# OPTIMAL EXPLOITATION OF RAW MATERIAL RESOURCES

**S.S. Rawat & P.K. Sarkar**

**Holtec Consulting Private Limited, Gurgaon, Haryana, India**

## Introduction

In the era of rapid growth of mineral based industries in developing countries, the nonrenewable mineral resources are depleting substantially. The exploitation of mineral resources has always been area of concern in the field of economics. The main concern is the economics of exploitation and the technique in which and the pace at which the deposit is mined in other words, what is the flow of production and what would be the deposit life. This situation warrants conservation of the valuable mineral by developing appropriate techniques for their optimal utilization. The best use of mineral can be achieved during mining operation by use of utilization of sub grade material by proper blending and beneficiation.

In this paper, various techniques that can be applied for optimal exploitation of mineral has been discussed.

## Exploration

The search for mineral begins with the development of ideas as to where the search should be conducted. Application of the most modern techniques such as geophysics, remote sensing etc can not be made until the geologist has decided where to begin. At present, geologist use computers to store data and calculate the economic viability of mineral deposits but capability of computer to find the deposit is yet not established. Possibly, computer can never will, as the human brain is still the best computer of all. However, it is obvious that increased research as to the application of computer technique to exploration will continue. In planning of exploration for minerals due attention should be given to the development of minerals through systematic investigation of various grade of material available in the prospect.

The ultimate exploration tool is diamond drill. There has been substantial improvement in reliability, portability and most important is the percentage of core recovery achievable by drilling equipment. Generally, the exploration drilling is carried out in two phases. In first phase, the outlines in terms of its shape, size of the deposit is determined. This phase of exploration determine the economic viability of the deposit. In second phase expensive close space drilling is required to determine final tonnage and grade estimate for mine planning and preparation of production schedule.

Special attention should be given to the survey and exploration of minerals which is low grade and has the potential of its use after judicial blending. The outcome of exploration should be reviewed periodically with a view to bringing about co-ordination among the survey and exploration agencies and to ensure planned mineral exploration & development. The most important aspects of exploration are:

- Preparation of detail scientific prospecting plan in consideration with topohgraphy and geology of the area aiming to possible ustilisation of sub grade to low grade material
- Precise geological mapping of the area
- Aiming at high core recovery
- Core logging and its interpretation
- Sampling and sample analysis for significant elements

**Deposit Evaluation**

The economic value of mineral deposit is first a function of its ore reserves. The reliable ore reserve estimation is of critical importance particularly as a basis for mine planning.

Estimation of reserves and grade for any mineral deposit has a significant importance to decide upon the utilization of mineral deposit for its economic exploitation for industrial purpose. Various methods of reserve estimation are in practice viz conventional cross sectional, average distance/ thickness and weight average method and geostatistical method. Since geostatistical methods involves complex matrix calculation at a time, a powerful tool to solve these complex matrix was developed in late eighties named as Computer Aided Deposit Evaluation (CADE). Quarry Scheduling & Optimization (QSO) deals with the technology of linear programming and artificial intelligence in the field of mining, while linear programming deals with blendability, artificial intelligence decides the mineability of the deposit.

Application of Computer Aided tools can provide the possibility of optimization of the reserves by sequential blending of high grade and low-grade material considering the cost and mineability factor at the same time. Optimization ensure the possibility of reserves enhancement without affecting the target quality. Since optimization also deals with target raw mix parameters, use of correctives can also be minimized which indirectly impacts the cost.

**Mine Planning**

Many factors govern the size, shape and method of mining, cut off grade is one of the important aspect in mine planning. The objective of mine planning and scheduling is to maximize the Net Present Value and return on investment that can be derived from the extraction. The method and sequence of extraction and the cutoff grade and production strategy will be affected by the following primary factors:

1. Location and distribution of the ore in respect of topography and elevation
2. Mineral type, physical characteristics and grade and tonnage distribution
3. Direct operating expenses associated with mining, processing

The procedure used to establish the optimal mining schedule can be divided into three stages:

The first defines the extraction order, the second defines the cutoff grade strategy and will be optimal for given set of production parameter and the third defines the combination of production rates of mine, will be optimal within the limits placed by logistical, financial and cost of production.

In order to develop an optimum production schedule, a extraction schedule must be determined. The extraction schedule again depends on two parameters viz: stripping ratio and the deposition of ore in respect of its mineability on long term. The other parameters consist of

cost associated with starting and maintaining the whole operation. Direct operation cost can be used to define a breakdown cutoff grade and the stripping ratio.

The main objective of Mine Planning should be to devise a strategy that will optimize the total production cost. Computer designed phases can be determined by feeding the data developed and stored in a computer block model into set of programmes that can be use to calculate an economic strategy of exploitation.

**Sensitivity Analysis**

Sensitivity analysis should be carried out for significant critical parameters. The sensitivity analysis can be best done by use of optimization technique for quick and precise results. Sensitivity is not only useful for cost analysis but also is very analysis of impact of change in quality over reserves and reject handling which ultimately results in cost of operation. Two examples of sensitivity analysis citing its implications on reserves and cost are presented.

**Example 1 (Implications on Plant Life and NPV)**

A limestone mine contains both low grade and cement grade limestone. The reserves of low grade limestone are large whereas the reserves of cement grade limestone are limited.

In this study, the use of limestone can be considered under two scenarios. In the first scenario, only use of cement grade limestone has been considered discarding the low grade limestone. In the second scenario use of entire deposit with suitably mixing sweetener (high grade limestone) for forming the cement grade limestone has been considered. In the first case scenario, by using only the cement grade limestone, the deposit life is estimated to be around 20 years. However, under the second scenario, the deposit life goes up to 55 years. However, we must compare the cost - benefit analysis under the above two cases as the cost of limestone goes up in the second case. Assuming cost of cement grade limestone, low grade limestone and high grade limestone at Rs 95/ t, 85/t and Rs 450 / t respectively. Use of high grade limestone has been considered at 20% of total raw mix. The cash cost of production and the revenues have been estimated for this analysis. Ownership costs like distribution expenses, admin expenses etc. have not been considered. We have also assumed that the investment costs are same under both the scenarios. The cash cost of production and the revenue generated are also assumed to be same for the entire plant life. Chart -1 illustrate the NPV of future earnings.

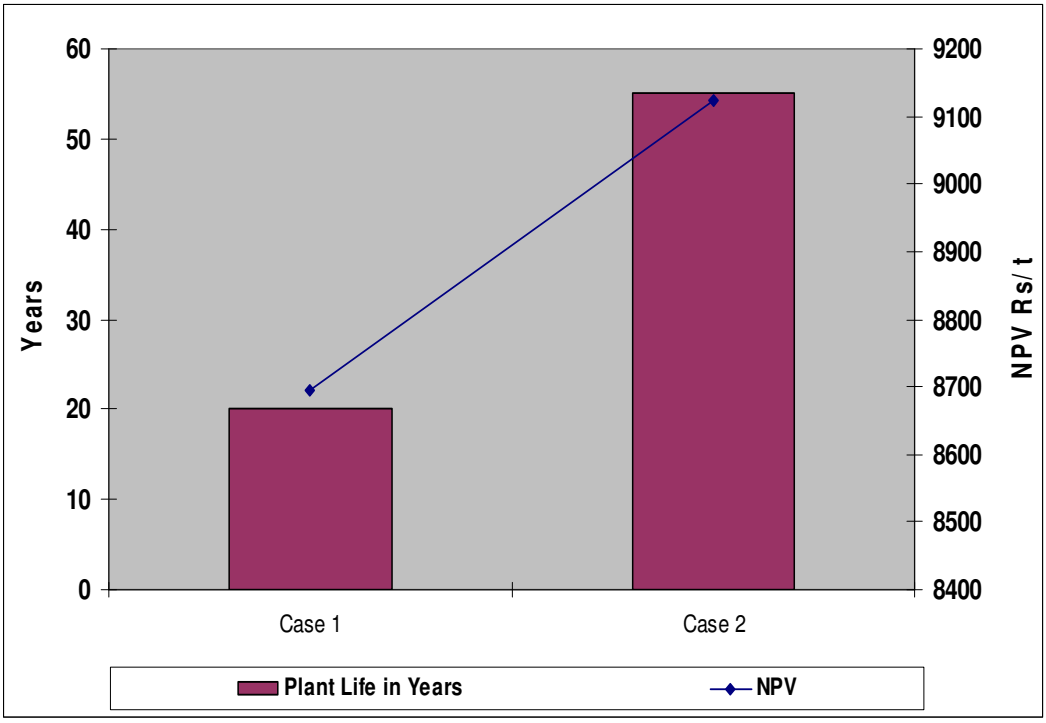


**Chart-1 : Illustrating NPV for both cases**

It can be observed that a substantial saving can be achieved on long term by using low grade limestone. Apart from saving, the use of low grade limestone shall contribute in conservation of valuable mineral.

**Example 2 (Implications on Reserves and Cost of Production)**

One of limestone mine is associated with low grade limestone in the top of the quarry followed by massive limestone of cement to high grade limestone quality. Utilization of low grade limestone by suitably blending with cement and high grade limestone has resulted not only reduction of rejects but also enhancing plant life by reducing cost of production.

The distribution of the over all reserves under all category of limestone apart from OB soil in the area is LG (Low to Marginal Grade) :CG (Cement Grade)::35:69 (in mio t). Rejecting low grade of reserves resulted in approximately 63 mio t of reserves with a recovery ratio of approximately 1:0.50 (Limestone : Waste) and leaving about 10 mio t of limestone insitu. A study on optimization of the reserves (utilization of low grade along with cement and high grade) by changing LSF level has been studied as depicted in Chart – 2 below, which clearly depicts that use of low grade increases the reserves substantially while reducing the reject handling to minimum resulting into a very lucrative situation both in terms of cost of material handling per t and life of the deposit.

| LSF | Reserve (mio t) | Sweetner/ High Grade (%) | Cement Grade (%) | Low Grade to Marginal (%) | RoM Cost per t | Waste | Cost per t of material | RR | Coal | Cost (Rs/ t) Assumed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***120**** | ***62.65*** | ***0.00*** | ***100.00*** | ***0.00*** | ***95.00*** | ***30.5*** | ***114.47*** | ***0.49*** | ***Indian*** | HG | 450 |
| 104 | 99.35 | 0.00 | 68.00 | 32.00 | 91.80 | 3.71 | 93.29 | 0.04 | Imported | CG | 95 |
| 106 | 95.45 | 0.00 | 71.00 | 29.00 | 92.10 | 7.82 | 95.38 | 0.08 | Imported | LG | 85 |
| 108 | 91.23 | 0.00 | 73.00 | 27.00 | 92.30 | 10.87 | 97.07 | 0.12 | Imported | Reject | 40 |
| 110 | 90.34 | 0.55 | 73.40 | 26.05 | 94.35 | 12.01 | 99.67 | 0.13 | Imported | | |
| 112 | 90.25 | 1.50 | 72.37 | 26.13 | 97.71 | 12.04 | 103.05 | 0.13 | Imported | | |
| 114 | 90.25 | 2.10 | 71.82 | 26.08 | 99.85 | 12.04 | 105.18 | 0.13 | Imported | | |
| 116 | 90.25 | 3.78 | 70.11 | 26.11 | 105.81 | 12.04 | 111.14 | 0.13 | Imported | | |
| 118 | 90.25 | 5.65 | 68.35 | 26.00 | 112.46 | 12.04 | 117.79 | 0.13 | Imported | | |
| 120 | 90.25 | 8.45 | 65.47 | 26.08 | 122.39 | 12.04 | 127.72 | 0.13 | Imported | | |

**** Scenario with Indian Coal***

*It is assumed that with change in coal quality even upto 104 LSF in RoM could be attained to manufacture quality clinker*

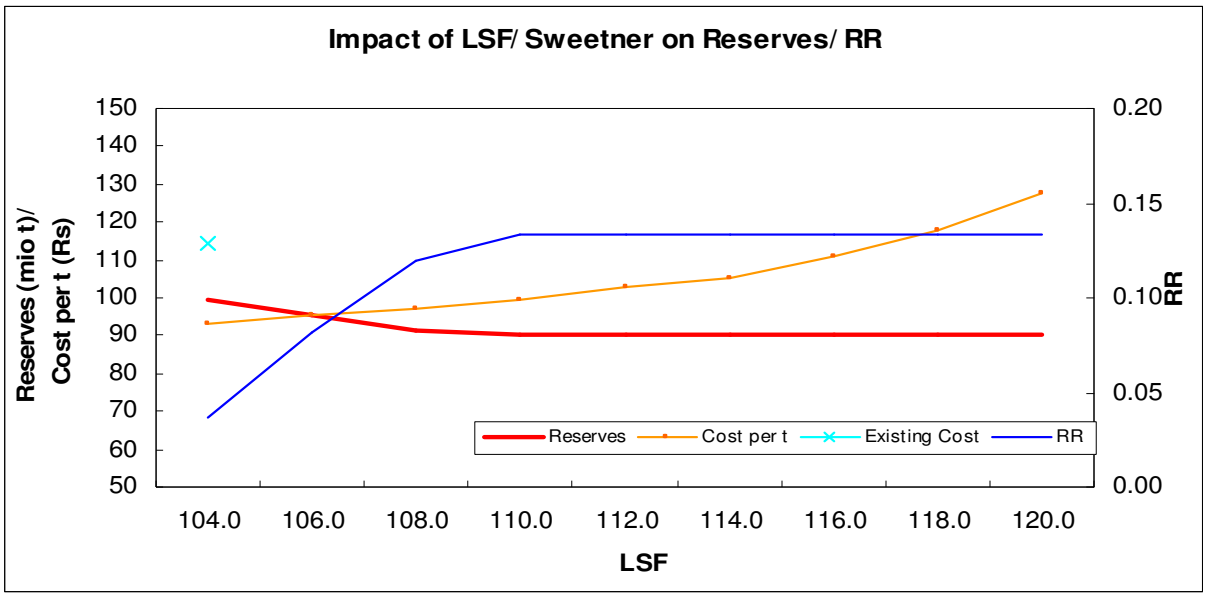


**Chart-2 : Impact of change in LSF and addistion of sweetner on reserves and recovery ratio**

From the above table and curves it may be observed that, with change in coal quality (assuming use of imported coal against indian coal) it is possible to optimize the reserves by consuming low grade limestone. The sensitivity study depicts that even in worst situation when LSF could not be lowered below 110 in the RoM, addition of sweetner limestone shall compensate the requirement of LSF to optimise the reserves. The study reveals that upto 116 LSF the use of sweetner is feasible as the cost per t of material handling still remains lower than the existing situation, while the reserves against existing situation is increasing

substantially. Assuming cost of cement grade limestone, low grade limestone and high grade limestone at Rs 95/ t, 85/t and Rs 450 / t respectively and Rs 40 per t of rejection, the RoM cost is approximately 114 Rs/ t in the existing scenario (at 120 LSF with indian coal). The same could be minimised to Rs 93 per t by optimally using low to marginal grade limestone from the mines which was erlier being rejected. This has further, benefited in terms of handling of rejection by land purchasing/ reclamation.

**Conclusion**

The exploitation of the mineral rests almost exclusively in the hand of the operating company. The optimised exploitation of deposit with use of sub grade material, not only enhances the reserve life but results into high profitability on long term.

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