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Hauling Distance Impact on Feasibility of Mining Coal Reserves

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ABSTRACT : *One of the important variables related to operational mining costs is distance. The distance variable will determine the number of mining costs. The farther the distance travelled to move the mined material, the higher the cost. The case study is a coal mining plan using the open pit mining method in the East Kalimantan area. The mining plan consists of mine design and mining cash flow plan according to the number of reserves that are feasible to be mined. The mining design optimization process is based on a simulation of the transportation distance plan based on the closest to the furthest distance based on conditions in the field. Based on the simulation results of the transport distance, a scenario of mining costs in the form of the cash flow will be obtained, along with the minimum amount of reserves that are feasible to be mined. Interim results show a reduction in the relative mining limit with an increase in haulage distance. The research results show that adding hauling distance will increase the transportation cost significantly, which is 3.3 $/ton to 5.1 $/ton. The addition of hauling distance will also significantly increase production costs, from 16.89 $/ton to 18.69 $/ton.*

KEYWORDS *: cost, distance, mining, optimization, planning*

I. INTRODUCTION

Cost is the main thing in a business, including the mining business. The mining business's costs consist of capital and operational costs, which consist of direct and administrative costs. The direct operational cost component is a component of costs incurred to carry out mining production, starting from land clearing and overburden removal to marketing (distribution) of mining products to consumers. All operational mining costs will be recorded in the company's cash flow. The number of operational costs incurred for mining production must be proportional to the number of reserves worth mining. If the number of reserves that are feasible to be mined is not proportional to the costs incurred, it will result in losses to the mining business. One of the important variables related to operational mining costs is distance. The distance variable will determine the number of mining costs. The farther the distance travelled to move the mined material, the higher the cost. The case study in this study is a coal mining plan using the open pit mining method in the East Kalimantan area, Indonesia. The mining plan consists of mine design and mining cash flow plan according to the number of reserves that are feasible to be mined. The mining design optimization process is based on a simulation of the transportation distance plan based on the closest to the furthest distance based on conditions in the field. Based on the hauling distance design simulation results, a scenario of mining costs in the form of the cash flow will be obtained, along with the minimum amount of reserves that are feasible to be mined.

II. METHODS

The stages of assessing coal reserves can be seen in Figure 1. It begins with data processing to obtain a cost model, which is presented in the form of a mining business cash flow. The data needed to get the cost model are capital expenditure (CAPEX/investment) and cost (including stripping cost), which are determined based on the variable transportation distance. Based on the cost model, the value of the break-even stripping ratio (BESR) can be determined as a measure of the ratio of the volume of overburden excavation to obtain each tonnage of coal. The volume of overburden and coal production has previously been determined based on the mining design.

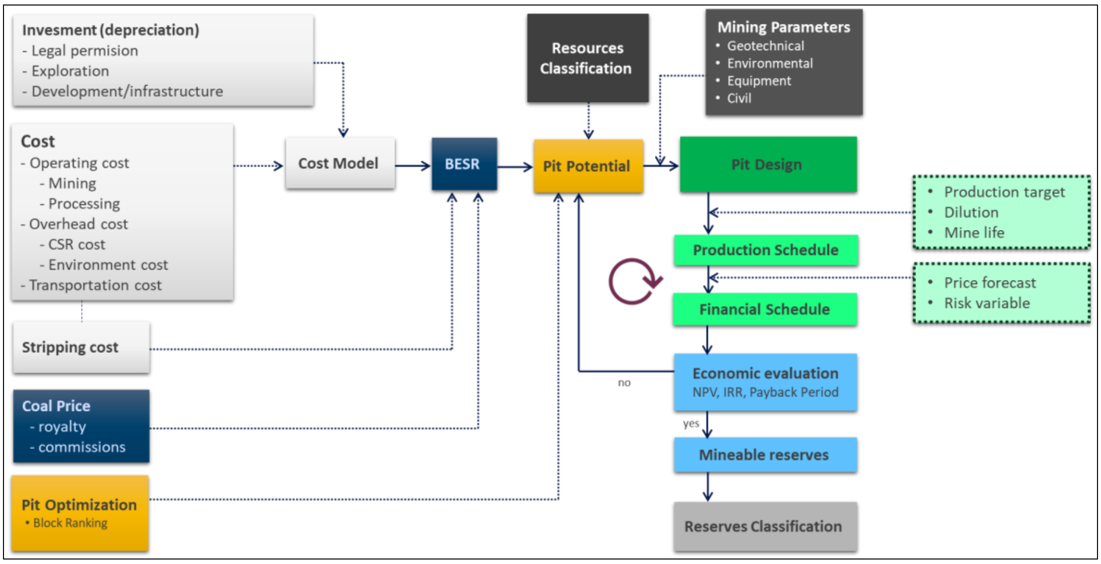

Fig 1. Stages of assessment of coal reserves

Based on the initial conditions of the mine design and the cash flow of the mining business, a pit potential can be designed, which shows the maximum pit opening limit. Furthermore, open pit designs can be made based on mining parameters such as geotechnical, environmental, equipment and infrastructure. Following the pit design, the next step is scheduling production and mining cash flow based on the mine life plan. For cash flows that are made according to the age of the mine, a business feasibility assessment is given based on the parameters of net present value (NPV), internal rate of return (IRR), and minimum attractive rate of return (MARR), etc. If the business feasibility assessment meets the parameters, the amount of reserves is economically feasible to mine. However, suppose it does not meet the business feasibility parameters. In that case, the process of determining the economic feasibility of mining coal reserves must be repeated from the stage of determining the pit potential (Hall, 2014).

Mining optimization using the open pit mining method, often known as pit optimization, is a way to determine the most optimal mining limit (ultimate pit limit) and the most optimal amount of reserves to produce the best profit margin value. Several methods can be applied in pit optimization, including the Lerch Grossman method, floating/moving cones, and incremental pit expansion. The Lerch Grossman and the floating/moving cone methods are often applied to mines with mineral commodity types (ore). In contrast, pit optimization in open pit mines with coal commodities mainly uses optimization methods by adding incremental pit expansion. The concept of the incremental pit expansion method is to apply the trial and error method.

The research method used is descriptive quantitative, a non-experimental research method that describes an event or events that occur factually, systematically and accurately. The quantitative method is a research method with quantitative data processing. In this study, the data used are secondary data obtained from the Coal Mining Company PT XYZ and cost data obtained from the Cost Estimation Data Set published by AusIMM. Then the data is processed to obtain mining costs based on variations in hauling distances and optimization of mining pits found on the minimum number of reserves that are feasible to be mined. The data processing in question is the pit optimization process to get the best profit margin. The data used are topographical data and drilling exploration of the PT XYZ Coal Mining Company. This data is used to model coal reserves and determine pit boundaries that are economically feasible to mine. The data processing uses the MineScape software. With the help of software, it is also possible to decide on the scenario of pit design changes based on changes in distance, which will result in varying mining production costs. Other data used in coal mining cost data published by AusIMM, which is processed using Microsoft Excel software to obtain coal mining production costs according to the planned pit design. The analytical method used is correlational, which is to detect the extent to which variations in a variable can affect one or more other variables based on the correlation coefficient. In this study, an analysis was carried out on the effect of mining costs based on variations in hauling distances on the minimum amount of feasible reserves in the mine.

III. RESULT AND DISCUSSION

Mining cost : Mining costs in this study are divided into direct costs and indirect costs. Direct costs are divided into cost components for overburden removal and coal mining costs. The cost of overburden removal is separated from the cost of overburden removal with less than 1 km transport at the cost of excess distance. In this study, the cost of the excess distance is the independent variable. The effect of this distance will affect the increase in mining costs which will practically affect the feasibility of the mine. The overall cost components used in this study are listed in the table below. Coal excavation costs are a component of excavation and loading costs (including stockpile management); processing; coal transportation and loading at the point of sale. Value this fee in $/ton. This fee is charged to the amount of coal production in each annual period. In this study, excavation costs are considered the same in various scenarios of hauling distances. Meanwhile, indirect costs include overhead, general administration; health and safety; community development, environmental; marketing; dead rents and royalties. These costs are also expressed in $/ton and are charged to annual coal production. This study applies several distance scenarios from 4km to 8km with 1km distance increments. So we get 5 (five) scenarios of the impact of distance on large reserves. With increasing distance, there will be mining costs. The current base hauling distance of overburden may fluctuate between 4 to 8 km. With the excess hauling distance cost of 0.45 $/ton-km, the total extra cost of transportation over a distance of 4 km is 3.30 $/ton. This cost increases to 5.10 $/ton when the haul distance is increased to 8 km. This increase became the basis for the implementation of this research—the effect of increasing transportation distance impacting production costs. The basic production cost at a 4 km distance is 16.89 $/ton, increasing to 18.68 $/ton at an 8 km distance. This simulation can be seen in Table 1.

Table 1. Effect of overburden transportation costs on total production costs

Unit Cost	Unit	Cost ($/t) 4 km	Cost ($/t) 5 km	Cost ($/t) 6 km	Cost ($/t) 7 km	Cost ($/t) 8 km
Direct Cost						
OB Removal Cost						
OB Removal (@ 1km) - (Incl. D&B, topsoil removal)	$/t	1.50	1.50	1.50	1.50	1.50
Overhaulage distance fee	$/t-km	0.45	0.45	0.45	0.45	0.45
OB Removal	$/t	3.30	3.75	4.20	4.65	5.10
Coal Cost						
Coal Getting (Incl. stockpile handling)	$/t	1.00	1.00	1.00	1.00	1.00
Coal Processing (Crushing, Grinding @ S/P)	$/t	1.00	1.00	1.00	1.00	1.00
Coal Hauling (S/P to Port)	$/t-km	0.13	0.13	0.13	0.13	0.13
Load to barge fee	$/t	0.25	0.25	0.25	0.25	0.25
Indirect Cost						
Overhead and GA	$/t	1.11	1.11	1.11	1.11	1.11
K3	$/t	0.02	0.02	0.02	0.02	0.02
Comdev / CSR	$/t	0.02	0.02	0.02	0.02	0.02
Enviromental	$/t	0.03	0.03	0.03	0.03	0.03
Marketing	$/t	0.00	0.00	0.00	0.00	0.00
Deadrent	$/t	2.88	2.88	2.88	2.88	2.88
Royalty	$/t	7.16	7.16	7.16	7.16	7.16
TOTAL PRODUCTION COST	**$/T**	**16.89**	**17.34**	**17.79**	**18.24**	**18.69**

Break-even stripping ratio (BESR) : The stripping ratio is an indicator in determining the boundaries of the pit area being mined. Although this method has some weaknesses in determining pit boundaries, it is sufficient to explain the increasing costs and their effect on the number of reserves. This study applies the block ranking method in the selection of optimization. The block ranking method requires the BESR value to determine the mining limits. The number of BESR can be seen in Table 2.

Table 2. Effect of overburden transportation costs on break-even stripping ratio

Unit Cost	Unit	Cost ($/t) 4 km	Cost ($/t) 5 km	Cost ($/t) 6 km	Cost ($/t) 7 km	Cost ($/t) 8 km
Direct Cost						
OB Removal Cost						
OB Removal (@ 1km) - (Incl. D&B, topsoil removal)	$/t	1.50	1.50	1.50	1.50	1.50
Overhaulage distance fee	$/t-km	0.45	0.45	0.45	0.45	0.45
OB Removal	$/t	3.30	3.75	4.20	4.65	5.10
Coal Cost						
Coal Getting (Incl. stockpile handling)	$/t	1.00	1.00	1.00	1.00	1.00
Coal Processing (Crushing, Grinding @ S/P)	$/t	1.00	1.00	1.00	1.00	1.00
Coal Hauling (S/P to Port)	$/t-km	0.13	0.13	0.13	0.13	0.13
Load to barge fee	$/t	0.25	0.25	0.25	0.25	0.25
Indirect Cost						
Overhead and GA	$/t	1.11	1.11	1.11	1.11	1.11
K3	$/t	0.02	0.02	0.02	0.02	0.02
Comdev / CSR	$/t	0.02	0.02	0.02	0.02	0.02
Enviromental	$/t	0.03	0.03	0.03	0.03	0.03
Marketing	$/t	0.00	0.00	0.00	0.00	0.00
Deadrent	$/t	2.88	2.88	2.88	2.88	2.88
Royalty	$/t	7.16	7.16	7.16	7.16	7.16
TOTAL PRODUCTION COST	**$/T**	**16.89**	**17.34**	**17.79**	**18.24**	**18.69**
BREAK EVEN STRIPPING RATIO	**BCM/T**	**11.94**	**10.51**	**9.38**	**8.48**	**7.73**

Based on the transportation scenario that has been described previously, optimization is carried out with mining simulations with variations in the stripping ratio so that the coal tonnage and volume of overburden are obtained as seen on Table 3.

Table 3. Overburden and coal mined

Stripping ratio	4	6	8	10	12
Overburden (BCM)	10,469,023	44,726,168	145,930,433	186,621,731	176,309,473
Coal (Tons)	2,484,339	6,418,561	16,353,403	19,613,805	17,532,441

The economic value of the pit is calculated by applying mining costs to the volume and tonnage of mining, and the profit margin is calculated by subtracting the value of mining revenue with mining cost components (OB cost, coal cost, indirect cost and capital cost). Tables 4 to 8 show the tabulation of the economics of each pit shell in various hauling distance scenarios. Based on the table, the project is said to be unfeasible in the 7 km hauling distance scenario; the overall profit margin value is negative.

Table 4. Pit optimization at a hauling distance of 4 km

OPSI PIT	OB (kbcm)	Coal (kt)	Avg. SR (bcm/t)	Inc.SR (bcm/t)	US$'000				Total Cost (US$'000)	Revenue (US$'000)	Profit Margin (US$'000)
					OB Cost	Coal Cost	Indirect Costs	Capital Costs			
PIT-1	10,469,023	2,484,339	4.21	4.00	34,547,775	5,900,305	27,852,913	58,744,687	127,045,681	131,669,973	4,624,293
PIT-2	44,726,168	6,418,561	6.97	6.00	147,596,354	15,244,082	71,961,034	58,744,687	293,546,157	340,183,718	46,637,561
PIT-3	145,930,433	16,353,403	8.92	8.00	481,570,430	38,839,332	183,344,496	58,744,687	762,498,944	866,730,347	104,231,403
PIT-4	186,621,735	19,613,805	9.51	12.00	615,851,727	46,582,788	219,898,165	58,744,687	941,077,366	1,039,531,685	98,454,318
PIT-5	176,309,473	17,532,441	10.06	10.00	581,821,261	41,639,547	196,563,159	58,744,687	878,768,653	929,219,357	50,450,704

Table 5. Pit optimization at a hauling distance of 5 km

OPSI PIT	OB (kbcm)	Coal (kt)	Avg. SR (bcm/t)	Inc.SR (bcm/t)	US$'000				Total Cost (US$'000)	Revenue (US$'000)	Profit Margin (US$'000)
					OB Cost	Coal Cost	Indirect Costs	Capital Costs			
PIT-1	10,469,023	2,484,339	4.21	4.00	39,258,836	5,900,305	27,852,913	58,744,687	131,756,741	131,669,973	- 86,768
PIT-2	44,726,168	6,418,561	6.97	6.00	167,723,129	15,244,082	71,961,034	58,744,687	313,672,932	340,183,718	26,510,786
PIT-3	145,930,433	16,353,403	8.92	8.00	547,239,124	38,839,332	183,344,496	58,744,687	828,167,639	866,730,347	38,562,708
PIT-4	186,621,735	19,613,805	9.51	12.00	699,831,508	46,582,788	219,898,165	58,744,687	1,025,057,147	1,039,531,685	14,474,538
PIT-5	176,309,473	17,532,441	10.06	10.00	661,160,524	41,639,547	196,563,159	58,744,687	958,107,916	929,219,357	- 28,888,559

Table 6. Pit optimization at a hauling distance of 6 km

OPSI PIT	OB (kbcm)	Coal (kt)	Avg. SR (bcm/t)	Inc.SR (bcm/t)	US$'000				Total Cost (US$'000)	Revenue (US$'000)	Profit Margin (US$'000)
					OB Cost	Coal Cost	Indirect Costs	Capital Costs			
PIT-1	10,469,023	2,484,339	4.21	4.00	43,969,896	5,900,305	27,852,913	58,744,687	136,467,801	131,669,973	- 4,797,828
PIT-2	44,726,168	6,418,561	6.97	6.00	187,849,905	15,244,082	71,961,034	58,744,687	333,799,708	340,183,718	6,384,010
PIT-3	145,930,433	16,353,403	8.92	8.00	612,907,819	38,839,332	183,344,496	58,744,687	893,836,334	866,730,347	- 27,105,987
PIT-4	186,621,735	19,613,805	9.51	12.00	783,811,288	46,582,788	219,898,165	58,744,687	1,109,036,928	1,039,531,685	- 69,505,243
PIT-5	176,309,473	17,532,441	10.06	10.00	740,499,787	41,639,547	196,563,159	58,744,687	1,037,447,179	929,219,357	- 108,227,822

Table 7. Pit optimization at a hauling distance of 7 km

OPSI PIT	OB (kbcm)	Coal (kt)	Avg. SR (bcm/t)	Inc.SR (bcm/t)	US$'000				Total Cost (US$'000)	Revenue (US$'000)	Profit Margin (US$'000)
					OB Cost	Coal Cost	Indirect Costs	Capital Costs			
PIT-1	10,469,023	2,484,339	4.21	4.00	48,680,956	5,900,305	27,852,913	58,744,687	141,178,861	131,669,973	- 9,508,888
PIT-2	44,726,168	6,418,561	6.97	6.00	207,976,680	15,244,082	71,961,034	58,744,687	353,926,483	340,183,718	- 13,742,765
PIT-3	145,930,433	16,353,403	8.92	8.00	678,576,514	38,839,332	183,344,496	58,744,687	959,505,029	866,730,347	- 92,774,682
PIT-4	186,621,735	19,613,805	9.51	12.00	867,791,069	46,582,788	219,898,165	58,744,687	1,193,016,709	1,039,531,685	- 153,485,024
PIT-5	176,309,473	17,532,441	10.06	10.00	819,839,050	41,639,547	196,563,159	58,744,687	1,116,786,442	929,219,357	- 187,567,085

Table 8. Pit optimization at a hauling distance of 8 km

OPSI PIT	OB (kbcm)	Coal (kt)	Avg. SR (bcm/t)	Inc.SR (bcm/t)	US$'000				Total Cost (US$'000)	Revenue (US$'000)	Profit Margin (US$'000)
					OB Cost	Coal Cost	Indirect Costs	Capital Costs			
PIT-1	10,469,023	2,484,339	4.21	4.00	53,392,016	5,900,305	27,852,913	58,744,687	145,889,922	131,669,973	- 14,219,948
PIT-2	44,726,168	6,418,561	6.97	6.00	228,103,456	15,244,082	71,961,034	58,744,687	374,053,259	340,183,718	- 33,869,541
PIT-3	145,930,433	16,353,403	8.92	8.00	744,245,209	38,839,332	183,344,496	58,744,687	1,025,173,724	866,730,347	- 158,443,377
PIT-4	186,621,735	19,613,805	9.51	12.00	951,770,850	46,582,788	219,898,165	58,744,687	1,276,996,490	1,039,531,685	- 237,464,805
PIT-5	176,309,473	17,532,441	10.06	10.00	899,178,313	41,639,547	196,563,159	58,744,687	1,196,125,705	929,219,357	- 266,906,348

Effect of Mining Distance on Feasibility of Reserves : Based on the results of this study, distance has a significant effect on the economic level of mining projects, indicated by the large economic value distance between projects with a hauling distance of 4 km to projects with a hauling distance of 8 km. The most significant variation of economic distance is seen in Pit-4 with the lowest and highest economic values of US$ -237M and US$ 98.4M, respectively, while the lowest variation is shown in Pit-1 with the lowest and highest values of US$ -14M and 4.6M. This result indicates that the larger the pit, the more sensitive the haul distance. Figure 2 shows that the highest economic value is in Pit-3 with a hauling distance of 4 km with a profit value of US$ 104M, while the lowest profit value is in Pit-5 with a hauling distance of 8 km of US$ -266M. Based on the considerations in this case study, it can say that Pit-3 is the best pit implemented, as indicated by its economic value. However, when considering the sensitivity of each pit, Pit-2 can still provide a positive valuation at a hauling distance of 6 km with a range of pit economic values that is still not too large. This result indicates the importance of considering distance variations in future planning. If distance variations are difficult to control in mine planning, it can provide significant variations. It would be better to consider the pits conservatively as in Pit-2, with an economical range that is not too large and still able to provide a positive valuation in conditions of long hauling distances. On the other hand, if the hauling distance is a variable easily regulated in planning, then Pit-3 can be an option because it has a potential economic value of 2 times higher than Pit-2.

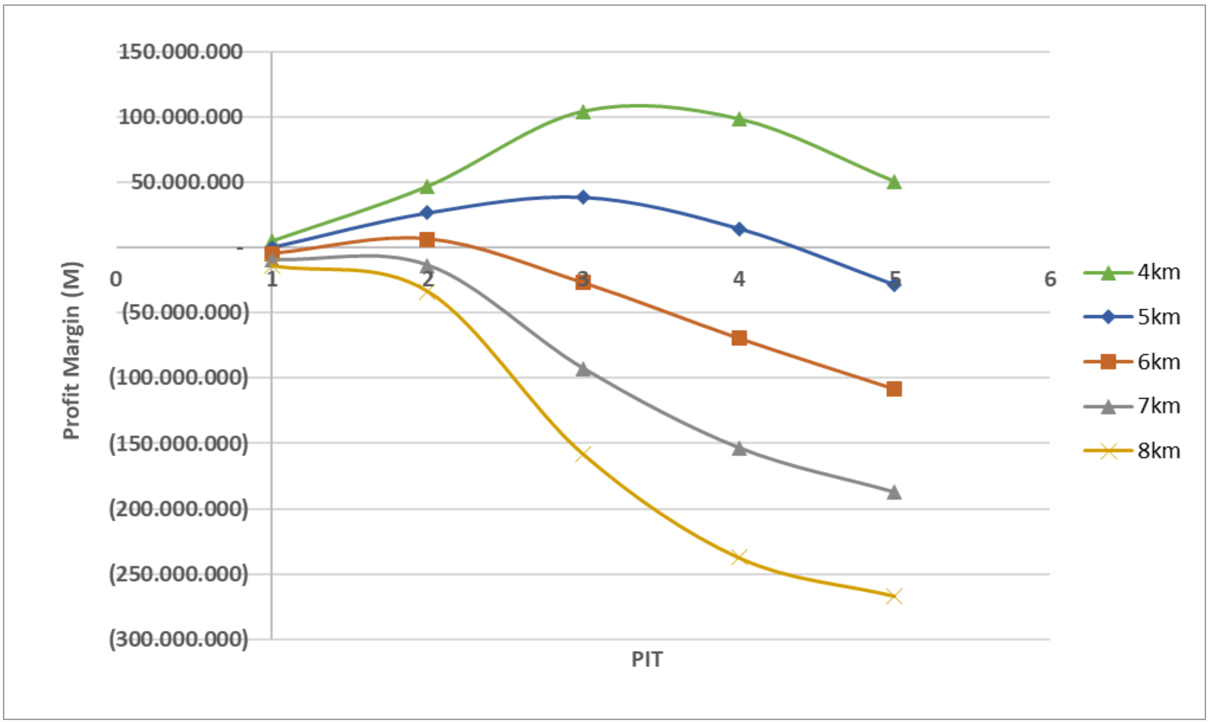

Fig 2. Comparison of hauling distance scenarios with profit margin

IV. CONCLUSIONS

The extra distance provides a significant increase in transportation costs. This increase ranges from 3.30 $/ton to 5.1 $/ton. The addition of distance provides a significant increase in production costs. This increase ranges between 16.89 $/ton to 18.69 $/ton. The addition of distance reduces the ability to mine, as indicated by a decrease in the BESR value. This decline has a range between 11.94 to 7.73. The highest mining profit is in Pit-3, with a hauling distance of 4 km at a value of US$ 104M. The lowest mining profit is located in Pit-5, with a hauling distance of 8 km at a value of -266M. Pit-3 has the best profit rate, while Pit-2 has the best sensitivity to hauling distance. The result can determine the best pit based on the planning conditions of the OB hauling distance in the field**.**

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