Mineral Metal Energy Oil Gas Aggregate, *1(1): 31-41; 2024. DOI: 10.18311/2MEOGA/2024/v1i1/44659* *TECHNICAL ARTICLE*

Print ISSN : XXXX-XXXX

INFORMATICS JOURNALS

Mineral Metal Energy Oil Gas and Aggregate

Contents available at: *www.informaticsjournals.com/index.php/2MEOGA*

2MEOGA

Investment Risk Assessment of the Expansion Consideration for an Old Lignite Mine

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Abstract

Investment risk assessment is an important and complicated aspect of the mining life cycle. Variations in mineral pricing, market demand, socio-economic issues etc. affect the investment decision critically. Investment risk for a lignite mine, captive to a thermal power plant, is analyzed and reported in this paper. The mine is proposed for an extension with different influencing parameters: poor slope stability, socio-economic issues, limited mining options and difficult terrain conditions. Modified Break-Even Stripping Ratio (BESR) analysis is carried out for the evaluation of mining extent. The modified BESR approach includes the financial liability of the constraints influencing the mining costs. It is observed that up to a 66 Ha area out of the available 126 Ha area can be mined profitable and worthy of investment. The decision to extend mining beyond this area may lead to severe financial loss.

Keywords: *Break-Even Stripping Ratio, Evaluation, Financial Feasibility, Investment Rick, Mining Option*

1.0 Introduction

In general, a mine is planned and designed before the commencement of mining in consideration of the parameters namely, geological distribution of ore body, mining options, market price of the product and cost of mining and others. However, a mine has a life span of 20 to 50 years. Many mines have been running for more than 100 years like Bingham copper mine[1] Kolar Gold Fields[2]. Khewra Salt Mine of Pakistan is reported to have been under operation in phases since the 16th century[3]. Changes in mineral pricing, market demand, technological shifting and socio-economic issues affect the decision process significantly. Therefore, the techno-economic analysis carried out during the mine planning stage may not be valid for the complete mining period[4]. Though several assumptions were made in the planning phase for the future price, operating cost etc., in practice the values differ significantly from the assumed values. Apart from the same, socio-political and site-specific additional costing, constraints are to be considered which are not considered during mine planning and designing. Therefore, time-to-time evaluations for mining options are required to be practised.

Gujarat Industries Power Company Limited (GIPCL), a public limited company under the auspices of the Government of Gujarat (GoG) owns the Vastan lignite mine to feed a 2 × 125 MW Surat lignite power plant which operates based on environment-friendly CFBC technology[5]. GIPCL has a mining lease with approved mining plans and environmental clearance for the Vastan lignite open-cast project for an area of 1536 Ha. The mining plan prepared to produce 1.20 million tonnes per year of lignite from the Vastan lignite mine was approved by the Ministry of Coal in 1995[6]. However, the techno-economic criteria, socio-political requirements

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and many other conditions and constraints have evolved since the commencement of mining. Therefore, it was found essential to carry out a fresh analysis to evaluate the mining options for the remaining deposits. This paper presents the process methodology and example analysis for the Vastan lignite opencast project.

2.0 Vastan Lignite Mine

Vastan lignite mine is being operated with a mining lease area of 1536 Ha in the district of Surat, Gujarat (Figure 1). The topography of the area is slightly undulating and is generally sloping towards the south-westerly side. The general surface elevation varies from 37m to 55m above mean sea level. In the core zone, there is a small seasonal nallahs (creek) of 3-4 m wide with a maximum water level of 2m during the monsoon period. Therefore, little or no adverse effect of the natural surface drainage system has been experienced so far. Further, it is considered that manageable and negligible effects of mining activities will be there when the activities are undertaken[7]. Thus, the mining was planned to be carried out without diversion of the water body.

Vastan lignite mine commenced its excavation in 1997. The mine is divided into two parts – the north block and the south block. The north block named the North Vastan pit was excavated ahead of the South Vastan pit and is currently exhausted. GIPCL felt the requirement of re-evaluation of the mineability of the South Vasan pit due to the following constraints –

i. The overburden and parting rock mostly comprises sandy clay or clayey sand having high water-holding potential and that when saturated is likely to fail[6]. This significantly influences the stability of the rock slopes for economics and safety. The evaluated slope angle for mining is 13.54 degrees.

ii. The overall slope angle has a significant impact on the stripping ratio. The stripping ratio sharply increases with the depth of the deposit. The lignite seam is dipping towards the farthest sides of the south pit. Thus, the stripping ratio will sharply increase with the progress in the mine.

iii. The mine lease area possesses many faults which result in the throw of the seam vertically as well as horizontally.

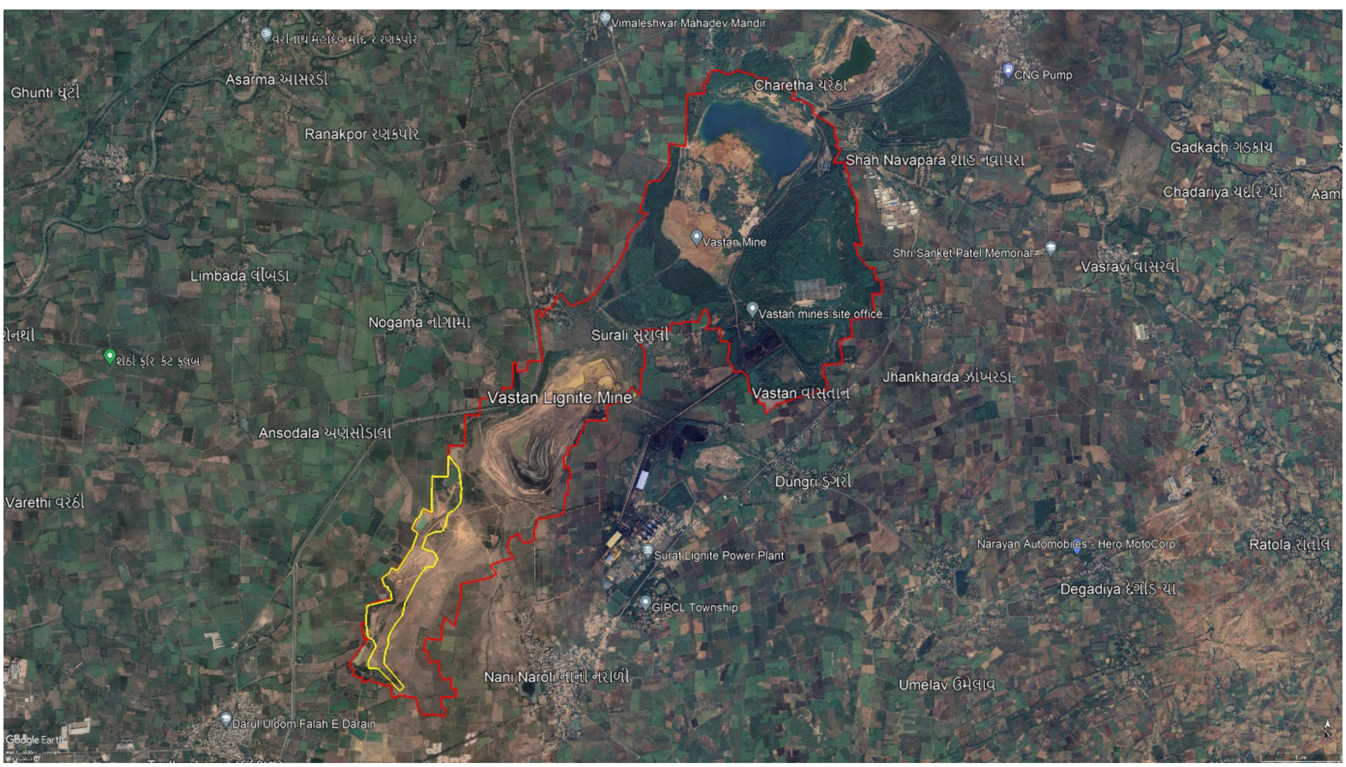

Figure 1. Satellite view of Vastan Lignite Mine[6].

iv. There have been many changes in the market value and resource availability for lignite mining in the country. The values envisaged in the mid-1990 for mine planning would not apply to the current planning inputs. Apart from the same, the socio-environmental issues and public visibility and concern- leading to scrutiny have considerably changed vis-à-vis national and international scenarios of scarcity, economics and trade.

Considering the same, an exercise of re-evaluating the mineability of the left-out area of the south block as per the current mine plan of the Vastan lignite mine was carried out and is reported in this paper.

3.0 Methodology for Determination of Mineability

The mineability for a surface mine is expressed in terms of feasibility which is the same as the benefit-cost ratio. The feasibility analysis is a combination of – (i) evaluation of Break- Even Stripping Ratio (BESR) (ii) iteration between mining options (iii) financial appraisal of each mining option (iv) influence of the constraints, namely, technical, environmental, safety, societal and legal issues[8,9].

BESR is defined as –

$$BESR = \frac{Price\ of\ one\ tonne\ coal - Mining\ cost\ of\ one\ tonne\ coal}{Overburden\ stripping\ cost\ for\ one\ tonne\ of\ coal}$$

A value of BESR <1 indicates that mining is no longer techno-economically feasible. The BESR ≥ 1 is considered a suitable mining option[9,10]. The mineability of a project is determined by its financial, technical, environmental and socio-economic feasibility. If the other conditions are considered universal, the financial appraisal is considered the decisive factor. However, the other factors also greatly influence the mineability at places. Unless considered as of strategic importance, it is a generalized practice that the final decision on mineability can be taken based on the financial acceptance of the project (i.e. the break-even stripping ratio > 1.0)[11]. For analysis of the same, all the constraints, namely environmental, societal, technical etc., should be converted into financial obligations and incorporated as alternatives. Figure 2 represents the methodology of financial analysis for determining the BESR.

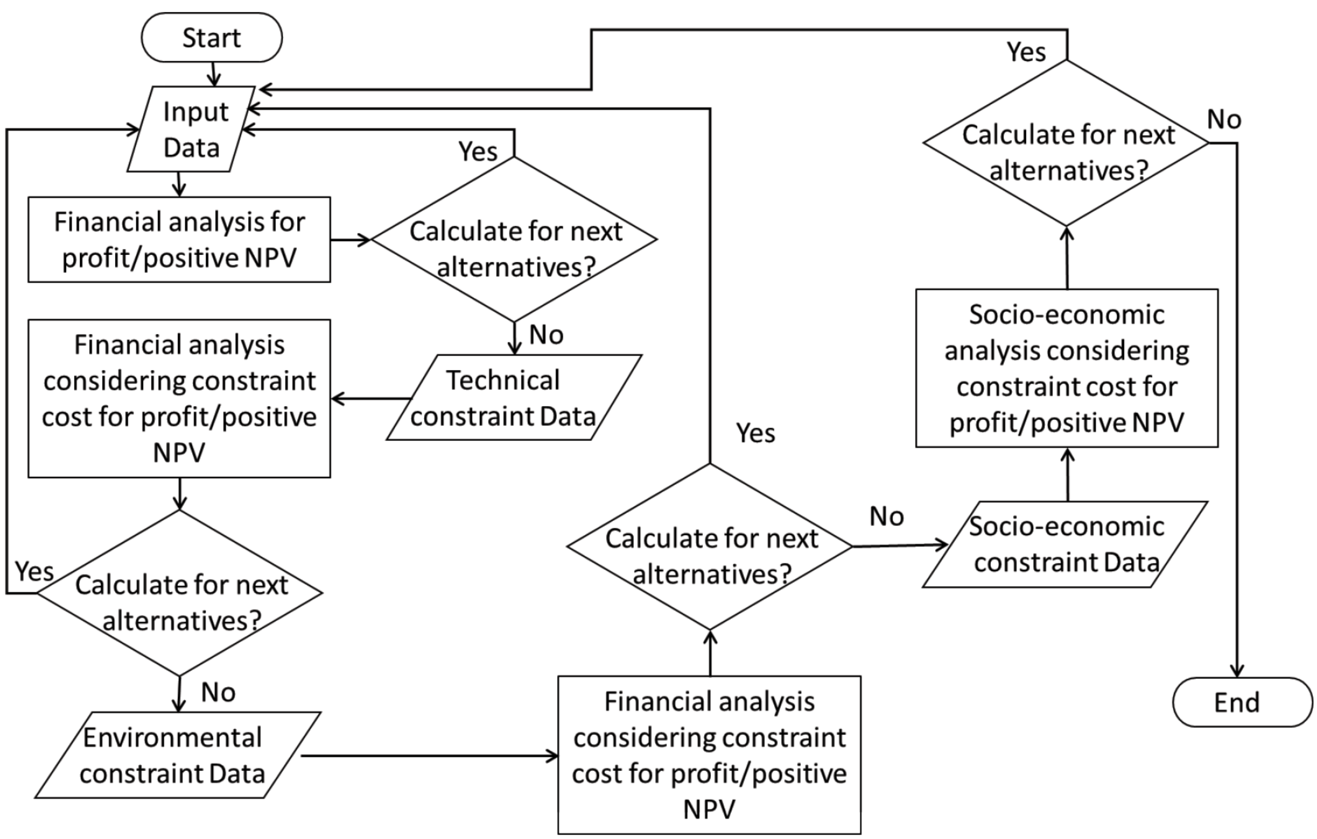

Figure 2. Methodology for financial analysis[10].

The methodology for financial analysis for the BERS starts with consideration of influencing parameters. In this case, the influencing parameters considered are – mining options, pricing of products, mining costings, waste removal costings, consideration of constraints and their corresponding financial impacts. The important technical constraint significantly impacting the BESR is slope stability. If the BESR exhibits a value ≥ 1.0, considering the technical constraint the system is considered as accepted. Similar calculations are required to be made for other technical constraints. Similarly, the cost impact of environmental constraints is to be considered. Environmental impacts may be the prohibition of blasting, treatment of mine effluents etc. If the financial analysis exhibits a BESR value ≥ 1.0 after considering the technical and environmental constraints the financial impacts of socio-economic constraints would be considered. This includes rehabilitation, relocations, emotional fulfilment etc. For each decision process, multiple alternatives are available. The iterations between the alternatives should be carried out. Finally, the best option for assuring the highest BESR values should be considered. While the decision to extend mining is being determined, the zone up to which the BESR value remains close to one should be considered a mining limit.

The standard process for cost calculation is to discount the future costs to the Present Value (PV). The present values of all future costs and revenues are to be summed up to arrive at the Net Present Value (NPV). A brief understanding of the discount rate and the benefit-cost ratio is presented below.

4.0 Discount Rate

The discount rate is defined as the rate of interest which the Reserve Bank of India (or Central Bank of the country) considers as the applicable charges to commercial banks or financial institutions for any short-term loans. Despite exceptions, the discount rate can also refer to the rate of interest to be used in Discounted Cash Flow (DCF) analysis while calculating the present value of future cash flows[12]. Nominally, relative depletion and asset specificity can be factored into the calculation of the discount rate. In ordinary cases, investors and businesses generally use the discount rate for potential investments. In an investment, the median of the current repo rates can be considered as the discount rate. In the figure below, one can see the repo rate fluctuations in India (Figure 3). A median data can be selected as the discount rate for a long-term project investment. Therefore, if the period between 2005 to 2020 is considered, the discount rate can be approximated as 7.5 per cent. NPV may be calculated considering the discount rate is variable for respective years.

Figure 3. Reserve Bank of India repo rate history from 2000 to 2023[13].

5.0 Benefit-cost ratio as an Indicator of Risk

One way of risk assessment is to think of the consequences as costs. These are mostly the negative cash flow in the calculation of net cash flow. In other words, if the expected negative cash flow increases, the net cash flow in a year would reduce and the period for NPV equaling zero or positive would increase if the discount rate remains the same. This has major implications for a project: lack of operating capital, reduction in investor interest, future project interest rates would be likely to change, the project approval ratings would be downgraded, etc. The procedural steps for risk analysis may be[12] –

i. Based on a cash-flow estimation for each scenario, establish the financial assessment in terms of market and social prices.
ii. The input values of the cash-flow analysis must be accounted for with the actual market prices along with the associated social prices (which must be handled independently).
iii. All the cash flows are presented in a cost-benefit term which can be utilized to compare the financial conditions without and with the project.
iv. The profitability of the investment indicators is established through the net cash-flows, which may further be defined in terms of market and social prices, i.e., NPV, IRR, and C/B ratio.
v. The feasibility of the project investment can be established through financial performance evaluation, referring to the calculation of profitability indicators such as net present value, internal rate of return, and cost-benefit ratio[12].

$$NPV = \sum_{i=0}^{t} \frac{R_t}{(1+i)^t} \qquad (1)$$

Where,

NPV = Net present value up to 't' th year

R_t = Cash flow at 't' th year

i = Discount rate

6.0 A Critique on Social Discount Rate and its Application in the Estimation

Weighing the upfront investment against the future social well-being is critical when engaging in Benefit-Cost Analysis (BCA) to evaluate the worthiness of a public project. The accuracy and credibility of the evaluation results are largely determined by the appropriateness of the Social Discount Rate (SDR) used. Applying a high SDR eliminates many projects which are less economically viable shortly but may generate large inter-generational benefits in the distant future. In contrast, adopting a low SDR would expose the lenders to excessive risks and reduce their expected return on investment[14].

Asian Development Bank (ADB) propose a weighted average approach to determine the SDR to reconcile the investment opportunity cost of public funding through private investment/consumption. This approach is in coherence with other multilateral development funding organizations in general support of countries in underdeveloped regions, namely, the World Bank, European Union etc.[15] ADB adopts a uniform Social Discount Rate (SDR) of 12% in both ex-ante analysis (during the estimation stage) and ex-post evaluation (during the actual realization phase) when calculating NPV, which ensures the comparability of BCA results in both stages[16]. This SDR is also regarded as the benchmark Economic Internal Rate of Return (EIRR) guiding project selection. ADB states that in the ex-ante stage, projects with an EIRR of higher than 12% or lower than 10% will be accepted or rejected respectively. For projects with an EIRR between 10% and 12%, decisions are made depending on the existence of provable extra economic benefits. In ex-post evaluation, the recalculated project EIRR is compared with this SDR, which is a key determinant in judging the efficiency of project implementation. Although a range of 10–12 % has been designated, ADB encourages discretion in project SDR based on factors including geographical region, industry section, economic condition and project-specific features[16].

7.0 Analysis of the Mineability

Vastan Lignite Mine has an additional leasehold area in the southern part of the existing mine (Figure 4). This comprises about 126 Ha of land in the southern part under the lease. The lignite seam is deep-seated, and depth is increased to 60 m to 80 m. The possible ultimate pit is designed following the approved pit slope angle of 13.54 degrees and working pit floor width of 200m. The volume is calculated through sections made at crosses (Section 2 to Section 6) as presented in Figure (5a to

5e). The mineable coal and overburden volumes are calculated by the survey section of the Vastan lignite mine using Autocad and other suitable soft computing systems. The depth of the pit is restricted by the floor level of the bottom-most seam. The mine lease has many faults and shifting of seams, which results in varying pit bottom levels across the north to south of the pit. Each section, drawn from the proposed final pit layouts, exhibits the corresponding pit bottoms. The calculated quantity and mining details for the excavation up to the extreme south of the pit from the current mining point are presented in Table 1.

During the analysis, it was found that the total quantity of available lignite is less and is mineable within one year for all the possible pit limits. Due to the unavailability of the pit width and to cater for the required stable pit slope angle, the mining is limited up to – 60 m RL for Section 2, – 20 m RL for Section 3, Zero RL for Section 4, 20 m RL for Section 5, 20 m RL for Section 6 respectively. This

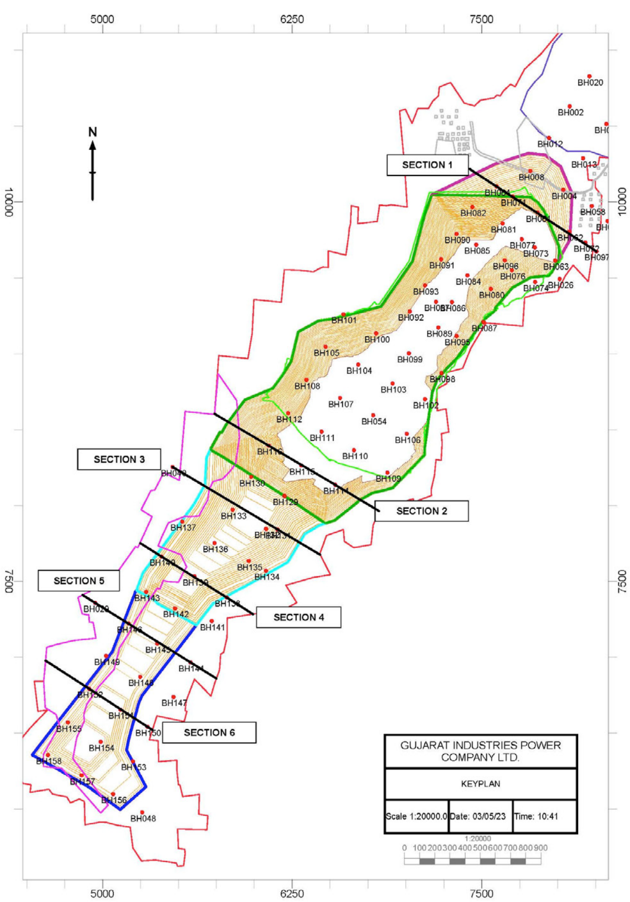

Figure 4. Plan view of Vastan lignite mine for volume calculation.

restricts the mineable quantity of lignite to 0.99 million tonnes. The quantity of lignite including the overburden can be mined within a year as per the designated capacity of the mine, Therefore, the calculated cost and revenue analysis does not require to be discounted as it exhibits the NPV itself. However, for a generalized case, NPV calculation is important.

It can be observed that for excavating the lignite the stripping ratio is increased to 38.18, which is extremely high. This resulted from the poor stability of the wall rocks (as the allowable slope angle is 13.45 degrees). The remaining lignite quantity is 0.99 million tonnes and the overburden rock to be handled is 37.8 million m^3. The mining in the Vastan lignite mine is being carried out by shovel and dumper combination. Both the lignite and overburden are extremely soft and thus excavatable by the shovel. Therefore, drilling and blasting are not required for excavation and blast-free mining is being practiced. The excavation of both lignite and overburden is outsourced and is carried out by the contractors as per the approved rate of GIPCL. The current excavation costing is given in Table 2. The lignite from the Vastan lignite mine is used in the Surat lignite power plants for power generation and thus is not subjected to market sale. Being the captive mine of power plants, the mine has different calculations for its commercial lignite pricing, and it is established as Rs. 2750.82 per tonne. Based on the commercial pricing of lignite and the mining cost of lignite and overburden the BESR is calculated.

The BESR is found 0.73 which is much below 1 and thus the execution of mining for the full southern part may not be recommended. Therefore, it is important to establish the optimum mining pit up to which the mine can be extended with financial acceptance. It is also observed that the lease hole area is not sufficiently wide and thus in the extreme southern part (Section 5 and Section 6) mining cannot reach the deep-seated lignite seam. Therefore, mining carried out in this part does not contribute any additional lignite quantity. Therefore, it is judicial to reject the mining at this part.

With this consideration, the extension of the pit up to 66 Ha of land in the southern part is considered. Similar calculations are again practised for this extension. The volume is calculated through sections made at crosses (Section 2 to Section 4). The calculated quantity and mining details for the excavation up to the extreme south

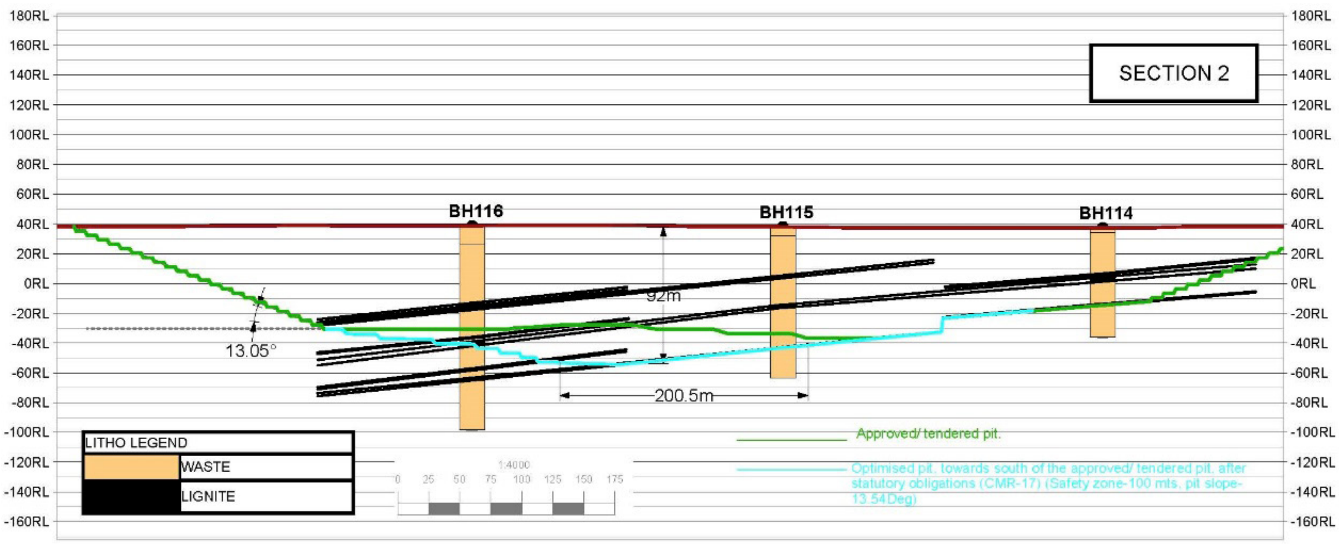

Figure 5a. Section 2 for volume calculation.

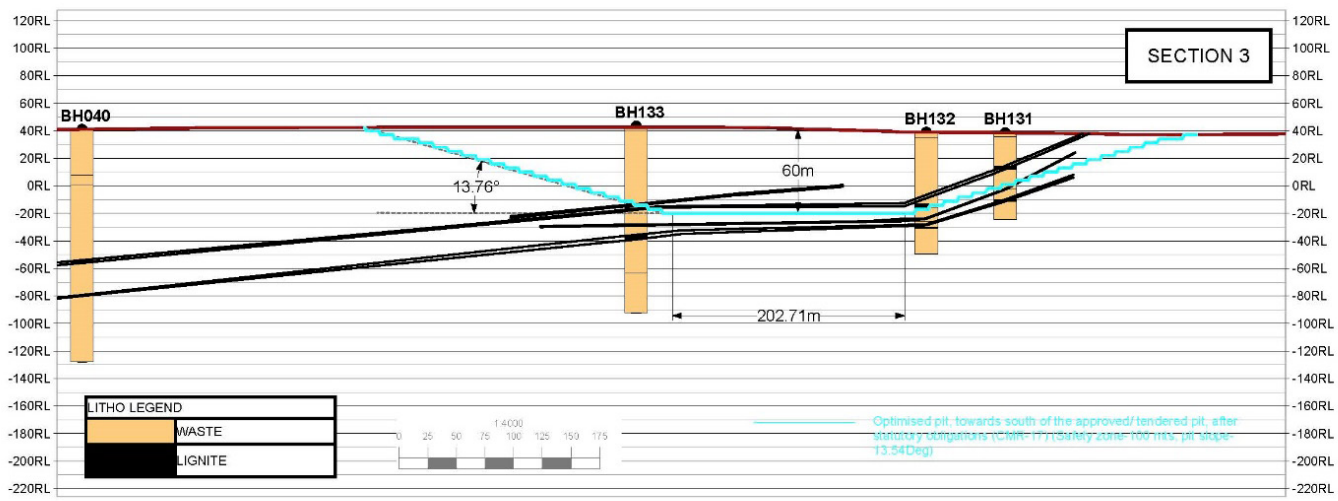

Figure 5b. Section 3 for volume calculation.

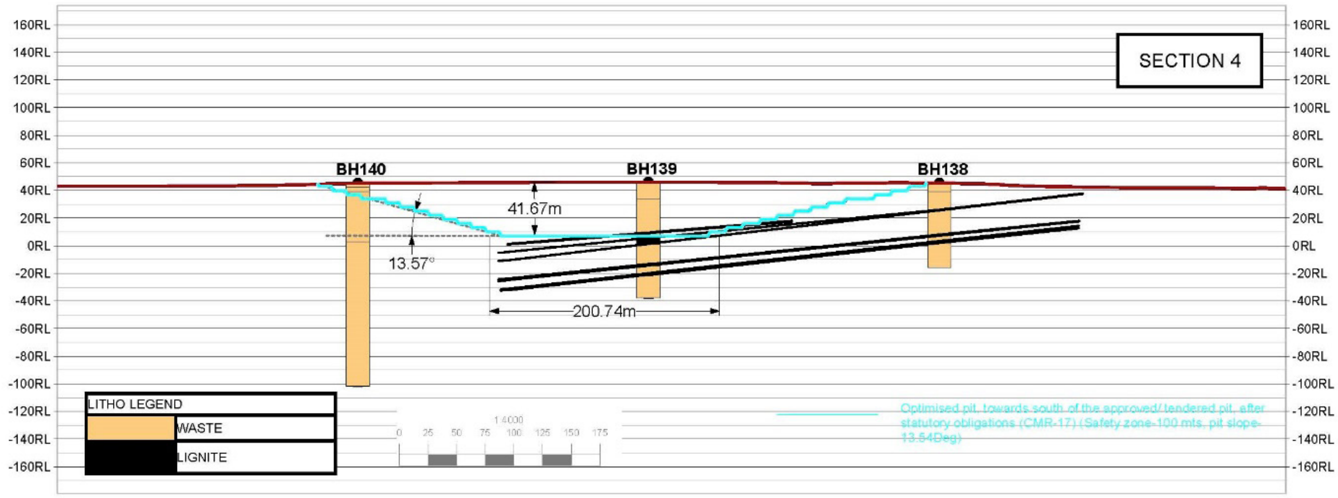

Figure 5c. Section 4 for volume calculation.

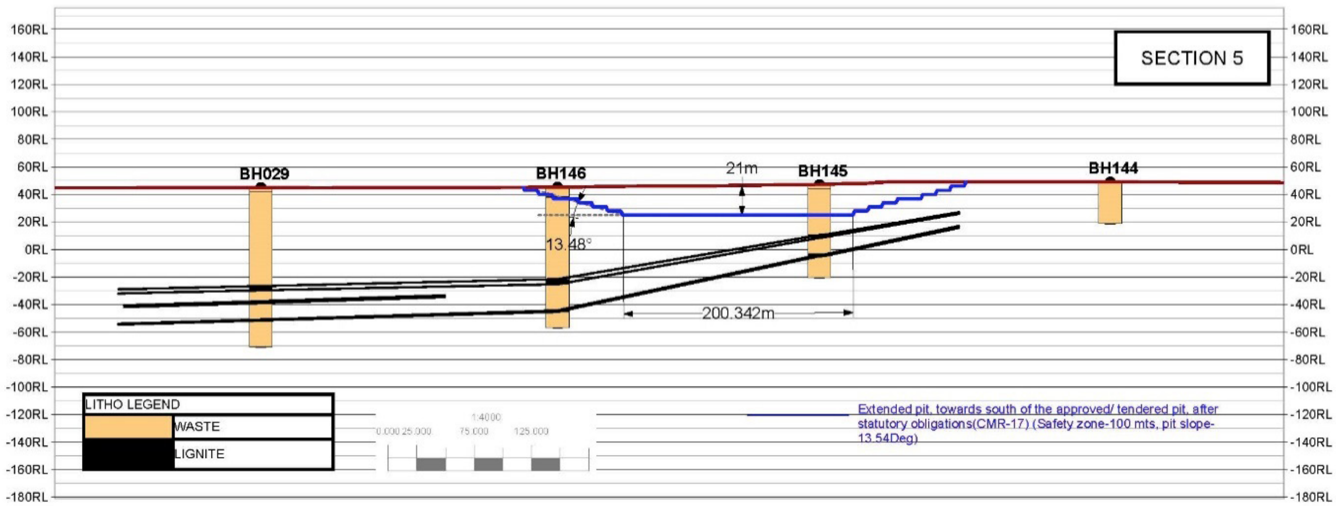

Figure 5d. Section 5 for volume calculation.

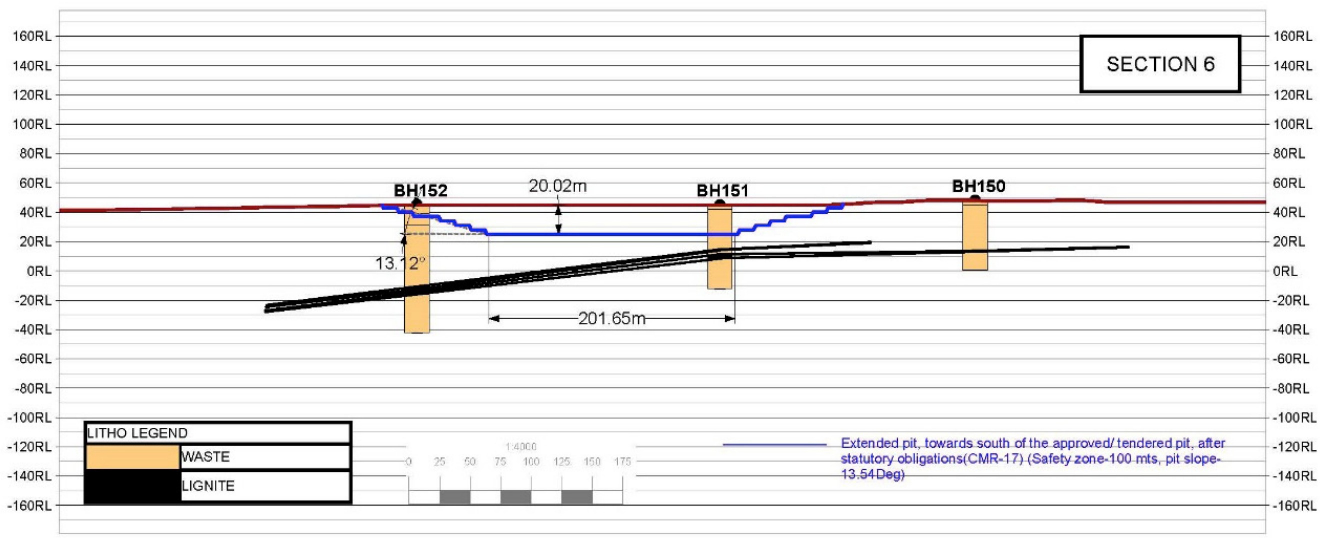

Figure 5e. Section 6 for volume calculation.

of the pit from the current mining point are presented in Table 3.

It can be observed that for excavating the lignite the stripping ratio is increased to 28.09. The remaining lignite quantity is 0.99 million tonnes and the overburden rock to be handled is 28.09 million m^3. The excavation of both lignite and overburden is outsourced and is carried out by the contractors as per the approved rate of GIPCL. The current excavation costing is given in Table 4. Based on the commercial pricing of lignite and mining cost of lignite and overburden the break-even stripping ratio is calculated.

The BESR is found 0.98 which can be approximated as 1 and thus the execution of mining up to this point may be recommended. Therefore, this mining pit can be considered as the optimum mining pit up to which the mine can be extended with financial acceptance.

Table 1. Excavation details for lignite and overburden for excavation of the complete area

Reserves in the extreme south of Vastan South Pit (full pit including the barrier of existing Vastan South Pit)		
Safety zone from lease		100 m
Additional Surface Area		126.15 Ha
No. of Boreholes		34
Approved mining capacity		1.20 million Tonne
Reserves	Lignite	0.99 million Tonne
	OB	37.80 million Cu m
	SR	38.18
Bench Configuration	Length	3m
	Width	9m + 1.73m (due to 60 Deg face angle) = 10.73m
	Face Angle	60 Deg
	Overall pit slope	13.54 Deg
Pit Floor width		200m
Depth of Floor		20m to 85m
Mine Life		1 year

Table 2. Excavation cost and calculation of BESR

Cost estimate for extreme south of Vastan south pit (full pit)		
Sr. No.	**Parameters**	**Quantity**
1	Lignite Quantity (In Tonne)	990000.00
2	OB Quantity (In m^3)	37800000.00
3	Lignite Commercial (Selling) Price (Rs/Tonne)	2750.82
4	Lignite Excavation rate (Rs/Tonne)	95.57
5	OB Excavation rate (Rs/m^3)	95.57
6	Total Lignite Commercial Selling Price (1 × 3)	2723311800.00
7	Total Lignite Excavation Price (1 × 4)	94614300.00
8	Total OB Excavation Price (2 × 5)	3612546000.00
9	**Break Even Stripping Ratio = ((6-7)/8)**	**0.73**

Table 3. Excavation details for lignite and overburden for excavation of optimized pit area

Reserves in the extreme south of Vastan South Pit (optimised pit including the barrier of existing Vastan South Pit)		
Safety zone from lease		100 m
Additional Surface Area		66.93 Ha
No. of Boreholes		16
Reserves	Lignite	0.99 million Tonne
	OB	28.09 million Cu m
	SR	28.37
Bench Configuration	Length	3m
	Width	9m + 1.73m (due to 60 Deg face angle) = 10.73m
	Face Angle	60 Deg
	Overall pit slope	13.54 Deg
Pit Floor width		200m
Depth of Floor		30m to 85m

Table 4. Excavation cost and calculation of break-even stripping ratio for optimized pit

Cost estimate of the extreme south of Vastan south pit (optimized pit)		
Sr. No.	**Parameters**	**Quantity**
1	Lignite Quantity (In Tonne)	990000.00
2	OB Quantity (In m^3)	28090000.00
3	Lignite Commercial (Selling) Price (Rs/Tonne)	2750.82
4	Lignite Excavation rate (Rs/Tonne)	95.57
5	OB Excavation rate (Rs/m^3)	95.57
6	Total Lignite Commercial Selling Price (1 × 3)	2723311800.00
7	Total Lignite Excavation Price (1 × 4)	94614300.00
8	Total OB Excavation Price (2 × 5)	2684561300.00
9	**Break Even Stripping Ratio = ((6-7)/8)**	**0.98**

8.0 Conclusion

This investigation aims to assess the investment risk assessment for the expansion of the Vastan lignite mine up to 126 Ha in the south part of the current mining location. The risk analysis is carried out considering – (i) evaluation of BESR (ii) iteration between mining options (iii) financial appraisal of each mining option (iv) influence of the constraints, namely, technical, environmental, safety, societal and legal. After the analysis, observations and conclusions are as follows -

i. Vastan lignite mine has soft lignite seam and very soft soil cover. This leads to a pit slope angle of 13.54 degrees, which is the main contributor to the high stripping ratio. Due to the precautionary requirements and machine dimensions, an operating area of width 200m at the pit floor is also required.
ii. There is 126 Ha of leasehold area available for mining in the southern part of the existing pit.
iii. Mining carried out for the complete southern part (126 Ha) may lead the GIPCL to a severe financial impact due to a BESR of 0.73.
iv. In search of the optimized pit and maximum lignite excavation (with financial acceptance) the analysis is carried out. It is observed that mining up to 66.97 Ha in the southern part of the existing mine may be carried out to achieve an acceptable BESR (≈1.0). Therefore, it is concluded that mining up to this optimized pit is acceptable.
v. Evaluation of Net Present Value (NPV) is important for risk assessment before investment. This current example exhibits the non-availability of lignite beyond one year of mining due to technical constraints. However, for other cases, NPV calculation with consideration of an acceptable discount rate should be considered.
vi. The discount rate is influenced by the repo rate. Consideration of the Social Discount Rate (SDR) is also important, especially for government or public sector undertaking organizations, where significant social liabilities are implied on the company. Consideration of inappropriate discount rates may result in critical investment risk.
vii. It is essential for each mine to re-evaluate its mine ability and financial status from time to time, as the considerations of the initial mine plan may become unacceptable due to changes in the technical know-how, socio-political issues and environmental norms.
viii. The evaluation guideline as depicted in Figure 2 can be considered the basis for financial analysis. All the socio-political issues and environmental norms should be converted to appropriate costs for the analysis.

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