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Evaluation Of Existing Hauling Road Geometry To Increase Nickel Laterite Production At PT. putra mekongga sejahtera

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Graphical Abstract

Abstract
PT Putra Mekongga Sejahtera is a nickel laterite mining company located in Pomalaa District, Kolaka Regency, Southeast Sulawesi Province. In a mining activity, many factors affect the aspects of production achievement, one of which is the haul road. Haul roads make a major contribution to smooth transportation operations if the road geometry is in accordance with the dimensions of the conveyance used, then the production target of 80,000 tons / month can be achieved. The current field conditions in terms of road geometry are considered unrepresentative for the movement of hauling equipment and can interfere with mining activities. Based on actual haul road geometric measurements between 5.41-16.98 meters while the theoretical road width for straight roads is 8.72 meters. The actual bend road width ranges from 5.50-15.10 meters while the theoretical bend road width is 14.32 meters. The actual road slope ranges from 0.35% to 17.30% while the maximum road slope is 12%. After evaluation, there are 4 straight road segments that need to be increased in width, namely segments AB, BC, CD and DE and 5 segments of bend road width, namely segments AB, BC, CD, DE and EF, as well as grade reduction in segments AB, BC, DE and EF. Hino FM 260 JD dump truck production before road geometry improvement is 3029 tons/day or 78761.75 tons/month. Hino FM 260 JD dump truck production after ideal road geometry improvement is 3143 tons/day or 81724.38 tons/month.

Keywords: Haul road, Road geometry, Production

1. INTRODUCTION

PT Putra Mekongga Sejahtera is one of the companies engaged in nickel laterite mining located in the Dawi-Dawi area, Pomalaa District, Kolaka Regency, Southeast Sulawesi Province. PT PMS has an IPPKH with an area of 388 Ha. PT Putra Mekongga Sejahtera applies open mining system with Open Cut and Open Pit methods with several mining operation locations.

Open pit mining is one of two known mining systems, namely open pit and underground mining. Where all mining activities or activities are carried out above or relatively near the surface of the earth and the workplace is directly related to the outside world. In the mining process with the open pit mining method, there are many factors that will affect mining activities. One of the mining activities that can affect production is the hauling process. In this transportation process, there are several factors that can affect transportation operations including road conditions, equipment conditions, weather conditions and so on [1].

Haul road geometry is a component of the haul road where in planning its manufacture for straight road reconstruction, road width on bends and road slopes. Production road geometry is a measure of the physical form of production roads which includes road width (in a straight state and width at the bend) and road slope [2].

One of the factors that cause the production target not to be achieved is the condition of the road geometry that is not in accordance with the haul road standard [3]. Based on the actual road at PT Putra Mekongga Sejahtera, there is a road width that does not reach the minimum standard and there is a road slope that exceeds the standard of 12%, causing the travel time of the conveyance to increase or get longer which causes the cycle time to get bigger.

Road geometry that is not in accordance with the standard causes production not to be achieved so it is necessary to evaluate road geometry on production. In this study, the evaluation of road geometry on production uses the standard Kepmen ESDM No 1827 Th (2018).

2. METHOD

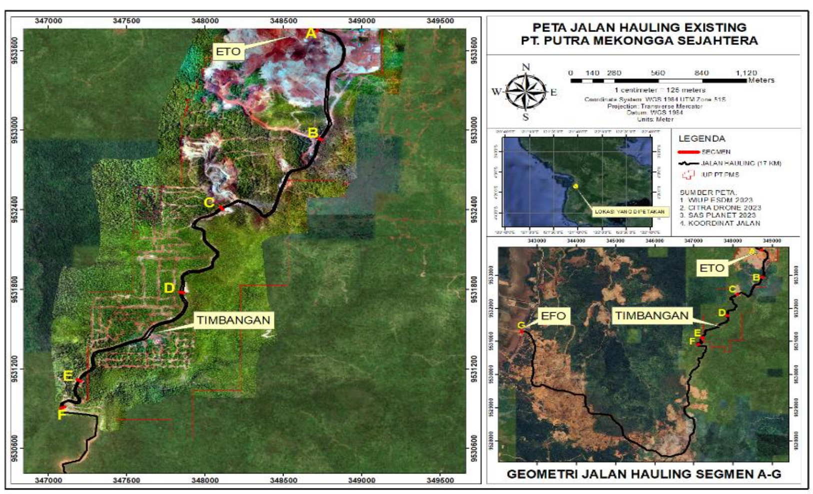
The research method applied while in the field is the direct observation method (observational) by collecting data using observation techniques (collecting data from direct observations at the research location) to complement the data from field observations with quantitative methods, namely research methods in which many numbers are used, starting from the data collection process to its interpretation.

3. RESULTS AND DISCUSSION

A. Road Geometry

This final project research was conducted on the mining road from the exportable transport ore (ETO) mine to the exportable final ore (EFO) location used for hauling ore with a track length of 17 km, but the road geometry evaluation only focuses on the road within the mining business license (IUP) with a track length of 4.38 km from the exportable transport ore (ETO). This activity was carried out from early November to late November. Heavy equipment used in ore hauling activities include Komatsu PC 200 and Komatsu PC 300 excavators and Hino FM 260 JD dump trucks. This study is divided into 6 road segments, namely segment AB which has a length of 1,071 meters, BC which has a length of 1,016 meters, CD which has a length of 900 meters, DE which has a length of 1,103 meters, EF which has a length of 297 meters and FG which has a length of 12,613 meters. Segments AB, BC, CD, DE and EF are road segments within the mining business license (IUP) while the FG segment is a road that is outside the mining business license (IUP).

Gambar 1. Mine road profile from pit to stockpile PT. Putra Mekongga Sejahtera



B. Straight Road Width

Based on the provisions of Kepmen ESDM No. 1827 Th (2018) the straight road width for Hino FM 260 JD dump trucks with a width of 2.49 m can be calculated using the following equation.

$$W = (1,5L + 0,5)X \quad (1)$$

Where W is the straight road width (meters), L is the number of lanes (meters) and Ct is the conveyance width (meters).

Therefore, the minimum road width for 2 lanes is:

$$\begin{aligned} W &= (1,5 \text{ x } 2 \text{ m} + 0,5) \text{ x } 2,49 \text{ m} \\ &= 3,5 \text{ m x } 2,49 \text{ m} \\ &= 8,715 \text{ m} \end{aligned}$$

Based on the research conducted, there are several road sections that do not meet the minimum road width for straight roads, so it is necessary to optimize the road width for straight roads. Straight road width data can be seen in Table 1 and Table 2.

Tabel 1 Straight Road Geometry Segment BC (Actual)

Segment section		Number of lanes	Minimum road width (m)	Actual road width (m)	Average Road Width (m)	Description
Load	Blank					
2	16	2	8,72	10,97	9,35	Safe
5	13			10,61		Safe
6	12			9,89		Safe
7	11			9,65		Safe
10	8			7,71		Unsafe
11	7			7,84		Unsafe
15	3			8,25		Unsafe
16	2			8,47		Unsafe
17	1			10,73		Safe

Tabel 2 Straight Road Geometry Segment BC (Repair)

Segment section		Number of lanes	Minimum road width (m)	Width of repair road (m)	Average Road Width (m)	Description
Load	Blank					
2	16	2	8,72	10,97	9,64	-
5	13			10,61		-
6	12			9,89		-
7	11			9,65		-
10	8			8,715		1,01
11	7			8,715		0,87
15	3			8,715		0,47
16	2			8,715		0,24
17	1			10,73		-

In this study, the hauling path is divided into 6 segments, namely AB, BC, CD, DE, EF and FG segments which have different lengths with a total distance of 17 km. Each segment is divided into sections that have different lengths. In this segment it was found that there are still parts of the road that do not meet the standard straight road width of 8,715 meters for 2 lanes. In segment AB there is 1 straight road section out of a total of 11 straight road sections that have a width less than the minimum straight road width, Segment BC there are 4 straight road sections out of a total of 9 straight road sections that have a width less than the minimum straight road width, Segment CD there are 2 straight road sections out of a total of 4 straight road sections that have a width less than the minimum straight road width, Segment DE there are 2 straight road sections out of a total of 7 straight road sections that have a width less than the minimum straight road width and Segment EF there are no straight road sections that have a width less than the minimum straight road width.

C. Bend Road Width

The width of the road at the bend is generally wider than the width of the straight mine road. This is done to provide more space for the operator if he makes a mistake when passing through the bend. The calculation of the minimum width of the bend mining road can be calculated using the following equation:

$$W_{min} = 2\,(U + Fa + Fb + Z) + C \quad (2)$$
$$C = Z = (U + Fa + Fb)/2$$

Where W is the width of the haul road at the bend (meters), Fa is the width of the front span (meters), Fb is the width of the rear span (meters), U is the width of the wheel tracks (meters), C is the distance between two dump trucks that will intersect and Z is the distance of the outer side of the dump truck to the edge of the road (meters).

Therefore, the minimum bend road width for 2 lanes is:

C= Z = (U + Fa + Fb)/2
= (2,05 m + 0,81 m + 1,23 m)/2
= 4,09 m / 2
= 2,045 m

W = 2 (U + Fa + Fb + Z) + C
= 2 (2,05 m + 0,81 m + 1,23 m + 2,045 m) + 2,045 m
= 2 (6,135 m) + 2,045 m
= 12,27 + 2,045 m
= 14,315 m

Based on the research conducted, there are several parts of the road that do not meet the minimum road width standard on the bend, which is 14.315 m for 2 lanes, so it is necessary to optimize the road width for the bend road. Straight road width data can be seen in Table 3 and Table 4.

Tabel 3 Segment AB Bend Road Geometry (Actual)

Segment section Load	Segment section Blank	Number of lanes	Minimum bend width (m)	Actual bend width (m)	Average bend width (m)	Description
3	14	2	14,32	7,55	9,22	Unsafe
4	13			8,69		Unsafe
6	11			6,38		Unsafe
7	10			9,08		Unsafe
11	6			14,39		Safe

Tabel 4 Segment AB Bend Road Geometry (repair)

Segment section Load	Segment section Blank	Number of lanes	Minimum bend width (m)	Bend width repair (m)	Average bend width (m)	Description
3	14	2	14,32	14,32	14,33	6,77
4	13			14,32		5,62
6	11			14,32		7,93
7	10			14,32		5,23
11	6			14,39		-

Based on the research conducted, it was found that many road bends did not meet the minimum width standard of the bend road which is 14.315 m for 2 lanes. In segment AB there are 4 bend sections out of a total of 5 bend sections that have less than the minimum width of the bend road, segment BC there are 8 bend sections out of a total of 8 bend sections that have less than the minimum width of the bend road, segment CD there are 5 bend sections out of a total of 5 bend sections that have less than the minimum width of the bend road, segment DE there are 6 bend sections out of a total of 7 bend sections that have less than the minimum width of the bend road and segment EF there are 7 bend sections out of a total of 7 bend sections that have less than the minimum width of the bend road. This can increase the risk of accidents and hinder the speed of dump trucks when passing.

D. Road Slope

Based on the provisions of the Minister of Energy and Mineral Resources Decree No. 1827 Th (2018), the maximum road slope that can be traversed properly by transport equipment, especially dump trucks, is 12%. The road slope can be calculated using the following equation:

$$Grade\ (\alpha) = \frac{\Delta h}{\Delta y} \times 100\% \quad (3)$$

Example of road slope calculation on Segment AB (load), part 1:

- High (Δh) : 1,05 m
- Lenght (Δy) : 49,57 m

$$Grade\ (\alpha) = \frac{\Delta h}{\Delta y} \times 100\%$$
$$= \frac{1,05}{49,57} \times 100\%$$
= 0,0211 m x 100%
= 2,11%

Based on the research conducted, there are several parts of the road slope above 12 or do not meet the maximum slope standards that have been determined, so it is necessary to optimize or improve the road slope. Straight road width data can be seen in Table 5 and Table 6.

Table 5 Road Slope Segment EF (Actual)

Segment section		Length	Actual	*Grade* (%)		Grade Average *(%)*		Description
Load	Blank	(m)	height (m)	Load	Blank	Load	Blank	
1	8	47,11	-3,61	-7,66	7,66	-8,76	8,76	Safe
2	7	36,85	-4,29	-11,65	11,65			Safe
3	6	52,51	-5,24	-9,99	9,99			Safe
4	5	25,62	-4,14	-16,17	16,17			Unsafe
5	4	35,75	-5,01	-14,02	14,02			Unsafe
6	3	14,88	-1,64	-11,05	11,05			Safe
7	2	55,82	-0,99	-1,77	1,77			Safe
8	1	29,23	0,65	2,21	-2,21			Safe

Table 6 Road Slope Segment EF (Repair)

Segment section		Length	High after	Cut (m)	Grade change *(%)*		Grade Average *(%)*	
Load	Blank	(m)	repair (m)		Load	Blank	Load	Blank
1	8	47,11	-5,11	1,5	-10,85	10,85	-8,32	8,32
2	7	36,85	-4,29	-	-11,64	11,64		
3	6	52,51	-6,25	1,0	-11,90	11,90		
4	5	25,62	-2,64	-1,5	-10,31	10,31		
5	4	35,75	-4,01	-1,0	-11,22	11,22		
6	3	14,88	-1,64	-	-11,05	11,05		
7	2	55,82	-0,99	-	-1,77	1,77		
8	1	29,23	0,65	-	2,21	-2,21		

Based on the research conducted, it was found that there are many road slopes that do not meet the maximum width standard of the road slope, which is 12% for the road. In segment AB there are 3 sections that exceed the road slope standard, segment BC there is 1 segment section that exceeds the road slope standard, segment DE there are 2 segment sections that exceed the road slope standard and segment EF there are 2 segment sections that exceed the road slope standard.

From several segments observed, there are different road slopes in each segment. The hauling road that has the biggest slope is in the DE and EF segments. This will affect the speed of the passing dump truck due to the large value of the road slope that the dump truck unit must overcome when crossing the road. Because the higher the slope of the road, it hinders the productivity of the conveyance because the slower the speed of the dump truck, the higher the cycle time, which causes lower productivity.

F. Dump Truck Load Time and Free Time

Load and empty dump truck time data is the time taken directly when the dump truck is operating or hauling ore. Data collection of load and empty times is carried out in each segment or hauling lane. Dump Truck load and empty time data can be seen in Table 7 and Table 8.

Table 7 Comparison of Travel Time Before and After Improvement (Load)

Segment	Time (second)		Difference
	Actual	Repair	(second)
AB	140,81	117,18	23,63
BC	134,31	123,98	10,33
CD	90,17	90,17	-
DE	308,53	230,19	78,34
EF	47,23	22,85	24,38
FG	2304,39	2304,39	-
Total Load Time (seconds)	3025,44	2888,76	136,68
Total Load Time (minutes)	50,42	48,146	2.27

Table 8 Comparison of Travel Time Before and After Improvement (Blank)

Segment	Time (second)		Difference
	Actual	Repair	(seconds)
GF	1545,96	1545,96	-
FE	41,46	30,24	11,22
ED	148,67	114,94	33,73
DC	86,70	86,70	-
CB	105,01	103,75	1,26
BA	117,26	107,67	9,56
Total Load Time (seconds)	2045,05	1989,26	55,79
Total Load Time (minutes)	34,08	33,15	0,93

G. Fixed Time

Fixed time data is the actual circulating time of the tool taken directly when the tool is operating. Fixed time data is one of the input data used in tool productivity. Fixed time data collection is carried out on exportable transport ore (ETO) and exportable final ore (EFO), fixed time data can be seen in Table 9.

Table 9 Fixed Time Details

Activity	Fixed Time (seconds)
Maneuvers Loading	42,22
Loading	120,53
Manuver Dumping	51,03
Dumping	60,66

H. Rimpull Dump Truck Hino FM 260 JD

To determine the ability of the dump truck to pull the load, the author uses the rimpull measurement method. The rimpull generated by the engine, listed in Table 10, must be greater than the sum of grade and rolling resistance for the dump truck to accelerate. Grade resistance is influenced by the slope of the road, it is positive when going uphill, but negative when going downhill. While rolling resistance is influenced by the condition of the mine road, both the type of coating, maintenance and the depth of tire penetration.

The rimpull value is obtained through calculation using the following equation.

$$Rimpul\ (RP) = \frac{375 \times \text{Power (hp)} \times efficiency\ Drive\ Tarin}{\text{Speed (mph)}} \quad (4)$$

An example calculation to get the maximum rimpull in 1st gear for a Hino FM 260 JD dump truck with a maximum power of 260 HP and a drive train efficiency of about 85% is as follows:

$$Rimpul\ (RP) = \frac{375 \times 260 \times 85\%}{6,13}$$

$$Rimpul\ (RP) = 13.519,58 \text{ lbs}$$

Table 10 Fixed Time Details

Teeth	Speed (kmh)	Speed (mph)	*Rimpul (lbs)*
C	6,84	4,25	19.500
1	9,86	6,13	13.519,58
2	13,85	8,61	9.625,436
3	18,75	11,65	7.113,734
4	25,02	15,55	5.329,582
5	34,29	21,31	3.889,019
6	48,19	29,95	2.767,112
7	65,20	40,52	2.045,286
8	87,04	54,09	1.532,169

The calculation of rolling resistance and grade values can be calculated using the following equation:

- *Rolling resistance*

$$RR = C_{RR} \text{ x Vehicle weight } (lbs) \quad (5)$$

- *Grade resistance*

$$GR = 20 \text{ x } Grade\,(\%) \text{ x Vehicle weight } (lbs) \quad (6)$$

Example of calculation of rolling resistance value and grade:
- Empety Weight : 12,00 ton / 26.455,47 lbs
- Fill Weight : 36,56 ton / 80.601,00 lbs
- *Grade* : - 5.92 (loaded) (segment AB section 12) and 5.92 (empty) (segment BA section 5)
- C_{RR} : 3% (load) (segment AB section 12) and (empty) (segment BA section 5)

1. *Dump Truck* load
   $RR = C_{RR}$ x Vehicle weight (*lbs*)
   RR = 3% x 80.601,00 lbs
   RR = 2418,03 lbs

   GR = 20 lbs/ton x *Grade* (%) x Vehicle weight (*lbs*)
   GR = 20 lbs/ton x -5,92 % x 36,56 ton
   GR = -4.314,08 lbs

   So the total minimum rimpull required for the dump truck to accelerate must be greater than 2,418.03 lbs + (-4,314.08) lbs = - 1,896.05 lbs, then theoretically the operator can use gear 7 with a maximum rimpull of 2,045.286 lbs and a maximum speed of 40.52 mph. this happens because the road conditions are downhill, so it requires excessive engine brake by using a low gear resulting in deceleration. However, the gear used is gear 4 with a maximum speed of 15.55 mph and an actual speed of 13.45 mph. this happens because the road conditions are downhill, so it takes excess engine brake by using a low gear so that deceleration occurs.

2. *Dump Truck* blank
   $RR = C_{RR}$ x Vehicle weight (*lbs*)
   RR = 3% x 26.455,47 lbs
   RR = 793,66 lbs

   GR = 20 lbs/ton x *Grade* (%) x Vehicle weight (*lbs*)
   GR = 20 lbs/ton x 5,92 % x 12 ton
   GR = 1.420,8 lbs

   So the total minimum rimpull required for the dump truck to accelerate must be greater than 793.66 lbs + 1,420.8 lbs = 2,214.46 lbs, then theoretically the operator can use gear 6 with a maximum rimpull of 3,889.019 lbs and a maximum speed of 29.95 mph. this happens because the road conditions are uphill, so excessive acceleration is required. However, the gear used is gear 5 with a maximum speed of 21.31 mph and an actual speed of 17.91 mph. this happens because the road conditions are uphill, so excessive acceleration is needed.

I. Cycle Time Dump Truck Hino FM 260 JD

The calculation is done by adding up the fixed time, loading time and empty time of the dump truck, listed in Table 11. The actual Cycle Time data was collected for the hauling road for the period of November 2023.

Table 11 Cycle Time

Activty	Value (Seconds)		
	Actual	Repair	Difference
Maneuvers Loading	42,22	42,22	-
Loading	120,53	120,53	-
Hauling (Load)	3.025,44	2.888,76	136,68
Manuver Dumping	51,03	51.03	-
Dumping	60,66	60.66	-
Hauling (Blank)	2.045,05	1.989,26	55,79
Cycle Time (Seconds)	5.344,93	5.152,46	192,47
Cycle Time (minutes)	89,1	85,87	3,23

J. Produktivity Dump Truck Hino FM 260 JD

Haulage productivity is closely related to the effective working time of the equipment which is influenced by the condition of the equipment and operator. The productivity of hauling equipment before and after changes in road geometry in mining activities at the mine front can be seen in Table 12.

Calculation of conveyance productivity before road geometry changes as follows:

Description:

- Production *dump truck* : 24,56 bcm (ton)
- Work efficiency : 63 %
- Totals *dump truck* : 29

$$Q = \frac{q \times 60 \times E \times M}{Cm} \quad (7)$$
$$Q = \frac{24{,}56\ ton \times 60 \times 0{,}63 \times 29}{89{,}1}$$
$$Q = \frac{11.168{,}71}{89{,}1}$$
$$Q = 302{,}93\ ton/hours$$
$$Q = 3.029{,}3\ ton/day \text{ (10 hours)}$$
$$Q = 78.761{,}75\ ton/month \text{ (26 day)}$$

Calculation of hauling equipment productivity after road geometry changes as follows:

Description :

- Production *dump truck* : 24,56 bcm (ton)
- Work efficiency : 63 %
- Totals *dump truck* : 29

$$Q = \frac{q \times 60 \times E \times M}{Cm} \quad (7)$$
$$Q = \frac{24{,}56\ ton \times 60 \times 0{,}63 \times 29}{85{,}87}$$
$$Q = \frac{11.168{,}71}{85{,}87}$$
$$Q = 314{,}32\ ton/hours$$
$$Q = 3.143{,}2\ ton/day \text{ (10 hours)}$$
$$Q = 81.724{,}38\ ton/month \text{ (26 day)}$$

Table 12 Productivity before and after road geometry changes

Produktivity	Ton/Hours	Ton/day	Ton/month
Before road geometry changes	302,93	3.029,3	78.761,75
After road geometry changes	314,32	3.143,2	81.724,38
Difference	11,39	113,9	2.962,63

4. CONCLUSIONS

Based on the research conducted, calculations and discussions regarding the evaluation and influence of hauling road geometry from the exportable transport ore (ETO) mine to the exportable final ore (EFO) location on increasing production at PT Putra Mekongga Sejahtera which has been discussed previously, the authors can draw conclusions, namely:

1. After evaluating the road geometry, there are 9 segments whose actual straight road width is below the minimum standard of straight road width, which is 8.715m. On the bend road width there are 30 segment sections whose actual road width is below the minimum standard of the bend road width of 14.32 m while on the road slope there are 18 segment sections that have a slope of more than 12%.
2. Road geometry greatly affects travel time, especially on the slope of the road because the higher the slope or the steeper the slope of a road, the travel time or speed of the tool decreases which results in a greater cycle time and makes productivity decrease. After simulating road geometry improvements, there was a decrease in travel time from 5,070.86 seconds to 4,878.02 seconds with a difference of 192.84 seconds or 3.214 minutes.

3. After the road geometry improvement simulation, there was an increase in dump truck productivity from 302.93 tons/hour or 78,761.75 tons/month to 314.32 tons/hour or 81,724.38 tons/month.

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