexim Kaliorang Village, Kaliorang Kec. Kaliorang, Kab. Kutai Timur, East Kalimantan."

2 Literature Review

2.1 Location and Regional Accomplishment

The Mining Business License (IUP) area carried out by PT Kalimantan Prima Persada Jobsite INDE is Located in procurement, Kaliorang, Cipta Graha, Kaubun, East Kutai Regency, East Kalimantan 75618 Indonesia. The following map shows the location of the area from Balikpapan City to PT. KPP Jobsite INDE in the following image.



Picture 1. Submission map of the region

2.2 Mining Road

To determine the ideal standard of mining roads, 3 reference parameters are used, the first based on the AASHTO (American Association of State Highway and Transportation Officials) method, Decree of the Minister of Energy and Mineral Resources 1827K Year 2018 and KPP Road Management System.

Table 1. Comparison of Road Parameters of 3 References

Road Parameters	AASHTO	Minister of Energy and Mineral Resources Decree 1827 in 2018	KPP Road Management System
Straight road width	3.5 times the largest conveyance	3.5 times the largest conveyance	3.5 times the largest conveyance
bend road width	depending on the type of conveyance	depending on the type of conveyance	depending on the type of conveyance
Superelevation	depending on the type of conveyance (Max 10%)	depending on the type of conveyance (Max 10%)	depending on the type of conveyance (Max 10%)
Road Grade	8-10%	8-12 %	8%
safety dike	-	3/4 diameter of the largest conveyance tire	3/4 diameter of the largest conveyance tire
Lane splitter	-	1/2 the height of the largest conveyance	1/2 the height of the largest conveyance

The main function of mining roads in general is to support the smooth running of mining operations, especially transportation. In order for the road to have no problems, it is necessary to analyze the right road geometry.

2.3 Haul Road Geometry

The main function of haul roads in general is to support the smooth running of mining operations, especially in transportation activities. The heavy terrain that may exist along the mine road route must be overcome by changing the road design to improve the benefits and safety aspects (awang suwandhi, 2004: 1).

The technical design of the haul road in accordance with the characteristics of the hauling equipment, it is expected that the function and life of the road can be maximized. Apart from the varying capacity of the equipment, the speed of the conveyance also has an influence in the technical design, namely on bends and visibility.

2.3.1 Haul Road Width

2.3.1.1 Straight Road Width

The determination of the minimum haul road width for straight roads is based on the "rule of thumb" proposed by the "Aashto Manual Rural Highway Design", namely that the number of lanes is multiplied by the width of the dump truck conveyance plus half the width of the dump truck for each left, right and distance between two dump trucks that are crossing.

To calculate the width of a straight road, the following formula can be used.

$$L(m) = n(Wt) + \{(n + 1) \times (1/2 \times Wt)\} \quad (1)$$

Description :

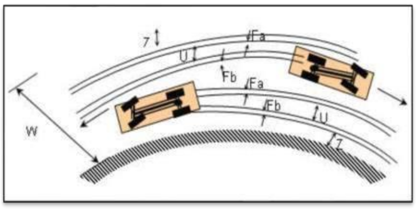
L(m) = Minimum mine road width (meters)

n = Number of lanes

Wt = Width of conveyance (meters)

2.3.1.2 Bend Road Width

After determining the width of the straight road, next determine the width of the road in the bend. The width of the bend road is different from the width of the road in the bend because when in the bend the vehicle requires more space so as not to widen beyond the width of the existing bend road.



Source: (Awang Suwandhi, 2004)

Picture 2. Minimum Width of the Bend Road

To determine the minimum road width at the bend is also adjusted to the largest conveyance used on the road and uses the formula:

$Lt = n\ x\ (U + Fa + Fb + Z) + C$ ....(2)

Description :

Lt : Minimum width of haul road on bends (meters)

U : width of wheel tracks (meters)

Fa : front overhang width (meters)

Fb : width of the rear overhang (meters)

Z : width of the roadside (meters) = ½ (U + Fa + Fb)

C : distance between conveyances when passing (meters) = ½ (U + Fa + Fb)

2.3.2 Bend Radius

The bend radius of the conveyance is related to the construction of the conveyance, especially in the horizontal distance between the front wheel axle and the rear wheels. So the radius of the bend can be calculated as follows:

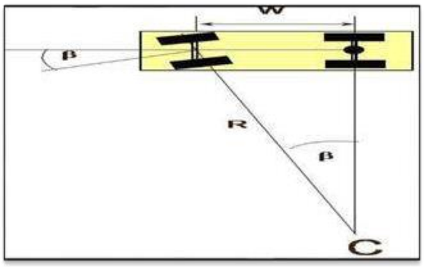
$R = \frac{w}{\sin \beta ...}$ ....(3)

Description :

R = the turning radius of the haul road

w = front and rear wheel axle distance

β = front wheel deviation angle



Picture 3. Radius of Bend

The formula is a road curve without considering the speed of the conveyance, tire friction with the road surface and superelevation, when considered the formula becomes :

$R = \frac{v^2}{127(e+f)}$ ....(4)

Description :

R = Bend radius (m)

V = Vehicle plan speed (Km/h)

e = Superelevation value

f = *Friction factor / Coefficient of Friction*

2.3.3 Superelevation

Superelevation is closely related to the turning radius, vehicle speed and speed change. It aims to obtain the weight component of the vehicle to compensate for the vehicle slipping off the track (Suwandhi, 2004). Superelevation can be calculated using the formula:

$e + f = \frac{v^2}{127\ x\ R}$ ....(5)

Description :

e : Superelevation Rate

f : Friction Factor

V : Conveyance Plan Speed (Km/h)

(Km/h) R : Bend radius (m)

2.3.4 Road Grade

In grade writing there is writing with a negative (-) which means that the road is a decline, while the grade value without negative writing means that the road is an incline.

The inclination is expressed as a percentage, 1% slope is an uphill or downhill slope of one meter vertically in a horizontal distance of 100 meters (Kaufmann,1977).

The slope of the road can be calculated using the formula:

$Grade(\%) = \frac{\Delta h}{\Delta x}\ x\ 100\%$ ....

Description :

Δh : Height difference between two measured points (Meters)

Δx : Flat distance between two measured points (Meters)

2.3.5 Cross Slope

Cross slope is the angle formed by the two sides of the road surface against the horizontal plane. In general, mining roads have a convex cross-sectional shape. Made so with the aim of facilitating drainage.

Cross Slope can be found using the formula:

$P = \frac{1}{2}\ x\ l$ ....

$Q = P\ x\ 40$ mm/m ....

Description :

P = Cross Slope (mm/m)

l = Road Width (m)

Q = Vertical Distance (m)

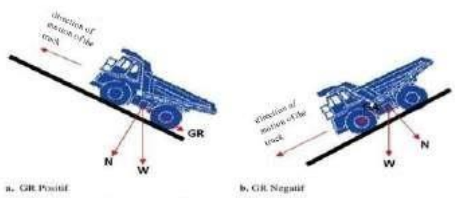
2.4 Rolling Resistance

One of the factors that affect the rolling resistance value is: Tire Penetration, which is the subsidence of the road due to the running tire and can increase the Rolling Resistance number. It is estimated that if the tire sinks 1 inch, it will increase the rolling resistance by 15 kg/ton and if the tire sinks 1 cm, it will increase the rolling resistance by 6 kg/ton.

2.5 Grade Resistance

Grade Resistance is the amount of force that helps the vehicle to move due to the slope of the road the vehicle is traveling on. The effect of the slope if the value is positive then the sign of the incline and if the value is minus then the sign of the descent. To get the Grade Resistance value, use the formula:

$Grade\ Resistance\ (GR) = \text{vehicle weight} \times \text{road grade}\ (13)$



Source : (*Awang Suwandhi, 2004*)

Picture 3. Grade Resistance

2.6 Rimpul

Rimpul (RP) is the amount of tensile strength that can be given by the machine or tool to the surface of the wheels or tires that touch the surface of the haul road. But if the skid, then the maximum RP will be equal to the amount of power on the drive wheel multiplied by the coefficient of traction. (Partanto, 1996). The amount of rimpul value can use the following formula.

$$Rimpul = \frac{\text{Vehicle HP x 375 X Mechanical Efficiency}}{\text{Speed (Km/h)}} \ldots\ldots$$

Keterangan:

RP: Rimpul (N)

P : Engine Power (hp)

V : Speed (Kmh / mph)

2.7 Operator Performance Improvement

2.7.1 Socialization and Refresh Knowladge

According to Soejono Dirdjosisworo (1985) for someone to know, understand and at the same time carry out their rights and obligations based on their respective status roles according to their duties, then every individual or human needs to socialize to learn and develop patterns of social behavior with other community members.

2.7.2 Operator Role Model (OPROM)

In an effort to increase the competitive spirit in each individual operator, as well as to test the best operator performance, operators who have the best skills are united in 1 PC 2000 fleet. Operator role model selection parameters are divided into 2 points. Namely ATR (Attendance Ratio) and MOR (Monthly Operator Report).

3 Research Methods

3.1 Research Design

3.1.1 Type of Research

In this study, the type of research used is quantitative research. This is because the research will use data in the form of numbers.

3.1.2 Research Instruments

The instruments or tools used in this research are: Geodetic GPS RTK Sokkia, Drone Mavic 2 Pro, Laptop, Garmin Virb and GPS Geo Tracker.

3.2 Types of Data

3.2.1 Primary Data

The data that the author obtained in the field are as follows:

a. Road Grade

The author takes data directly to the field in the form of road grade data on the overburden hauling process.

b. Road Width

The author takes data directly to the field in the form of road width data on the overburden hauling process.

3.2.2 Secondary Data

Secondary data is data that can be obtained from PT Kalimantan Prima Persada, the data that the author can get is as follows:

a. Topographic Map
b. Transport equipment specifications (Komatsu HD 785-7)
c. Production performance data
d. Operator data

3.3 Data Collection Techniques

3.3.1 Literature Review

This activity is carried out by studying theories related to the material to be carried out in the field through books, literature via the internet and research reports related to road geometry, Total Resistance, Increased speed, and Dumptruck Productivity.

3.3.2 Field Observation

The field observation activities consist of:

a. Road geometry data collection
b. Cycle Time Measurement of Transport and Loading Equipment
c. Cycle Time Measurement of Loading Equipment.

3.4 Data Analysis Technique

The next step is to perform data processing and analysis so that the results of the analysis and discussion are obtained. Some of the data analyzed include:

a. Total road geometry calculation.
b. Total Resistance Calculation (Rolling Resistance, Grade Resistance).
c. Rimpul Calculation.
d. Percentage increase in speed of Komatsu HD 785- 7
e. Percentage increase in production of Komatsu HD 785-7.

4 Result and Discussion

4.1 Research Data

The overburden haul road to be discussed is located in the Tempudo 3 pit area, where there are 2 roads, namely Bajaka Road and Jati Road. Both roads connect from the Highwall loading point area to the WD07 RL210 disposal dumping point which has a length of +- 2436.2Km. the actual condition of this haul road is a lane for loaded condition conveyance and empty condition conveyance and the author divides 17 segments. The haul road geometry data to be discussed are straight road width, bend road width, grade, superelevation, cross slope.

4.1.1 Haul Road Width

The division of segments on the haul road can be seen in the table below.

Table 2. Road Segment Division

NO	SEGMEN	STATION		road length (m)	straight road width (m)	bend road width (m)
		A	A'			
1	A-B	0 + 000	0 + 080.6	80.6	21.7	-
2	B-C	0 + 080.6	0 + 144.4	63.8	20.9	-
3	C-D	0 + 144.4	0 + 200.1	55.7	-	22.4
4	D-E	0 + 200.1	0 + 318	117.9	-	18.5
5	E-F	0 + 318	0 + 501.7	183.7	22.7	-
6	F-G	0 + 501.7	0 + 660.4	158.7	28	-
7	G-H	0 + 660.4	0 + 742.2	81.8	-	17
8	H-I	0 + 742.2	0 + 991.9	249.7	21.3	-
9	I-J	0 + 991.9	1 + 128.4	136.5	-	21
10	J-K	1 + 128.4	1 + 250.4	122	41.4	-
11	K-L	1 + 250.4	1 + 379.1	128.7	40.5	-
12	L-M	1 + 379.1	1 + 495	115.9	-	35.4
13	M-N	1 + 495	1 + 701.6	206.6	26.8	-
14	N-O	1 + 701.6	1 + 972.9	271.3	21.9	-
15	O-P	1 + 972.9	2 + 194.9	222	22.5	-
16	P-Q	2 + 194.9	2 + 295.9	101	30.5	-
17	Q-R	2 + 295.9	2 + 436.2	140.3	31.7	-

4.1.2 Road Slope (Grade)

The slope of the production haul road is also one of the factors directly related to the ability of the hauling equipment in transportation operations. The haul road is divided into 17 road segments consisting of 12 straight road segments and 5 bend road segments.

The division of these road segments is based on changes in road slope (grade) and the presence of bends on the road. From each division of these road segments, road conditions on each segments can be determined such as road grade, superelevation, cross slope, and road speed.

Table 3. Grade

NO	SEGMEN	STATION		Δh (m)	Δx (m)	Grade (%)	Standart Grade (%)	Over Grade (%)
		A	A'					
1	A-B	0 + 000	0 + 080.6	-5.3	80.6	-6.6	8	-
2	B-C	0 + 080.6	0 + 144.4	-1.7	63.8	-2.6	8	-
3	C-D	0 + 144.4	0 + 200.1	-0.9	55.7	-1.6	8	-
4	D-E	0 + 200.1	0 + 318	1.3	117.9	1.1	8	-
5	E-F	0 + 318	0 + 501.7	-4.4	183.7	-2.4	8	-
6	F-G	0 + 501.7	0 + 660.4	2.0	158.7	1.3	8	-
7	G-H	0 + 660.4	0 + 742.2	5.4	81.8	6.6	8	-
8	H-I	0 + 742.2	0 + 991.9	14.0	249.7	5.6	8	-
9	I-J	0 + 991.9	1 + 128.4	11.9	136.5	8.7	8	0.7
10	J-K	1 + 128.4	1 + 250.4	12.4	122.0	10.2	8	2.2
11	K-L	1 + 250.4	1 + 379.1	9.3	128.7	7.2	8	-
12	L-M	1 + 379.1	1 + 495	7.1	115.9	6.2	8	-
13	M-N	1 + 495	1 + 701.6	10.4	206.6	5.0	8	-
14	N-O	1 + 701.6	1 + 972.9	20.0	271.3	7.4	8	-
15	O-P	1 + 972.9	2 + 194.9	14.0	222.0	6.3	8	-
16	P-Q	2 + 194.9	2 + 295.9	2.0	101.0	2.0	8	-
17	Q-R	2 + 295.9	2 + 436.2	3.8	140.3	2.7	8	-

4.1.3 Digging and loading tools

The excavator used for overburden excavation in Tempudo Pit 3 is a Komatsu PC 2000 eqnum EX3016 excavator. The number of excavators operating is 1 unit to serve 6 dump trucks. From field observation data, it is known that the excavator cycle time averages 27 seconds with clay (blast) material.

4.1.4 Conveyance

The conveyance used for the transportation of overburden to RL + 210 is Komatsu HD 785. The specifications of the conveyance can be seen in the Appendix. The number of dump trucks operating in Fleet PC2000 eqnum EX3016 is 6 units. From observations in the field, it is known that the cycle time of dump trucks averages 20.08 minutes.

4.2 Data Analysis

4.2.1 Road Geometry Analysis

In the discussion of haul road geometry, the author divides the research road into 17 (seventeen) road segments, of which there are 11 (eleven) segments on straight roads and 5 (five) segments on bend roads and is divided based on the state of the road grade and the difference in the state of the road situation.

a. Straight Road Width

The number of lanes on the Tempudo 3 Pit road consists of 2 lanes, namely lanes for loaded and empty conveyance conditions. For the largest conveyance that passes through, Komatsu HD 785-7. The width of the Komatsu HD 785-7 body is 6.885 meters. So for the ideal straight road width crossed by Komatsu HD 785-7 can use the following formula.

$$Lmin = (n\,x\,Wt) + (n + 1)\,x\,(1/2\,x\,Wt)$$

$$= (2\,x\,6.885) + (2+1)x\left(\tfrac{1}{2}x\,6.885\right)$$

$$= 24.09\ Meter$$

From the above calculations, the minimum road width is 24.09 meters, but for road maintenance considerations, the minimum road width of 25 meters is taken.

Table 4. Comparison of Actual and Ideal Straight Road Width

NO	SEGMEN	STATION		Straight road width (m)	Ideal straight road width (m)	additional road width(m)
		A	A'			
1	A-B	0 + 000	0 + 080.6	21.7	25	3.3
2	B-C	0 + 080.6	0 + 144.4	20.9	25	4.1
3	E-F	0 + 318	0 + 501.7	22.7	25	2.3
4	F-G	0 + 501.7	0 + 660.4	28	25	-
5	H-I	0 + 742.2	0 + 991.9	21.3	25	3.7
6	J-K	1 + 128.4	1 + 250.4	41.4	25	-
7	K-L	1 + 250.4	1 + 379.1	40.5	25	-
8	M-N	1 + 495	1 + 701.6	26.8	25	-
9	N-O	1 + 701.6	1 + 972.9	21.9	25	3.1
10	O-P	1 + 972.9	2 + 194.9	22.5	25	2.5
11	P-Q	2 + 194.9	2 + 295.9	30.5	25	-
12	Q-R	2 + 295.9	2 + 436.2	31.7	25	-

Based on the data above, there are 12 segments of straight road width from Higthwall to RL210 that are not in accordance with the minimum standard of 1071.1 m out of 1928.4m. This can cause disruption to the work traffic of the conveyance because when two conveyances are passing the conveyance in empty conditions must prioritize the loaded conveyance for the road first due to the narrow road width. So it is necessary to make improvements by increasing the width according to the minimum road width so that the productivity of the equipment can be optimized.

b. Bend Road Width

From the calculation, it is obtained that the width of the bend road for 2 lanes of HD 785 conveyance is 27.357 m or can be rounded up to 27.5 m. The following is a comparison between actual and ideal road bends from the following table.

Table 5. Bend Road Width

NO	SEGMEN	STATION		Straight road width(m)	Ideal straight road width(m)	Additional road width(m)
		A	A'			
1	C-D	0+144.4	0+200.1	22.4	27.5	5.1
2	D-E	0+200.1	0+318	18.5	27.5	9
3	G-H	0+660.4	0+742.2	17	27.5	10.5
4	I-J	0+991.9	1+128.4	21	27.5	6.5
5	L-M	1+379.1	1+495	35.4	27.5	-

c. Grade

On the haul road, the author divides it into 17 road segments consisting of 12 straight road segments and 5 bend road segments on each road segment divided based on changes in road slope (grade) and the presence of bends on the road. From each division of these road segments, road conditions can be determined in each segment such as road grade, superelevation, cross slope.

Picture 3. Road Grade Segment

From observations in the field the author gets the slope of the haul road from HigtWall to RL + 210 varies as in Table 8. The calculation for road slope can use the following formula:

$$Grade\ (\%) = \frac{\Delta h}{\Delta x} x\ 100\%$$

Description :

Δh : Height difference between two points of the measured segment (m)

Δx : Flat distance between two points of the measured road segment (m)

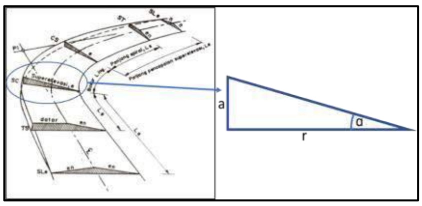
Example of grade calculation on segment a-b:

Grade (%) Segment a – b = (-5,3 / 80.6) × 100 %

= -6,6 %

4.2.2 Superelevation on Curves

Superelevation aims to help the vehicle overcome the bend so that the conveyance does not skid when passing through the bend at maximum spend.



Picture 4. Superelevation

Superelevation or slope at the bend is expressed in tangent angle or can also be expressed in units of mm/m, which is measured from the inner and outer sides of the bend. To get the superelevation value, the speed used is the average speed of the conveyance when passing through the bend which is 40 km/h, while the friction coefficient can use the following calculation:

For V < 80 km/h

$$f = (-0{,}00065\ x\ V) + 0{,}192$$

For V between 80 – 112 km/hour

$$f = (-0{,}00125\ x\ V) + 0{,}24$$

So for the friction coefficient with V = 40 km/hour is:

f = -0.00065 × V + 0.192

= -0.00065 × 40 + 0.192

= 0.166

$$e + f = \frac{V^2}{127\ x\ R}$$

Information :

e = superelevation value

f = friction coefficient

v = speed (km/hour)

R = bend radius (m)

$$R = \frac{v^2}{127 + (e + f)}$$

R = $(40)^2$ / 127 + (0.04 + 0.166)

= 61.15740387

$$e + f = \frac{127\ \times\ R}{v^2}$$

e + 0.166 = (127 × 61.15740387) / 40^2

e = 0.04 m/m

After the superelevation number is obtained, then the height difference that must be made between the inner and outer sides of the bend can be known. By using a superelevation number of 0.04 m/m, the height difference that must be made is:

$$\tan \propto = e$$

tg α = 0,04 ; so α = 2,29˚

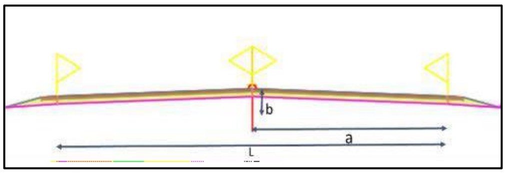
a = r x sin α

= 27,357 m x sin 2,29˚

= 1,093 meter

Based on the above calculations, the result of the calculation of the height difference between the inner and outer sides of the bend that should be made is 1.093 meters or 109.3 cm for the minimum width of the bend road of 27.5 meters.

4.2.3 Cross Slope



Picture 7. Cross Slope

In the conditions in the field the author could not find a cross slope on the research road, so the authors recommend according to the calculation of the minimum haul road width in Table 6, then haul roads with a minimum width of 25 m, the calculation for cross slope and which should be applied by PT Kalimantan Prima persada on the highwall to RL + 210 can use the following formula:

$$a = ½\, x\, L$$

$$b = a\, x\, 20\, mm/m$$

a = ½ x 25 m

a = 12,5 m

b = 12,5 m x 20 mm/m

b = 250 mm = 25 cm

4.2.4 Rolling Resistance

In each segment of the Tempudo Pit Road 3 PT Kalimantan Prima Persada Jobsite INDE has a Rolling Resistance Coefficient value that includes soil or loose sand and crushed stone so that it has a Rolling Resistance Coefficient (CRR) value of 10%. The following is the Rolling Resistance value of segment 1 HD 785 Loaded condition and HD 785 Empty condition.

Rolling Resistance = CRR X Weight of loaded vehicle

= 100 Kg/Ton X 163,08 Ton
= 16.308 kg = 16,3 Ton
Rolling Resistance = CRR X Empty vehicle weight
= 100 Kg/Ton X 72 Ton
= 7.200 kg = 7,2 Ton

4.2.5 Grade Resistance

Grade Resistance is a resistance or the amount of heavy force that resists or helps the conveyance because of the slope of the road traversed by the conveyance. For PT Kalimantan Prima Persada Jobsite INDE has a grade resistance value that varies between segments.

Table 6. Grade Resistance

NO	SEGMEN	Grade (%)	Empty vehicle weight (tons)	Load vehicle weight (tons)	Empty resistance grade (tons)	Payload resistance grade (tons)
1	A-B	-6.6	72	163.08	-473	-1072
2	B-C	-2.6	72	163.08	-186	-422
3	C-D	-1.6	72	163.08	-112	-255
4	D-E	1.1	72	163.08	79	178
5	E-F	-2.4	72	163.08	-171	-388
6	F-G	1.3	72	163.08	91	206
7	G-H	6.6	72	163.08	477	1081
8	H-I	5.6	72	163.08	404	915
9	I-J	8.7	72	163.08	630	1427
10	J-K	10.2	72	163.08	734	1662
11	K-L	7.2	72	163.08	520	1178
12	L-M	6.2	72	163.08	443	1003
13	M-N	5.0	72	163.08	361	819
14	N-O	7.4	72	163.08	531	1202
15	O-P	6.3	72	163.08	454	1028
16	P-Q	2.0	72	163.08	143	323
17	Q-R	2.7	72	163.08	194	441

Table 7. Empty Rimpul Before Repair

No	road segment	Road length	Road width		Grade	GR	For rimpul	For rimpul	Available	speed	time
		(KM)	straight(m)	curve(m)		(kg/ton/%)	RR (kg)	GR (kg)	rimpul (kg)	(Km/jam)	(menit)
1	a-b	0.081	21.7	-	6.6	4.7	7200.0	2241.54	9441.5	38.13	0.13
2	b-c	0.064	20.9	-	2.6	1.9	7200.0	346.73	7546.7	40	0.10
3	c-d	0.056	-	22.4	1.6	1.1	7200.0	126.47	7326.5	40	0.08
4	d-e	0.118	-	18.5	-1.1	0.8	7200.0	0	7200.0	40	0.18
5	e-f	0.184	22.7	-	2.4	1.7	7200.0	293.37	7493.4	40	0.28
6	f-g	0.159	28	-	-1.3	0.9	7200.0	0	7200.0	40	0.24
7	g-h	0.082	-	17	-6.6	4.8	7200.0	0	7200.0	40	0.12
8	h-i	0.250	21.3	-	-5.6	4.0	7200.0	0	7200.0	40	0.37
9	i-j	0.137	-	21	-8.7	6.3	7200.0	0	7200.0	40	0.20
10	j-k	0.122	41.4	-	-10.2	7.3	7200.0	0	7200.0	40	0.18
11	k-l	0.129	40.5	-	-7.2	5.2	7200.0	0	7200.0	40	0.19
12	l-m	0.116	-	35.4	-6.2	4.4	7200.0	0	7200.0	40	0.17
13	m-n	0.207	26.8	-	-5.0	3.6	7200.0	0	7200.0	40	0.31
14	n-o	0.271	21.9	-	-7.4	5.3	7200.0	0	7200.0	40	0.41
15	o-p	0.222	22.5	-	-6.3	4.5	7200.0	0	7200.0	40	0.33
16	p-q	0.101	30.5	-	-2.0	1.4	7200.0	0	7200.0	40	0.15
17	q-r	0.140	31.7	-	-2.7	1.9	7200.0	0	7200.0	40	0.21
	Jumlah										3.66
	Waktu Hauling Isian (Detik)										219.61
	Rata-rata Kecepatan									38.13	

Total Time is 3.66 which means written in decimal numbers, to convert in time (back of the comma x 60)/100 = 3:40 minutes.

Table 8. Load Rimpul Before Repair

No	Road segment	Road length	Road width		Grade	GR	For Rimpul	For Rimpul	available	speed	time
		(KM)	staight (m)	curve (m)		(kg/ton/%)	RR (kg)	GR (kg)	rimpul(kg)	(Km/h)	(Minute)
1	a-b	0.081	21.7	-	-6.6	10.7	16308.0	0	16308.0	22.08	0.22
2	b-c	0.064	20.9	-	-2.6	4.2	16308.0	0	16308.0	22.08	0.17
3	c-d	0.056	-	22.4	-1.6	2.5	16308.0	0	16308.0	22.08	0.15
4	d-e	0.118	-	18.5	1.1	1.8	16308.0	140.57	16448.6	21.89	0.32
5	e-f	0.184	22.7	-	-2.4	3.9	16308.0	0	16308.0	22.08	0.50
6	f-g	0.159	28	-	1.3	2.1	16308.0	186.48	16494.5	21.83	0.44
7	g-h	0.082	-	17	6.6	10.8	16308.0	5154.96	21463.0	16.77	0.29
8	h-i	0.250	21.3	-	5.6	9.1	16308.0	3696.34	20004.3	18.00	0.83
9	i-j	0.137	-	21	8.7	14.3	16308.0	8984.14	25292.1	14.23	0.58
10	j-k	0.122	41.4	-	10.2	16.6	16308.0	12188.66	28496.7	12.63	0.58
11	k-l	0.129	40.5	-	7.2	11.8	16308.0	6131.15	22439.2	16.04	0.48
12	l-m	0.116	-	35.4	6.2	10.0	16308.0	4443.71	20751.7	17.35	0.40
13	m-n	0.207	26.8	-	5.0	8.2	16308.0	2958.22	19266.2	18.69	0.66
14	n-o	0.271	21.9	-	7.4	12.0	16308.0	6381.07	22689.1	15.87	1.03
15	o-p	0.222	22.5	-	6.3	10.3	16308.0	4669.64	20977.6	17.16	0.78
16	p-q	0.101	30.5	-	2.0	3.2	16308.0	460.42	16768.4	21.47	0.28
17	q-r	0.140	31.7	-	2.7	4.4	16308.0	856.83	17164.8	20.97	0.40
	Jumlah										8.11
	Waktu Hauling Isian (Detik)										486.84
	Rata-rata Kecepatan									18.89	

Total time is 8.11 minutes which means it is written in decimal numbers, to convert it into time (back of the comma x 60)/100 = 8:06 minutes.

Table 9. Estimated Conveyance Cycletime Before Improvement

Loader	Loaded Travel Time	Spotting Time di disposal	Dumping	Empty Travel Time	Spotting Time di Front	Total
00.02.28	00.08.06	00.00.35	00.00.34	00.03.40	00.00.16	00.15.40

4.2.6 Haulage Production After Road Geometry Improvement

In field observations after road geometry improvements, data from the Komatsu HD 785 cycle time was obtained and has been averaged with the results of calculations based on cycle time observations in the field (Appendix 4). The actual cycle time of Komatsu HD 785 is as follows:

Table 10. Actual Cycle Time KOMATSU HD785-7

Loader	Loaded Travel Time	Spotting Time di disposal	Dumping	Empty Travel Time	Spoting Time di Front	Total
00.02.28	00.07.28	00.00.35	00.00.34	00.05.45	00.00.16	00.17.07

There are 6 units of Komatsu HD 785 hauling equipment operating for overburden stripping in Higtwall loading to RL 210. To be able to compare production after actual

improvement and after theoretical improvement we calculate the production with the following formula:

$$Q = \frac{q1 \times k \times n \times eff \times 60}{CT}$$

In the following table is the calculation of the actual production of Komatsu HD 785 conveyance with Komatsu PC 2000 excavator.

Table 11. Actual Production Before Improvement

Actual HD 785-7 Production			
Bucket Capacity	q1	12	m^3
Bucket Fill Factor	K	0.85	
Fill amount	N	5	
Work efficiency	E	0.83	
Cycle Time	CTm	1024.2	S
Swell Factor	Sf	0.83	
Effective working hours		20.75	h
Number of haulers		6	
Production	Q	123.49	BCM/h
		204.80	BCM/h/km
		2,562.49	BCM/Day
		15,374.94	BCM/Day/6 unit
		461,248.21	BCM/Month

4.2.7 Rimpul Analysis

Table 12. Analysis of Empty Rimpul After Improvement

No	Road segment	Road Length	Road width		Grade	GR	For rimpul	For rimpul	available	speed	time
		(KM)	straight	curve (m)		(kg/ton/%)	RR (kg)	GR (kg)	rimpul (kg)	(Km/h)	(minutes)
1	a-b	0.081	21.7	-	6.6	4.7	7200.0	2241.54	9441.5	38.13	0.13
2	b-c	0.064	20.9	-	2.6	1.9	7200.0	346.73	7546.7	40	0.10
3	c-d	0.056	-	22.4	1.6	1.1	7200.0	126.47	7326.5	40	0.08
4	d-e	0.118	-	18.5	-1.1	0.8	7200.0	0	7200.0	40	0.18
5	e-f	0.184	22.7	-	2.4	1.7	7200.0	293.37	7493.4	40	0.28
6	f-g	0.159	28	-	-1.3	0.9	7200.0	0	7200.0	40	0.24
7	g-h	0.082	-	17	-6.6	4.8	7200.0	0	7200.0	40	0.12
8	h-i	0.250	21.3	-	-5.6	4.0	7200.0	0	7200.0	40	0.37
9	i-j	0.137	-	21	-8.0	5.8	7200.0	0	7200.0	40	0.20
10	j-k	0.122	41.4	-	-8.0	5.8	7200.0	0	7200.0	40	0.18
11	k-l	0.129	40.5	-	-7.2	5.2	7200.0	0	7200.0	40	0.19
12	l-m	0.116	-	35.4	-6.2	4.4	7200.0	0	7200.0	40	0.17
13	m-n	0.207	26.8	-	-5.0	3.6	7200.0	0	7200.0	40	0.31
14	n-o	0.271	21.9	-	-7.4	5.3	7200.0	0	7200.0	40	0.41
15	o-p	0.222	22.5	-	-6.3	4.5	7200.0	0	7200.0	40	0.33
16	p-q	0.101	30.5	-	-2.0	1.4	7200.0	0	7200.0	40	0.15
17	q-r	0.140	31.7	-	2.7	1.9	7200.0	378.29	7578.3	40	0.21
	Jumlah										3.66
	Waktu Hauling Isian (Detik)										219.61
	Rata-rata Kecepatan									38.13	

The total time is 3.66 minutes which means that written in decimal numbers, to convert in time (back of the comma x 60)/100 = 3:40 minutes.

Table 13. Load Rimpul After Repair

No	Road segment	Road length (KM)	Road width		Grade	GR (kg/ton/%)	For rimpul RR (kg)	For rimpul GR (kg)	available rimpul (kg)	speed (Km/h)	time (Minutes
			straight(m)	curve (m)							
1	a-b	0.081	21.7	-	-6.6	10.7	16308.0	0	16308.0	22.08	0.22
2	b-c	0.064	20.9	-	-2.6	4.2	16308.0	0	16308.0	22.08	0.17
3	c-d	0.056	-	22.4	-1.6	2.5	16308.0	0	16308.0	22.08	0.15
4	d-e	0.118	-	18.5	1.1	1.8	16308.0	140.57	16448.6	21.89	0.32
5	e-f	0.184	22.7	-	-2.4	3.9	16308.0	0	16308.0	22.08	0.50
6	f-g	0.159	28	-	1.3	2.1	16308.0	186.48	16494.5	21.83	0.44
7	g-h	0.082	-	17	6.6	10.8	16308.0	5154.96	21463.0	16.77	0.29
8	h-i	0.250	21.3	-	5.6	9.1	16308.0	3696.34	20004.3	18.00	0.83
9	i-j	0.137	-	21	8.0	13.0	16308.0	7514.73	23822.7	15.11	0.54
10	j-k	0.122	41.4	-	8.0	13.0	16308.0	7514.73	23822.7	15.11	0.48
11	k-l	0.129	40.5	-	7.2	11.8	16308.0	6131.15	22439.2	16.04	0.48
12	l-m	0.116	-	35.4	6.2	10.0	16308.0	4443.71	20751.7	17.35	0.40
13	m-n	0.207	26.8	-	5.0	8.2	16308.0	2958.22	19266.2	18.69	0.66
14	n-o	0.271	21.9	-	7.4	12.0	16308.0	6381.07	22689.1	15.87	1.03
15	o-p	0.222	22.5	-	6.3	10.3	16308.0	4669.64	20977.6	17.16	0.78
16	p-q	0.101	30.5	-	2.0	3.2	16308.0	460.42	16768.4	21.47	0.28
17	q-r	0.140	31.7	-	2.7	4.4	16308.0	856.83	17164.8	20.97	0.40
	total										7.99
	Fill Hauling Time (Seconds)										479.13
	Average Speed									19.09	

The total time is 7.99 minutes which means that written in decimal numbers, to convert to time (back of the comma x 60)/100 = 8:59 minutes.

Table 14. Estimated Conveyance Cycletime After Improvement

Loader	Loaded Travel Time	Spotting Time di disposal	Dumping	Empty Travel Time	Spoting Time di Front	Total
00.02.28	00.07.59	00.00.35	00.00.34	00.03.40	00.00.16	00.15.33

4.2.8 Theoretical Production of Haulage Equipment After Road Improvement

Road condition improvement simulation is used to estimate the theoretical production of the haulage equipment. It is based on the data of haul road conditions that have been improved, and simulated based on data analysis.

Table 15. Production Conveyance Rhizome Analysis After Improvement

Actual HD 785-7 Production			
Bucket Capacity	q1	12	m³
Bucket Fill Factor	K	0.85	
Fill amount	N	5	
Work efficiency	E	0.83	
Cycle Time	CTm	919.8	S
Swell Factor	Sf	0.83	
Effective working hours		20.75	h
Number of haulers		6	
Production	Q	137,51	BCM/h
		228,04	BCM/h/Km
		2.853,34	BCM/Day
		17.120,04	BCM/Day/6 unit
		513.601,24	BCM/Month

Based on the results of actual and theoretical production calculations after road geometry improvements, the actual production still does not reach the expected target but from the production data the results of the rhombus analysis have met the targets set by the company.

Table 16. Production After Improvement

	Actual production after improvement	Production analysis after improvement	Unit
Q	123.49	137,51	BCM/h
	204.8	228,04	BCM/h/Km
	2,562.49	2.853,34	BCM/Day
	15,374.94	17.120,04	BCM/Day/6 unit
	461,248.21	513.601,24	BCM/Month

Based on the actual average speed before the improvement of road geometry in March with a value of 17.76 Km/h and when the road geometry improvement process in April got an average speed value of 18.30 km/h. Meanwhile, the average speed value after the improvement in May 19.13 km/h. Meanwhile, the average speed value after repairs in May 19.13km/h.

Picture 8. Trend Speed HD 785-7 March-May Period

Based on the results of the improvement of road geometry, the average speed is 19.13 Km/h but this value still does not reach the target speed set by the company which is 20.5 Km/h.

4.2.9 Improved Operator Performance

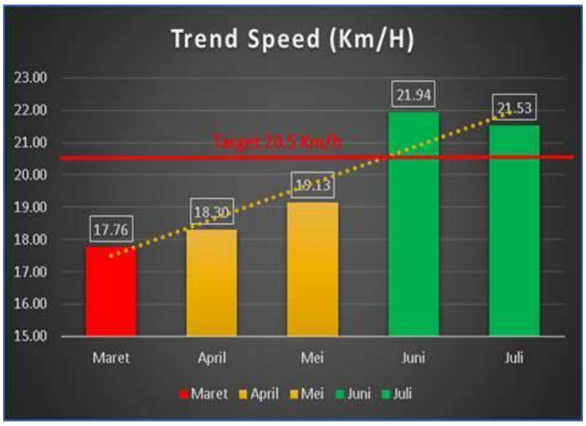
4.2.9.1 Socialization and refresh knowladge

According to Soejono Dirdjosisworo (1985) for someone to know, understand and at the same time carry out their rights and obligations based on their respective status roles according to their duties, each individual or human being needs to socialize to learn and develop patterns of social behavior with other community members.

4.2.9.2 Operator Role Model (OPROM)

In an effort to increase the competitive spirit in each individual operator, as well as to test the best performance of operators, the operators who have the best skills are united in 1 PC 2000 fleet.

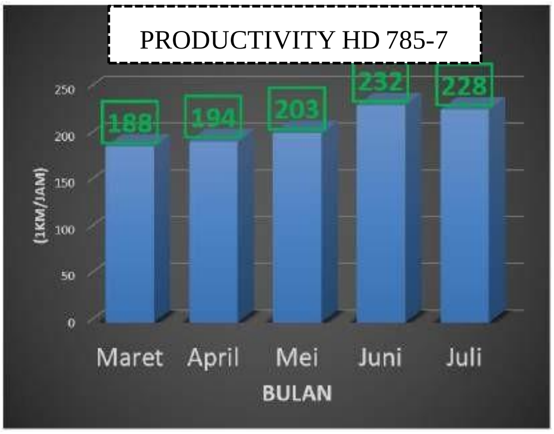
Operator performance in June-July has increased, in June getting an average speed of 21.94 km/h and in July 21.53 km/h. From the speed obtained, it has evceeded the target set by the company which is 20.5 km/h.



Picture 9. Speed of operator performance improvement.

4.2.10 Conveyance Productivity

The average speed of HD785-7 from April to July, it has an effect on increasing the productivity of HD 785 with the best achievement at 232 BCM/hour.



Picture 10. Trend Productivity HD785-7 March-July Period

5 Conclusions and Suggestions

5.1 Conclusions

From the results of this study, there are several things that can be concluded as follows:

a. The results of the improvement of road geometry obtained the average speed value from 17.76 Km/h to 19.13 Km/h. but the value still does not reach the target speed set by the company which is 20.5 Km/h. As for the efforts to improve operator performance in June-July so that the month has increased. In June, the avarage speed was 21.94 km/h and in July it was 21.53 km/h. From the speed obtained, it has exceeded the target set by the company which is 20.5 Km/h.

b. From the production analysis of Komatsu HD 785 hauling equipment operating for overburden stripping at Higtwall loading to RL 210, there are 6 units. The production of Komatsu HD 785-7 before repair is 104.98 BCM/hour. For the analysis of the estimated production of Komatsu HD785-7 conveyance after repair is 137.51 BCM/Hour. The percentage increase in production before the repair of 104.98 increased to 131.62 BCM/Hour or an increase of 32.11%. But it is still below the estimated production of rhizome analysis results after improvement, which is 137.51 BCM/hour or -4.28%.

c. With efforts to improve operator performance in June-July so that the month has increased. In June, the avarage speed was 21.94 km/h and in July 21.53 Km/h. From the speed obtained, it has exceeded the target set by the company which is 20.5 Km/h. Based on the achievement of monthly production has increased from June-July which is where the actual production value after improvement has exceeded the company's target that has been planned.

5.2 Suggestions

The author suggests that:

a. Supervise the road geometry as well as the texture of the haul road surface which causes the total resistance to increase so as to reduce the speed value and increase the productivity of Komatsu HD 785-7 by conducting inspections with the Production group leader team every day so that the overburden transportation process has no obstacles.

b. Longterm and midterm road segments are paved and AWR (All Weather Road) so that later support equipment (graders) can focus on roads that have poor soil bearing capacity.

c. Increase the installation of signs and post guides along the haul road for guidance for heavy equipment operators.

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