ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

‘OPTMINEINVEST’ - A Model for Optimum Mine Investment Decision

Dr. J.K. Mohnot, Dr. U.K. Singh

Abstract*— The economic success of a mining project depends upon proper investment decision which enables the achievement of planned profitability throughout the life of the mine. The new investment model has been developed with the use of NPV technique to determine the optimum investment, operating cost and mine life for the planned profitability. The correlations have been developed for (i) optimum investment and revenue (ii) optimum operating cost and revenue. For determination of optimum values of the economic parameters, computer programs developed in C++ for decision model analysis using optimisation criteria of NPV=0 & VI/n and other input parameters. The results of the correlation are plotted for different life of the mine to find out the optimum values. The model also provides the quick determination of optimum production rate for the available capital. The model is useful for quick and advance determination of optimum financial parameters prior to preparation of detailed feasibility reports.

***Index Terms*—mine life, mine profitability, mineral revenue, mining operating cost, NPV, optimum mine investment**

I. INTRODUCTION

A vast majority of mining firms pursue the achievement of multiple goals in their investment decision analysis, especially during the development stage of a mining system where large capital outlays are involved. The goals, each of which partially captures different interests of the investor, range from optimum investment to the mine life or operating cost to the revenue, and the planned profitability with consideration of discounted cash flow, depreciation and taxes, etc.

The economic success of a mining venture in a competitive market depends on financial decisions undertaken for optimum investment. The problem of assessing the profit potential of mining investment proposal, especially in the development of new deposits, is receiving ever-increasing attention. As capital is expensive and may be scarce, the basic objective of the mine owner is to maximise the gross profit, i.e. revenue minus operating cost [1].

It is estimated that in the next ten years, the mining industry will need more and more investment to bring new mines and investors are seeking more elaborate approaches to appraisal of the worth of mining investment that will provide more comprehensive assessments. The essence of capital investment analysis is the comparison of the benefits that accrue over a period with the amount invested. This comparison is made with a view to judge whether the benefits are optimum in response to the amount invested [2].

It has been revealed that a gap exists with the problem for determining the optimum investment, operating cost and mine life to achieve planned profitability based on revenue and discounted cash flow. The values of these economical objectives are essential in taking up decision to commence any mining venture.

Thus, there is a need for methodology based on mathematical analysis for quick determination of these values. This requirement has attracted for research work in this area to formulate an optimum investment decision model for economic evaluation of a mining venture.

In formulation of the model, the new technique has been developed by the authors to evaluate a project by combined analysis of total investment, operating cost, cost of production, working profitability, mine construction period, mine life and the net present value (NPV). A comparison of two investment proposals on the basis of such an analysis would immediately indicate which yielded better values.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

II. FORMULATION OF INVESTMENT DECISION MODEL - 'OPTMINEINVEST'

The following assumptions are considered for the formulation of this model.

(i) Costs, prices, production rates and project profitability remain constant over the life of mine. No escalation of either mineral prices or capital or operating costs is considered. This approach is based on the concept that on the average, both will change in an equivalent manner during the project life such that project profitability will be unaffected.

(ii) In assessing cost of production, the original investment is written off on a straight-line basis over the economic life of the mine [3].

For subsequent analysis, the symbols are defined as follows:

I	=	Original investment to bring the mine into production
R	=	Gross annual revenue accruing from the sale of mineral
C	=	Annual total operating cost represented in percentage of revenue. It indicates the maximum funds available or allowable towards operating cost, including royalty and equipment replacement cost, and excluding interest expenses and depreciation.
GP	=	Gross profit i.e. (R-C) represented in percentage of revenue
M	=	Profitability represented in percentage of revenue (this includes the percentage sum of net profit and interest charges in relation to revenue)
V	=	Present value of an amount of $1 per year for n years and discounted at r% per annum, payment being made at the end of each year
V_{out}	=	Present value of an amount of $1 received as annual cash flow over the mine life n years and further discounted over the construction period m years with rate of r% per annum
V_{in}	=	Present value of an amount of $1 invested per year for m years with discount rate of r% per annum
P_{out}	=	Amount of uniform annual cash flow during the mining period
P_{in}	=	Principal amount invested i.e. I, distributed uniformly over the mine construction period
r	=	Discount rate (may constitute real interest and project risks) in %
q	=	Amount of $1 with one year's interest = (1+r)
n	=	Estimated economic life of the mine in years
m	=	Mine construction period in years
t	=	Tax rate in percentage
Q	=	Mine production in tonnes per year
S	=	Market price of the mineral

A. *Annual Cash Flow*

Annual cash flows, which combine the after-tax gross profit with the tax benefit from the depreciation [4]. The value of depreciation would be I/n given the assumption of straight-line basis, which is applicable for mining ventures and this special condition distinguishes the mining industry from other industry. Thus, the annual cash flow is formulated as follows by the authors [5]:

$$\text{Annual Cash Flow } (P_{out}) = R\text{-}C\text{-}Tax = (R\text{-}C)(1\text{-}t) + \frac{tI}{n} \quad (1)$$

Where, $\quad Tax = t\,(R\text{-}C\text{-}Depreciation) \quad (2)$

and $\quad Depreciation = \frac{I}{n} \quad (3)$

Initial Investment $(P_{in}) = I \quad (4)$

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

B. Net Present Value

The Net Present Value (NPV) refers to the sum of the discounted value of the future stream of costs and receipts. Therefore, it is the Gross Present Value (GPV) minus the investment made [6]. The NPV in equation form is represented as follows by the author [7]:

$$NPV = P_{out}V_{out} - P_{in}V_{in} = V_{out}\,[\,R\text{-}C\text{-}\,Tax] - V_{in}I$$

$$= V_{out}\,[(R - C)\,(1 - t) + \frac{tI}{n}] - V_{in}\,I \qquad (5)$$

If the NPV ≥ 0, the project is feasible. The values of V_{in} and V_{out} can be determined as follows under two conditions.

(i) **When mine construction period m=0**

This indicates that there is no construction period i.e. a running mine is purchased. In this condition the values can be represented as follows:

$$V_{in} = 1 \qquad (6)$$

$$V_{out} = \frac{q^n - 1}{q^n\,(q - 1)} = V \qquad (7)$$

(ii) **When mine construction period m ≥ 1**

This indicates that the construction period (m) is required before the production stage of the mine and the uniform investment is made over the construction period, the values can be represented as follows:

$$V_{in} = \left[\frac{q^m - 1}{q^{m-1}(q-1)}\right]\frac{1}{m} \qquad (8)$$

$$V_{out} = \frac{q^n - 1}{q^n(q - 1)} \times \frac{1}{(q)^m} \qquad (9)$$

C. Annual Cost, Profitability and Revenue

The annual cost of production is the sum of total annual operating cost, the amount of depreciation and tax [8], [9].

$$\text{Annual Cost of Production} = C + \frac{I}{n} + Tax$$

Under optimum condition, the annual cost of production should remain equal to the total expenditures. This can be represented as follows by the author [7]:

$$\text{Annual Cost of Production} = \text{Total Expenditures}$$

or $$C + \frac{I}{n} + Tax = (1\text{-}M)\,R$$

or $$\frac{I}{n} = (\,R - C - Tax\,) - MR \qquad (10)$$

The value of tax can be substituted from Equation (2).

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

D. Optimisation Criteria

In net present value method, the mine is considered feasible when NPV ≥ 0. The internal rate of return (IRR) is the discount rate (r) that results in a zero NPV, therefore, the NPV=0 optimisation criterion also represents the IRR. The following optimisation criteria are considered for determination of optimum economical parameters by the author [7].

(i) **When NPV = 0 and Mine Construction Period m = 0 or m ≥ 1**

The NPV=0, indicates that a marginal mine has been selected for mining. This is some time necessary because of employment creation or mining of a mineral as a import substitute.

(ii) **When NPV = $\frac{VI}{n}$ and Mine Construction Period m = 0 or m ≥ 1**

The NPV = $\frac{VI}{n}$, indicates that Net Present Value of the project would be equal to the annual sum of $\frac{I}{n}$ amount over the economic life of the mine. This amount earned would help the mine owner to plan a future mine.

(iii) **Optimum Value Selection Condition**

The optimisation condition of C=0.5R has been evolved based on detailed study. This optimisation condition for the above two NPV optimisation criteria will provide the optimum values of investment and mine life by formulation and analysis of the model.

E. Determination of Decision Model

The authors have developed the mathematical model for Optimum Mine Investment Decision (OPTMINEINVEST) by analysis of above described relationships as shown in NPV Equation (5) and total annual cost, profitability & revenue Equation (10). On solving these two equations for different profitability criteria, we get the decision model correlations in 'I & R' and 'C & R' as follows [7]:

Case 1 (a): Optimization Criteria, When NPV=0 and m=0

$$\mathbf{I} = \frac{VM}{\left(1-\frac{V}{n}\right)} \times \mathbf{R} \qquad \text{(M1)}$$

$$\mathbf{C} = \left[1 + \frac{M\left(\frac{Vt}{n}-1\right)}{(1-t)\left(1-\frac{V}{n}\right)}\right]\mathbf{R} \qquad \text{(M2)}$$

Case 1 (b): Optimization Criteria, When NPV=0 and m ≥ 1

$$\mathbf{I} = \frac{V_{out}M}{\left(V_{in}-\frac{V_{out}}{n}\right)} \times \mathbf{R} \qquad \text{(M3)}$$

$$\mathbf{C} = \left[1 - M\left\{\frac{1}{(1-t)} + \frac{V_{out}}{n\left(V_{in}-\frac{V_{out}}{n}\right)}\right\}\right]\mathbf{R} \qquad \text{(M4)}$$

Case 2 (a): Optimisation Criteria, When NPV= $\frac{VI}{n}$ and m=0

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

$$\mathbf{I} = \mathrm{VM}\mathbf{R} \tag{M5}$$

$$\mathbf{C} = \left[1 - \mathrm{M}\left\{\frac{\mathrm{V}}{\mathrm{n}} + \frac{1}{(1-\mathrm{t})}\right\}\right] \mathbf{R} \tag{M6}$$

Case 2 (b): Optimization Criteria, When NPV= $\frac{VI}{n}$ **and m ≥ 1**

$$\mathbf{I} = \frac{\mathrm{V_{out}\,M}}{\mathrm{V_{in}}} \times \mathbf{R} \tag{M7}$$

$$\mathbf{C} = \left[1 - \mathrm{M}\left\{\frac{\mathrm{V_{out}}}{\mathrm{n\,V_{in}}} + \frac{1}{(1-\mathrm{t})}\right\}\right] \mathbf{R} \tag{M8}$$

On solving the above decision model Equations (M1) to (M8) for different criteria by substituting the values of r, t, M, m and n, we get the desired **correlations between (i) optimum investment and revenue (ii) optimum operating cost and revenue**. The novelty of the model is that we get all **correlations and results in terms of revenue (R)** i.e. in % of R, therefore it enhances the wider application of the model for all types of mineral and eliminates the problems due to different international currencies in practice. The values obtained for I, C, and GP in terms of R for different set of data can be plotted with mine life as shown in Fig.1. The point of intersection of GP and C indicate the optimum value of I, C, and mine life and it also reveals the optimisation criteria of C = 0.5R. The value of operating cost helps in deciding the mining of mineral within the limit. Thus, the values determined by this model guide in decision making for mining with achievement of planned targets**.** Alternatively, the values of mine production can be calculated by the model correlations in I and R for particular parameters if the decision maker knows the amount of investment available, because the revenue (R) is the product of annual mine production (Q) and market price of the mineral (S).

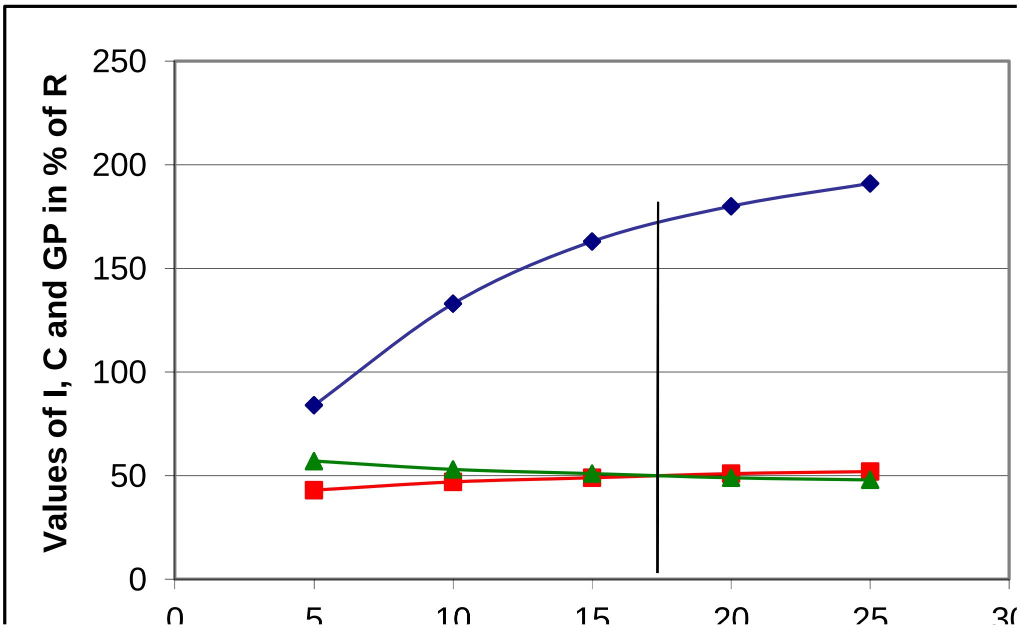

Fig.1: Graph Showing Optimum I, C, and Mine Life at point of intersection (When r=11%, t=30%, M=28%, NPV=VI/n, m=3)

III. DISCUSSIONS

The following observations are described from the results of the model and its sensitivity analysis.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

1. The model is developed with two optimisation criteria of NPV=0 and NPV= $\frac{VI}{n}$. The first criterion NPV=0, indicates that a marginal mine has been selected for mining. This is sometimes necessary because of employment reasons or mining of a mineral as an import substitute to fulfill the need of the country. The second criterion NPV= $\frac{VI}{n}$ indicates that net present value of the project would be equal to annual sum of $\frac{I}{n}$ amount over the economic life of the mine. This generated amount would help the mine owner to plan another mine in future by investing the same.

   The graphs plotted for these criteria suggest the lower mine life and investment for second criterion as compared to first criterion. This phenomenon is due to the maximisation of present value for the second criterion compared to first one.

2. The results of the model analysis verifies the optimisation condition of Annual Total Operating Cost 'C' = 0.5 Annual Revenue 'R' for the different NPV optimisation criteria of NPV=0 and NPV=VI/n and provide the optimum values of investment and mine life.

3. The correlations indicate that investment (I) is independent of tax rate (t) and directly proportional to the profitability (M) and Revenue (R). The optimum investment will only be indirectly affected by changes in cash flow due to the changes in tax rate.

4. The funds available to meet operating costs increase with increase in mine life. Therefore, a higher degree of mechanization can be installed as a consequence of the availability of more funds if the mine has a longer life.

5. The sensitivity analysis for discount rate indicates that (a) optimum mine life is increasing with decrease in discount rate and (b) the higher mine investment can be made with decrease in discount rate.

6. The mine can be planned for longer period with bigger investment where profitability is more and discount rate is less.

7. The sensitivity analysis for tax rate indicates that (a) optimization of mine life is achieved at higher mine life with increase in tax rate and (b) the optimum mine investment is almost constant with changes in tax rate for NPV=0 criteria, because investment is independent of tax rate and it is indirectly affected by changes in cash flow by changes in tax rate. Therefore, the value of optimum investment increases with tax rate for the NPV=VI/n criteria.

8. The mine can be planned for longer period with larger amount of investment where tax rate and profitability are more.

9. The sensitivity analysis for profitability indicate that (a) optimum mine life is increasing with increase in profitability and (b) the higher mine investment can be made with increase in profitability. Therefore, the mining ventures can be planned for higher mine life and larger investments when the profitability is more.

10. It is also observed in all the cases that mining venture with higher mine life and investment can be planned when mine construction period (m) is less.

11. The model is verified with the data of existing successful mining ventures: (i) Asia Pacific Potash Corporation's Udon Thani Potash Mine in Thailand [10] and (ii) Zawar Mala-Baroi Lead Zinc Mine of Hindustan Zinc Limited, India, for which the economic appraisal was conducted by Arthur G. Mckee and Co., California [3]. The results obtained with the model are very close to the economic financial data for these projects (within 90-95%). Thus, the model has shown capability for providing a quick and advance determination of the optimum financial parameters before detailed feasibility reports are prepared. The verification of the model with case studies and accuracy of the results encourages for its wider application.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

IV. CONCLUSIONS

The model has been developed as a new mathematical tool for rapid investment decision and economic evaluation of mining venture, which utilises the NPV method for determining the time value of money and the profitability criteria with consideration of depreciation, tax, mine construction period and other parameters with combined analysis. The novelty and uniqueness of the model is that it provides the values of the economic decision parameters in terms of revenue. The model determines the two important correlations between (i) optimum investment **I** and revenue **R** (ii) optimum operating cost **C** and revenue **R**. The results obtained in terms of % of 'R' extend the application of the model for all types of minerals and it eliminates the problems due to different types of international currencies in practice. It can also be utilized for economic viability study of other similar industries.

The verification of the model with case studies of existing successful mining ventures and accuracy of the results encourage for its wider applications. The model is useful for providing a quick and advance determination of optimum financial parameters prior to preparation of detailed economic feasibility reports.

ACKNOWLEDGMENT

The authors are thankful to their organizations CSIR - Central Institute of Mining & Fuel Research, Dhanbad and Indian School of Mines, Dhanbad and Directors of the institutes for providing help during the research work.

REFERENCES

[1] J. D. Gardner, "Concepts of Mine Evaluation and Design Optimization", Deptt. of Mining and Fuels Engg., Ph.D. thesis, The University of Utah, pp 31-39, 1981.

[2] Atmanand, "Managerial Economics", Excel Books, New Delhi, pp 158-62, 1997.

[3] HZL Report, "Feasibility and Conceptual Engineering Study for Zawar Mala-Baroi Project", Hindustan Zinc Limited, Udaipur, India, prepared by Arthur G. Mckee & Company, California, Section 3-4,1974.

[4] I. M. Pandey, "Financial Management", Vikas Publishing House Pvt. Ltd., New Delhi, pp 49, 131-33, 450-76, 2000.

[5] J. K. Mohnot, U. K. Singh and A. K. Dube, "Formulation of a Model for Determining the Optimum Investment, Operating Cost and Mine Life to achieve Planned Profitability", Trans. of the Institution of Mining and Metallurgy, Section - A: Mining Technology, Vol.110, pp A129-132, London, Aug., 2001.

[6] T. J. O'Neil and D.W. Gentry, "Investment Analysis, Chapter in SME Mining Engineering Handbook", Ed. H.L. Hartman, Published by Society for Mining, Metallurgy and Exploration, Inc., Littleton, Colorado, pp 452-57, 1992.

[7] J. K. Mohnot, "Formulation of Optimum Investment Decision Model for Economic Evaluation of Mining Venture", Ph.D. thesis, ISM, Dhanbad, India, p174, 2002.

[8] H. L. Hartman, "Introductory Mining Engineering", John Wiley & Sons, New York, pp 488-90, 1987.

[9] K. K. Dewett, "Modern Economic Theory", S. Chand & Company Ltd., New Delhi, pp 148-57, 1998.

[10] APPC Report, "Project Economics", Asia Pacific Potash Corporation, Udon Thani, Thailand, pp 2-3, 1999.

AUTHORS BIOGRAPHY

Dr. J. K. Mohnot is working as Sr. Principal Scientist in CSIR - Central Institute of Mining & Fuel Research (CIMFR), Regional Centre, CBRI, Roorkee, India and he has joined CIMFR in 1989 as Scientist. He graduated in Mining Engineering from Jodhpur University in 1987 and post graduated in Science & Technology from BITS, Pilani in 1992. He is holder of First Class Metalliferous Mine Manager's Certificate (FCC-Metal) from DGMS, Dhanbad since 1996. He has obtained Ph.D. (Mining) from Indian School of Mines, Dhanbad in year 2003 for his thesis on "Formulation of Optimum Investment Decision Model for Economic Evaluation of Mining Venture". He is the Fellow (Mining) of the Institution of Engineers (India).

Dr. Mohnot has excellent application-oriented R&D contributions and significantly completed about 50 research and consultancy projects on mining, slope stabilisation, underground space, tunnelling for railway, highway and hydro-electric projects for civil engineering applications and internationally travelled on deputations for collaborative research projects with Russia and Czech Republic. He is Life Member of ISRM and member of leading professional societies.

He received the prestigious National Mineral Award-2004 in the field of Mining Technology by Ministry of Mines, Govt. of India. He is a member of the Mentor Council for Mining & Mineral Processing Sector, Directorate General of Employment and Training, Ministry of Labour and Employment, Govt. of India. (Emails: jkmohnot@hotmail.com; jkmohnot@gmail.com; jkmohnot@cimfr.res.in).

Dr. Upendra K. Singh is B.Tech. in Mining Engineering from Banaras Hindu University, Varanasi, India, in 1979. After a short employment at Hindustan Zinc Ltd., Udaipur, he obtained Ph.D. from Lulea University of Technology, Sweden, in 1988. He worked as Scientist-EI in Central Mining Research Institute, Dhanbad, India after his Ph.D. degree. He is working as Professor of Metal Mining & Rock Mechanics in the Department of Mining Engineering, Indian School of Mines, Dhanbad since year 1993 and also worked as Head of Department. (Email: singh.uk.me@ismdhanbad.ac.in).