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# Influence of Block Dimension and Equipment Selection On the Final Pit Determination of Small Coal Deposit At Bojan Village, Heenherp District, Vientiane Province, Lao PDR

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***Abstract:*** The aim of this study is to investigate the factors which affect pit mining. Block dimensions, including bench width and height, and equipment size, are some of the factors which directly affect the quantity of mineable reserve and the final pit limit. Therefore, this paper addressed these factors as a part of mine planning and design of a small coal deposit in Lao PDR through the changes of block dimensions and the use of increasingly larger equipment. Minesight@ 3D software was used to simulate the ore body and delineate the 3D block model. The work has identified equipment size and evaluated their costs due to the increasing block dimension to estimate an economic block value. The spread of results from this study illustrated the varying of mineable reserves and other relevant pit geometry for each scenario of block dimension. Since the use of larger equipment with less unit cost, a larger block dimension produces more mineable reserves and productions. Also, it generates a broader and deeper pit shell than the small block dimension. The findings of the current study could be used to provide the best option before starting up an operation, which produced higher productivity, more mineable reserve, and less total cost.

***Keywords:*** *Block dimension, equipment size, mineable reserve, final pit limit*

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## I. INTRODUCTION

Since Laos's economy is expanding vastly, the use of minerals also increased. Minerals are powerfully related to economic prosperity, state organizations, and the private sectors that concern with the policy determination and plan for using minerals. Coal resources are prioritized to be significant potential which supports to Lao PDR's industrial development especially for cement industries, mineral processing, metal refinery, power plant, and pottery industries. At the late of 2015, the new small anthracite coal deposit at Bojan village, Heenherp district, Vientiane province, Lao PDR was discovered by a Lao state enterprise company. This coal deposit becomes a significant raw energy material which will supply cement industries in the middle part of Lao PDR.

To promote the sustainable development policy especially for the efficiency mineral utilization, it is necessary to consider the efficient technique to recover, at less cost and yield the highest profit from the mining operation [1]. The goal of open pit mine design is to achieve more mineable reserve and determine the annual production that yields the highest net profit. In addition, extracting a mineral resource is started by estimating economic parameters such as extraction capacity, extraction costs, and sale price [**?** 2, 3]. Two influence factors namely block dimension and equipment selection was addressed in this study in order to provide the best option before start up an operation, which produced higher productivity, more mineable reserve and less total cost.

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## II. THE BOJAN COAL DEPOSIT

The anthracite coal deposit situates at Bojan village, Heenherp district, Vientiane province, Lao PDR. This deposit is located between the contractions of Shan-Thai microcontinent and Indochina microcontinent at Southeast-Asia Ocean. The Shan-Thai microcontinent and Indochina microcontinent has continuous movement since the Permian period to the late Triassic period [4]. The contractions of Shan-Thai microcontinent and Indochina microcontinent created the fold belt from the northern part of Laos to Loie and Sakeo province of Thailand namely Laungphabang, Loie and Phetsaboun fold belt [5, 6]. Rock units that can be found along the contraction are Limestone, Chert, Clastic rock, Sandstone, Siltstone, Quartzite, Phylite, etc. The rock units found in the Vientiane basin can be grouped and arranged from youngest to oldest which are Ord-Silurian Era, Devonian Era, Carboniferous Era, Permian Era, Permo Triassic granite/volcanic intrusive Era, Triassic redbeds Era, Jurassic redbeds Era and Quarternary Era (Fig. 1).

With regard to the exploration report (2016), there were drilling of 26 bore holes with totaling of 1,800 m, a seismic survey of 3,000 m, 62 samples were analyzed. The coal seams at Vientiane province situate not much deeper and dip 40 to 75 degrees shallow down to southwest at 230 degrees. The thickness of seam ranges from 0.51 to 6.3 meters with a total of 13,900 meters length (discontinuous) [7, 8]. The coal deposit mainly contains in the sedimentary rock types such as black mudstone, siltstone, Shale, Conglomerate, etc.

TABLE 1
CHARACTERISTIC OF COAL AT BOJAN. (DATA SOURCES FROM LAO STAGE ENTERPRISE COMPANY)

| No | Description | Unit | Min | Max | Average |
|---|---|---|---|---|---|
| 1 | Coal shape and structure | Black shiny and weak | | | |
| 2 | Humidity ($W^{pt}$) | % | 0.82 | 1.77 | 1.23 |
| 3 | Ash ($A^{k}$) | % | 13.78 | 76.54 | 42.15 |
| 4 | Evaporation ($V^{ch}$) | % | 7.07 | 11.82 | 7.89 |
| 5 | Heating ($Q^{k}$) | Kcal/ Kg | 1,058 | 6,898 | 4,136 |
| 6 | Burning ($Q^{ch}$) | KJ/ Kg | 4,431 | 28,876 | 17,391 |
| 7 | Sulfur ($S^{ch}$) | % | | | 0.76 |

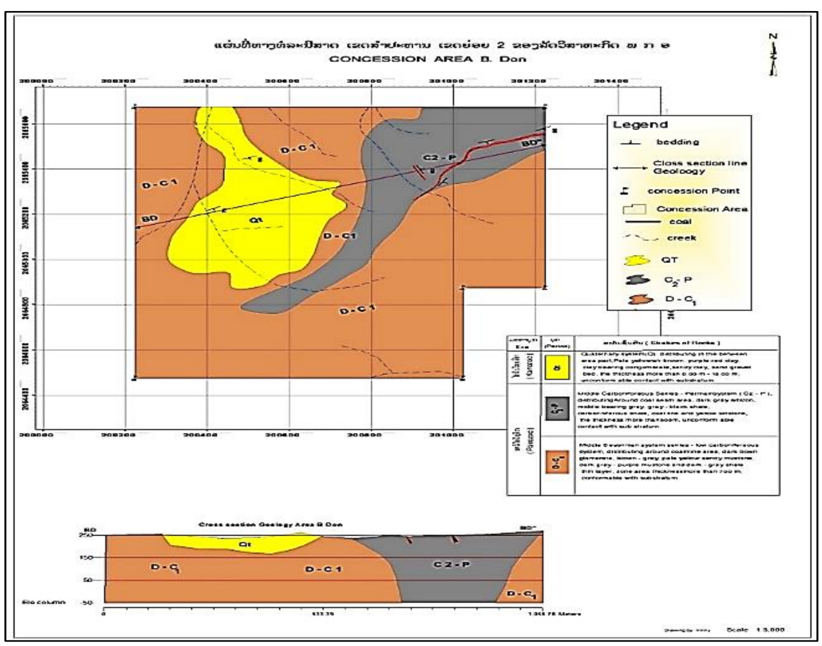


Fig. 1. Regional geology of Bojan coal deposit at Vientiane province, Lao PDR (Data source from Lao Stage Enterprise Company)

## III. METHODS AND MATERIALS

The study has been done through three main parts which are the evaluation and classifying of the ore deposit, the selection of equipment and cost estimation, and the last part is the determination of the final pit limit. Minesight@ software was used in order to simulate ore body and determine a final pit limit except for the part of equipment selection and cost estimation.

### A. Evaluating and delineating ore deposit

1. Determining a block dimension and the coordinate of the interesting area through a process of project setting or model setting. The thickness (Bz) of the blocks is usually set to planned bench height. The block width (Bx) and (By) height dimensions are chosen arbitrarily. Three sizes of block dimension were decided in this study for 3 cases as below:

- The case I for block dimension 20m*20m*4m;
- Case II for block dimension 20m*20m*6m;
- Case III for block dimension 25m*25m*8m.

2. Constructing the database inventory especially the data that have been taken such as spatial coordinates of drill holes, geological formations that they intersect, depths of formations and their assay values. Surface determinations or topography are almost entirely related to GPS data.

3. Estimating grade value/thickness of ore from each drill hole. The mechanical properties of waste layers and quality values of ore layer are determined by applying several tests on hole cores. Generally, the mineral formation is not monolithic and single piece body. Inter-burden layers may intersect mass or mineralization and occur with waste layers in alternating forms. During numerical calculations, a single thickness and grade value may be needed. The process was done through a computation tool of Minesight@ software by considering the following criteria:

- Cut-off grade is > 1,000 Kcal/kg;
- Minimum mineable thickness is >= 0.3m;
- Parting (waste) is < 0.3m.

4. Gridding, triangular, rectangular mesh generation and assignment method. The 2D and 3D visual was constructed through numerical processes. The 2D visual represents of the contour isopach, 2D cross-section and ore zone. Meanwhile, the 3D visual contains the 3D surface, 2D or 3D model (ore body blocks, 3D geo-section), etc.

5. Estimating the deposit volume and geologic reserve. At this stage, the 3D block model contains coal tonnage and qualities.

### B. Equipment selection and cost estimation

*1) Equipment selection:* Evaluating and matching equipment performance thorough understanding of the unique features of each excavating equipment especially for backhoes and trucks are required in order to determine the best scenario from given bench heights. The optimum equipment selection can only be achieved if the characteristics of the ore body and the unique ability of the equipment are matched. Partial parameter list should be considered when selecting equipment are:

a. Mine parameters: the life of mine, bench height, haul distance.

b. Characteristic of the overburden: soil characteristic, swell factor, fill factor.

c. Types of equipment: backhoes and trucks.

d. Equipment characteristics: bucket size, work cycle, and speed.

e. Production rate: the yearly amount of material to be excavated.

f. Operating cost: including maintenance and repair, tires, fuel, electricity, and wages.

In this study, the design considers two types of equipment which are an excavator and truck. Basically, the truck information is based on the manufacturing company database especially for truck capacity, specification, and cost. As a result, the selection of these mining equipment fleet for three cases is shown in Table 2.

TABLE 2
SELECTION OF MINING EQUIPMENT FLEET AND THEIR CAPACITY

| NO | DESCRIBTION | Case I | | Case II | | Case III | |
|---|---|---|---|---|---|---|---|
| | | 20*20 *4 (m) | Capacity ($m^3$) | 20*20 *6 (m) | Capacity ($m^3$) | 25*25 *8 (m) | Capacity ($m^3$) |
| | | | Coal extraction | | | | |
| 1 | Hourly production (T) | 95 | - | 156 | - | 189 | - |
| 2 | Number of excavator | 1 | 0.8 | 1 | 1.4 | 1 | 1.8 |
| 3 | Number of trucks | 2 | 10 | 2 | 10 | 2 | 10 |
| | | | Overburden removal | | | | |
| 1 | Hourly production (BCM) | 104 | - | 126 | - | 151 | - |
| 2 | Number of excavators | 2 | 1.4 | 2 | 1.8 | 2 | 2.28 |
| 3 | Number of trucks | 7 | 10 | 7 | 10 | 7 | 10 |

*2) Estimating the equipment costs:* There are a number of different types of costs which are incurred in a mining operation [9]. Three cost categories are a capital cost, operating cost and general and administrative cost [10]. The capital cost, in this case, could be translated into a cost per ton basis just as the operating cost. The costs might then become, ownership cost, production cost, and general and administrative cost. Equipment ownership costs are fixed costs that are incurred each year, regardless of whether the equipment is operated or idle. Initial cost consists of the following items; the price at the factory, extra equipment, sales tax, shipping, assembling, and erection [11].

Operating costs of the equipment which represent a significant cost category are those costs associated with the operation of a piece of equipment. Operating costs of the equipment are also called "variable" costs because they depend on several factors such as the number of operating hours, the types of equipment used [11, 12]. With regards to the number of equipment, their costs were estimated through their specification and physical condition. Table 3 below shows the amount of ownership and operating costs of the equipment that were applied to each block dimension in order to extract coal and remove overburden. If the cases use the same truck size and type, the ownership and operating costs do not change.

TABLE 3
THE EQUIPMENT OWNERSHIP AND OPERATING COST

| NO | DESCRIBTION | Ownership and Operating cost ($/Hr) | | |
|---|---|---|---|---|
| | | Case I | Case II | Case III |
| 1 | Coal extraction | | | |
| | excavator | 85 | 103 | 115 |
| | truck | 89.8 | 89.8 | 89.8 |
| 2 | Overburden removal | | | |
| | excavator | 206 | 230 | 280 |
| | truck | 314.3 | 314.3 | 314.3 |

*3) Unit cost and economic parameters estimation.* The unit cost estimation as shown in Table 4 is based on Lao Stage Enterprise Company database and the best practice from other mining companies in conjunction with Laos' law and regulations. The computation assigned each annual cost and fund divided by the annual coal production.

TABLE 4
TECHNICAL AND ECONOMIC PARAMETERS DESIGNING OF COAL DEPOSIT AT BOJAN

| No | Parameter | Quantity | | | Unit | Remark |
|---|---|---|---|---|---|---|
| | | Case I (20*20*4) | Case II (20*20*6) | Case III (25*25*8) | | |
| 1 | Mining cost (MC) | 2.90 | 2.45 | 2.35 | $/T | |
| 2 | Waste cost (WC) | 2.83 | 2.73 | 2.64 | $/BCM | |
| 3 | Processing cost (PC) | 3.23 | 3.23 | 3.23 | $/T | Based on company database |
| 4 | Overhead mining cost (OMC) | 3.11 | 1.88 | 1.55 | $/T | |
| 5 | Overhead processing cost (OPC) | 1.04 | 0.63 | 0.52 | $/T | |
| 6 | Agreement financial obligation (AF) | 0.24 | 0.14 | 0.12 | $/T | |
| 7 | Exploration and Compensation Amortization (EA) | 2.55 | 2.46 | 2.25 | $/T | |
| 8 | VAT | | 10 | | % | From revenue |
| 9 | Royalty | | 6 | | % | From revenue |
| 10 | Minimum profit | | 0.829 | | $/T | |
| 11 | Coal price | | 60 | | $/T | |
| 13 | Mining recovery | | 90 | | % | Based on company database |

### C. Determining a final pit limit and mineable reserve

This process was done through Minesight@ software by applying the technical and an economic parameter from Table 4 to computation of 3D model in order to estimate an economic block value. Estimating an economic block value can be done by the following equation.

$A_0 = R - M - P - C$ Where:

- $A_0$ An economic block value;

- R Revenue from each block;

- M Mining cost;

- P Processing cost;

- C Other related costs including overhead mining cost, overhead processing cost, royalty, agreement financial obligation, exploration and compensation amortization, and VAT).

From the economic block values, the final pit limit shell can be calculated by the Lerch-Grossmann optimization technique. In this estimation, an overall slope angle 50° was used, and a pit layout for each block dimension was output as shown in Figure 9, 10 and 11. Meanwhile, a mineable reserve for each case was also determined through a function of Minesight@ reserve estimation tools or an automatic pit design simulation.

### D. Dilution and mining loss

Referring to a mining block, dilution happens in two different areas. Sometimes within a mining block, there are waste inclusions or low-grade pockets of ore that cannot be separated and are inevitably mined with the mining block. This is called internal dilution. The amount of internal dilution varies in different types of deposits. External dilution also called contact dilution refers to the waste outside of the ore body that is mined within the mining block. External dilution varies based on geology, a shape of the ore body, drilling and blasting techniques, a scale of operation and equipment size. Dilution can be evaluated by the following equation [13]:

$$Dilution = \frac{\text{Waste tonnes}}{\text{Ore tonnes + Waste tonnes}} X100\%$$

## IV. RESULTS AND DISCUSSION

Coal deposit at Bojan was modeled into eight seams with the dip from 40-75 degrees shallow down to south-west at 230 degrees. The thickness of seam ranged from 0.51 to 6.3 meters with a 13,900 meters length, but it was discontinuous. The geology reserve was estimated at approximately 0.93 Mt.

Table 5 indicates the result of the study for each block dimension through mine planning and design.

TABLE 5
OUTPUT OF THE STUDY

| Description | Case I (20*20*4) | Case II (20*20*6) | Case III (25*25*8) |
|---|---|---|---|
| Mineable reserve (t) | 435,196 | 445,532 | 488,632 |
| Final production (t) | 304,637 | 311,872 | 342,042 |
| Waste (BCM) | 2,012,444 | 2,157,482 | 2,481,245 |
| Total Cost ($) | 13,017,106 | 12,298,749 | 13,268,404 |
| Net profit ($) | 5,261,151 | 6,413,603 | 7,254,160 |
| Maintenance ($/y) | 201,153 | 219,285 | 241,960 |
| Dilution (%) | 0.918 | 0.923 | 0.927 |

Fig. 2 clearly shows the mineable reserve of each block dimension scenario. The largest block particularly cases III produces 488,632 *t* higher than case II 12.2% and higher than case III 8.9%, while the case II also produces 3.7% higher than the case I.

Since the operation was carried on by less mining costs and produced more mineable reserve, case II and III able to yield a more net profit. Fig. 3 compares the amount of net profit without discount cash flow. Net profit trends to increase when a block size is increased. For instance, case III achieves 11.58% more profit than case II and 27.47% more than case I. In addition, case II earns more profit of 17.96% over case I.

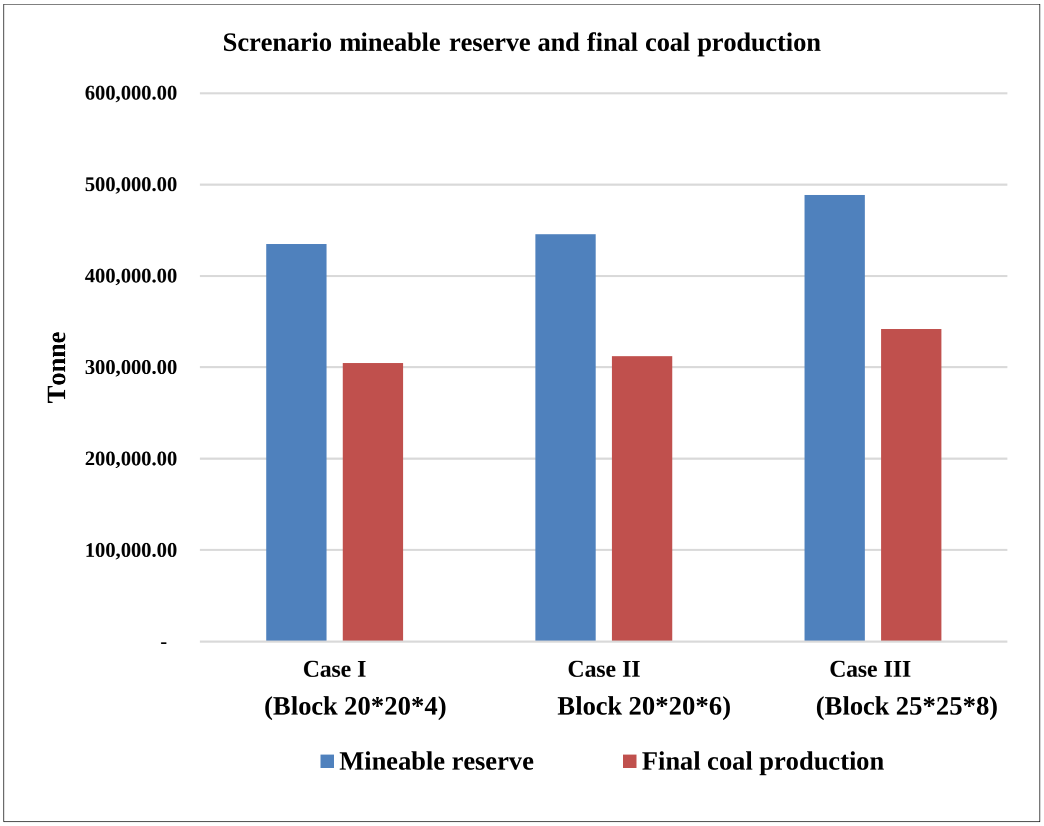


Fig. 2. Scenario mineable reserve

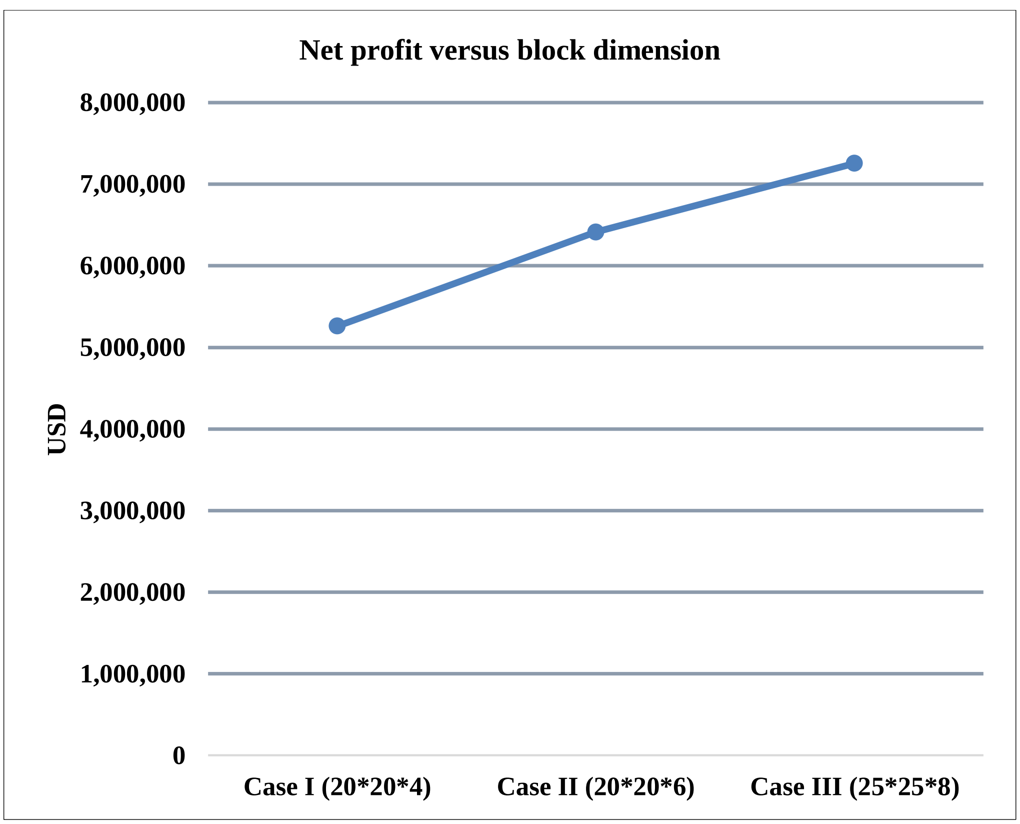


Fig. 3. Comparison of net profit (Without discount cash flow)

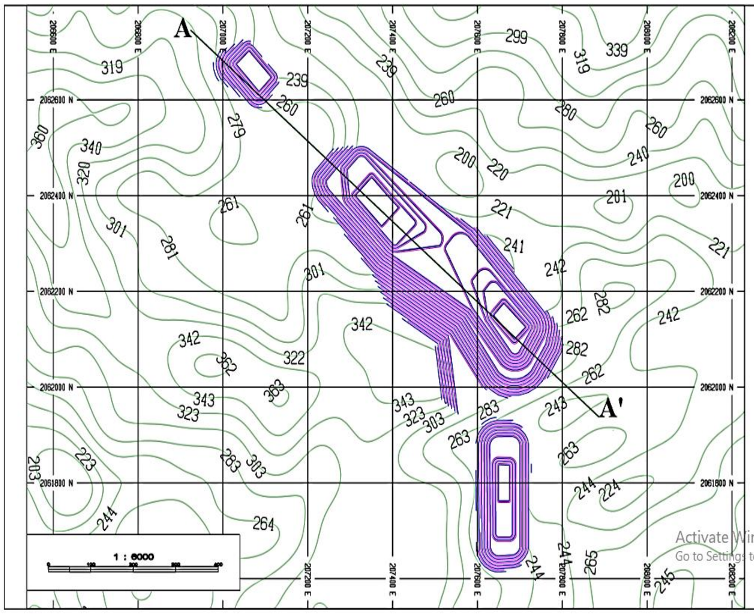


Fig. 4. Plan view pit layout east-west section A-A

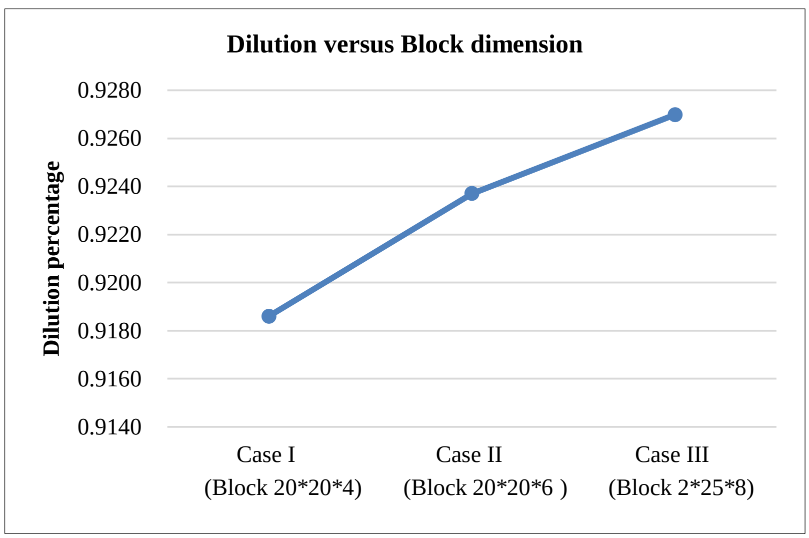


Fig. 5. The increasing of mining production dilution each block dimension

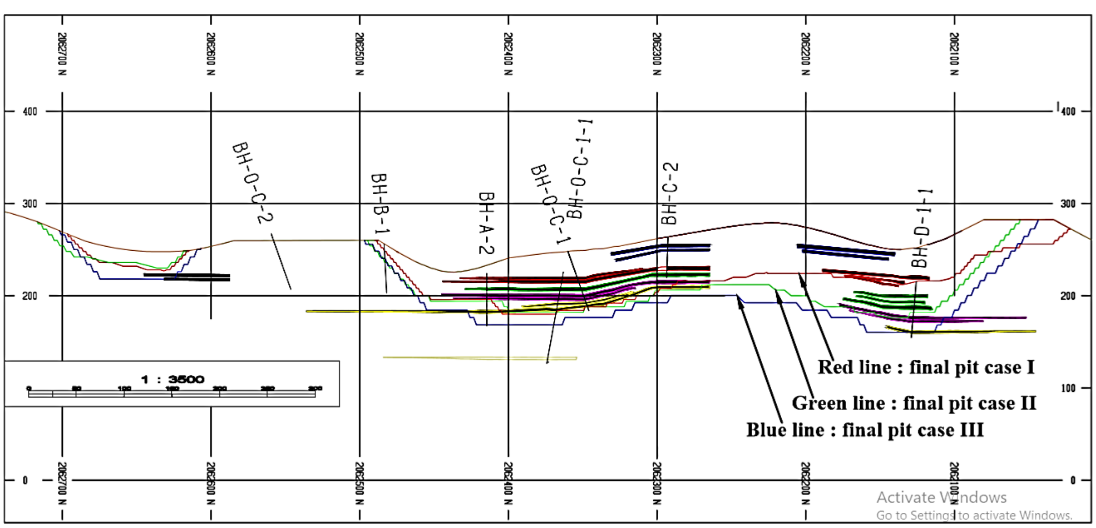


Fig. 6. Comparison of three final pit shells (Cross section East west A-A)

Fig. 6 demonstrates the final pit limit of each block dimension scenario. It is observed that the larger block dimension generated a pit shell deeper and wider than a small block. The biggest block case III has a pit bottom 6m deeper than case II and 10m deeper than case I. While the pit bottom from case II is deeper 4m than case I.

Fig. 5 describes the percentage of mining dilution for each block dimension. A larger block which applying larger equipment tends to increase the percentage of dilution than other small blocks. Meanwhile, the maintenance and repair cost for the larger equipment as shown in Fig. 7 tends to increase as well.

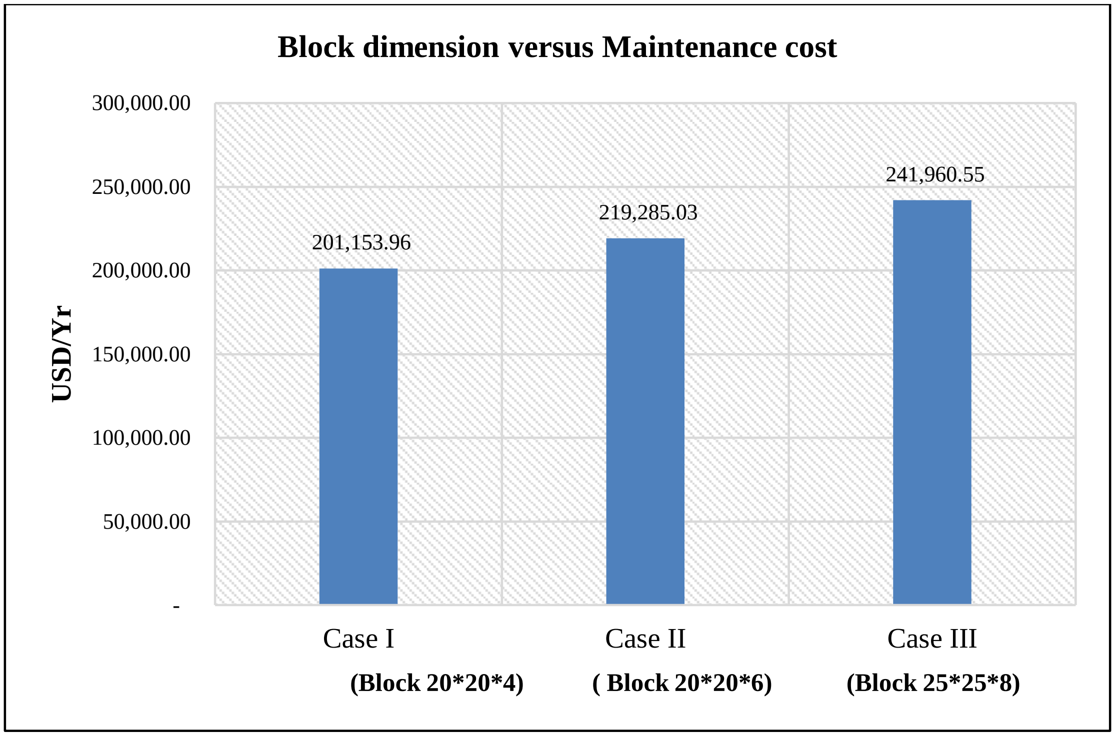


Fig. 7. The increasing of maintenance cost of equipment applying to each mining block

Regarding the coal requirement especially for cement industries in Laos is approximately 1.5 Mt each year (Statistic from the Ministry of Industrial and Trade). Lao Stage Enterprise Company (1st and 2nd plant) requires coal about 56,000 t each year (Company's reported on 2016) which means the coal deposit at Bojan able to supply cement plant for 8.73 years for case III, 7.96 years for case II and around 7.77 years for case I.

## V. CONCLUSION AND RECOMMENDATIONS

In this paper, a comprehensive methodology has been introduced to a process of mine planning and design namely ore deposit evaluation and classification, equipment selection and cost estimation and the final pit limit determination. The effect of changing block dimension and a larger equipment selection on final pit limit and their corresponding mineable reserves has been studied.

Mineable reserve or coal reserve of this deposit become an important potential which supports two cement plants of Lao Stage Enterprise Company in order to reduce cement production cost. The larger block dimension can dramatically inuence mine geometry and equipment size. Larger block dimension requires greater equipment size in order to produce production rate, discover mineable reserve. As a result, larger block and equipment size produces more production rate, discovers more mineable reserve and generates pit shell wider and deeper than small block dimension.

By analysis of the results without considering of discounted cash flow, could be concluded that the best pit designed with block 25*25*8 (case III) is the one that discovers highest mineable reserve of 488,632 tons of ore with a waste/ore ratio of 12 and a gross profit of US$ 7,254,160.

However, a significant point to note is that a larger block dimension which carries out by the larger equipment will result in poorer dilution percentage or mining production selective and higher maintenance and repair costs.

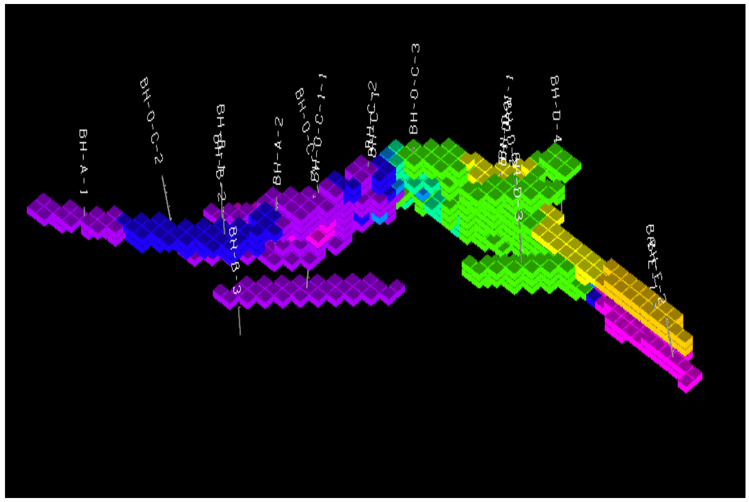

Fig. 8. The overview of 3D block model (without scale)

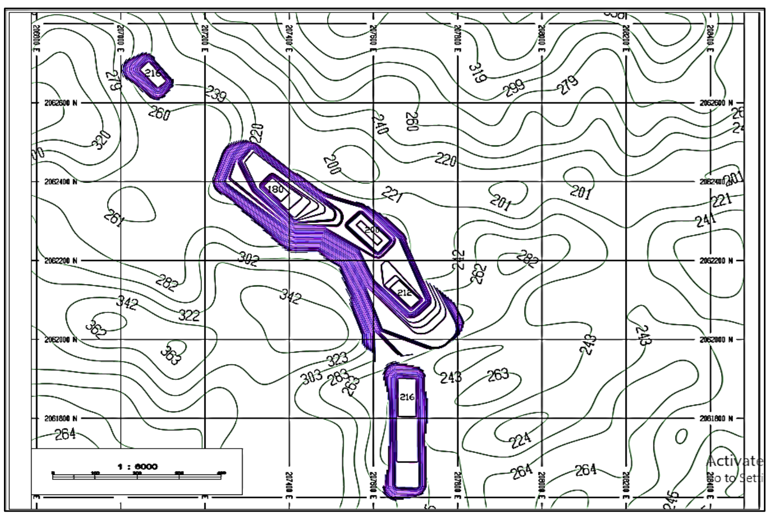

Fig. 9. Final pit layout for case I

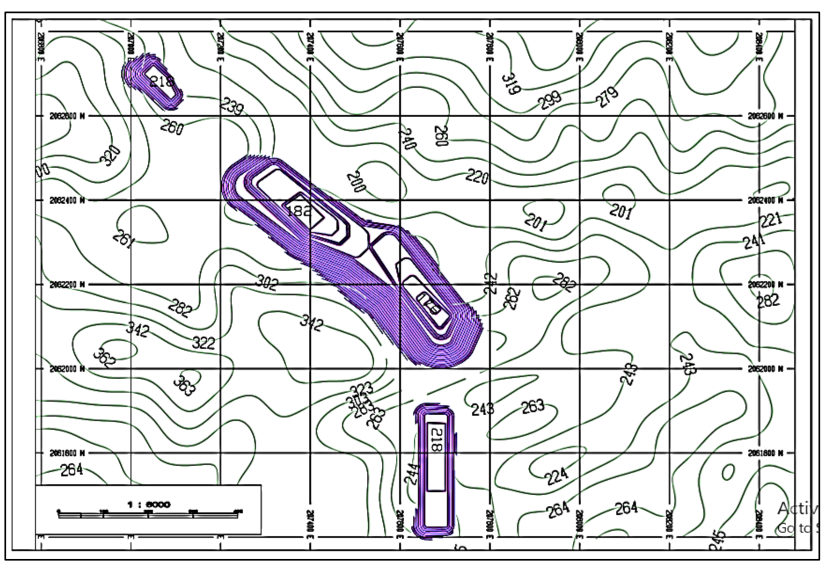

Fig. 10. Final pit layout for case II

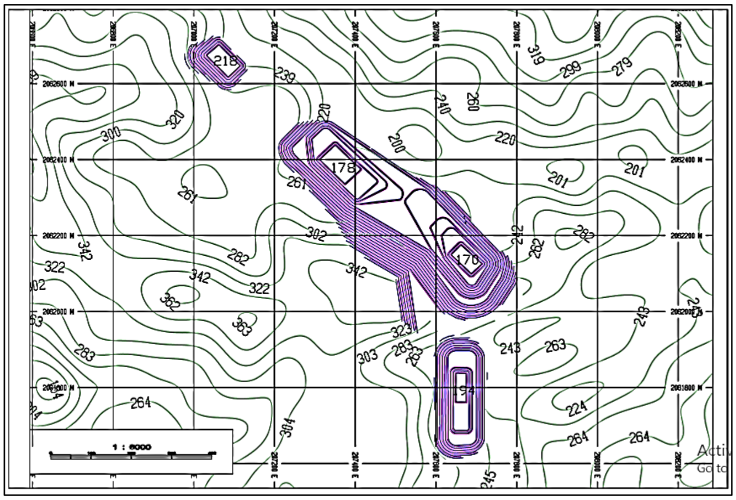


Fig. 11. Final pit layout for case III

The findings of the current study could be used to provide the best option before starting up an operation, which produced higher productivity, more mineable reserve, and less total cost. Furthermore, further investigation in current domain are encouraged.

## Declaration of Conflicting Interests

Authors make a declaration that there are no conflicts of interests in the current work.

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